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ON THE
COMPOSITION OF FOODS

IN RELATION TO

RESPIRATION

AND THE

FEEDING OF ANIMALS.

By J. B. LAWES, Esq.,
Of Rothamsted ;

AND

J. H. GILBERT, Ph.D., F.C.S.

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On the Composition of Foods, in relation to Respiration and the Feeding of Animals. By J. B. LAWES, Esq., of Rothamsted; and J. H. GILBERT, Ph.D., F.C.S.

DURING the last twelve years our knowledge of the adaptation of food, according to its composition, to the various exigencies of the animal system, has assumed much of definiteness; and it is to the experiments and writings of MM. Boussingault, Liebig, and Dumas, that we must attribute, either directly or indirectly, much of the progress that has been made. There are, however, connected with this important subject still many open questions; and it is with the hope of aiding the solution of one or two of these, and thus providing a new starting-point for further inquiry, that we propose in the present paper to bring forward some results of our own which bear upon them, and to point out the conclusions to which they appear to us to lead.

The writers to whom we have above referred, as well as many others, whether themselves experimenters or more systematic writers on the subject of the chemistry of food, may, with few exceptions, and with some limitations, be said to agree on two main points, viz. on the one hand, as to the connection of the *nitrogenous* constituents of the food, with the formation in the animal body of compounds containing nitrogen, and with the exercise of force; and on the other, as to the general relationship of the *non-nitrogenous* constituents of the food with respiration, and with the deposition of animal fat. It is indeed upon the assumption of this broad and fundamental classification of the constituents of food, according to their varied offices in the animal economy, that a vast series of analyses of foods have of late years been made and published; whilst, founded upon the results of these analyses numerous tables have been constructed, professing to arrange the current articles of diet both of man and other animals, according to their comparative values as such. Among the labourers in this field of inquiry, we are much indebted to MM. Liebig, Dumas, Boussingault, Payen, Playfair, R. D. Thomson, Horsford, Schlossberger and Kemp, and others.

When speaking generally then, of the various requirements of the animal organism, the more special adaptations of the several proximate compounds and ultimate elements of which our vegetable and animal aliments are made up, are, as we have already said, fully admitted; but in attempting to apply to practice the principles herein involved, by the construction of tables of the comparative value of foods, it seems to have been generally assumed, that our current food-stuffs are thus measurable rather by their flesh-forming than by their more specially respiratory and fat-forming capacities. Hence, with some limitations, the per-centage of nitrogen has always been taken as the standard of comparison.

Founded upon their per-centage of nitrogen, M. Boussingault first arranged tables of the comparative values of different articles of food, chiefly in reference to the dieting of the animals of the farm; and with this method Professor Liebig has expressed his concurrence. At page 369 of the 3rd edition of his *Chemical Letters*, he says—"The admirable experiments of Boussingault prove, that the increase in the weight of the body in the fattening or feeding of stock (just as is the case with the supply of milk obtained from milch cows), is in proportion to the amount of plastic constituents in the daily supply of fodder." And at page 349 of the same, speaking of the nitrogenous compounds of food, he says—"It is found that animals require for their support less of any vegetable food in proportion as it is richer in these peculiar matters, and cannot be nourished by vegetables in which these matters are absent."

In like manner, various specimens of flour and of bread have been arranged by Dr. R. D. Thomson; other articles of vegetable diet by Mr. Horsford; and

a large series of aliments from the animal kingdom by MM. Schlossberger and Kemp. Dr. Anderson also, in his valuable Report on the Composition of Turnips, grown under different circumstances and in different localities, has taken their per-centage of nitrogen as the measure of their comparative feeding value.

The views which have thus led to a vast number of analyses of foods, as well as the information supplied by the analyses themselves, have contributed much to the advancement of our knowledge of the chemistry of food. It has however been found, that the indications of tables of the comparative values of foods, founded on the per-centages of proteine compounds, were frequently discrepant with those which common usage or direct experiment affords. These discrepancies have not escaped the attention of the authors of the theoretical tables; but they have attributed them rather to the erroneous teachings of common practice or experiments on feeding, than to any defect in the theoretical method of estimation. On all hands, however, it has been admitted, that further direct experiment bearing upon this important subject was much needed; and it is the acknowledgement of this necessity that seems to justify the publication, under the auspices of the British Association, of the results of this kind which we have now to submit.

The question to which we shall first call attention, is, whether, in the use of our current foods, under ordinary circumstances, but especially in the case of animals fattening for the butcher, *the amount of food consumed*, and that of *increase produced*, have a closer relationship to the supplies in such foods of the *nitrogenous*, or of the *non-nitrogenous* constituents? That is to say, whether the sum of the requirements of the animal system is such, that, in ordinary circumstances, and in the use of ordinary articles of food, the measure of the *amount taken*, or of the *increase produced*, will be regulated more by the supplies of the "Plastic," or of the more peculiarly respiratory and fat-forming constituents. According to the views upon which all the tables of the comparative values of foods are constructed, it is the supplies of the plastic elements of food chiefly, that should regulate both the consumption, and the increase in weight, of a fattening animal. If, however, we bear in mind the views which are generally entertained as to the influence of respiration on the demands of the system for the oxidizable elements of food, it would appear more consistent to suppose that the measure, at least of the *consumption* of food, would be chiefly regulated by its supplies of those elements.

In the experiments to which we shall call attention, sheep and pigs have been the subjects. As, however, their object has partly been the solution of certain questions of a more purely agricultural character than those now under consideration, the details, as to the selection of the animals, and the general management of the experiments, will be given more appropriately in another place. Indeed, the particulars of some of the experiments with sheep, so far as their agricultural bearings are concerned, have already appeared in the Journals of the Royal Agricultural Society of England; and those of the rest, and also of the experiments with pigs, will probably do so shortly. It should here be stated, however, that the general plan has been to select several different descriptions of food, containing respectively various amounts of nitrogenous and non-nitrogenous constituents, the proportions of which were ascertained by analysis. To one or more sets of animals to be compared, a fixed and limited amount of food of a high or of a low per-centage of nitrogen, as the case might be, was allotted, and they were then allowed to take *ad libitum* of another or complementary food. In this way, in obedience to the instinctive demands of the system, the animals were enabled to fix for themselves, according to the composition of the respective foods, the quantities of each class of constituents which they required.

In the tables which follow, the results of the experiments are arranged to show—

1st. The amounts respectively of the *nitrogenous* and the *non-nitrogenous* constituents *consumed weekly per 100 lbs. live weight of animal*.

2nd. The amounts consumed of each of these classes of constituents *to produce 100 lbs. increase in live weight*.

Summary tables of the results of the analyses of the foods are also given.

In the tables showing the amounts of the constituents consumed, &c.—the weights of the animals themselves—of the foods consumed—and their per-centages, of dry matter, of ash, and of nitrogen—have formed the basis of the calculations. Thus, the column of nitrogenous substances consumed, is obtained by multiplying the amount of nitrogen by 6.3, on the assumption that they all exist as proteine compounds. This method of estimation will, we think, be found sufficient for our present purpose; though, as we shall have occasion to point out further on, it is frequently far from accurate, and especially when applied to succulent vegetable substances.

The amounts of *non-nitrogenous* constituents are obtained by deducting those of the mineral and nitrogenous constituents from the amount of the total dry matter consumed.

In the tables showing the amounts of the respective constituents consumed *by a given weight of animal within a given time*, it is their *mean weights* that are taken for the calculation; namely, those obtained by adding together their weights at the commencement and at the conclusion of the experiment, and dividing by 2.

In the tables showing the constituents consumed *to produce a given weight of increase*, the figures are obtained by simple rule of three; taking as the elements of calculation, the consumption during the total period of the experiment, and the total increase in weight during the same period.

With these short explanations we may now introduce the tables themselves.

TABLE I.

Summary Table of the Per-centage Composition of the Sheep Foods.

Foods eaten by Series 1.						
Description of Food.	Mean Per-centage Results.					
	Dry Matter.		Ash.		Nitrogen.	
	Inclusive of Ash.	Exclusive of Ash.	In Fresh Substance.	In Dry Matter.	In Fresh Substance.	In Dry Matter.
Swedish Turnips, No. 1. ...	10.58	10.00	0.577	5.46	0.263	2.49
Swedish Turnips, No. 2. ...	12.12	11.49	0.632	5.21	0.151	1.25
American Oil-cake	89.50	84.08	5.42	6.06	5.08	5.68
Oats	85.18	82.24	2.94	3.45	2.08	2.44
Clover Chaff	78.61	72.33	6.28	7.99	1.85	2.35
Oat-straw Chaff.....	81.28	74.86	6.42	7.87		
Foods eaten by Series 2.						
Oil-cake	87.36	81.88	5.48	6.27	5.01	5.74
Linseed, No. 1.	90.56	86.28	4.28	4.72	3.68	4.07
Linseed, No. 2.	91.54	87.46	4.08	4.45	4.05	4.44
Barley	85.54	83.23	2.31	2.70	1.49	1.74
Malt	91.65	89.34	2.31	2.52	1.51	1.65
Clover-chaff	84.66	77.39	7.27	8.58	2.11	2.50

TABLE I. (continued.)

Foods eaten by Series 3.						
Description of Food.	Mean Per-centage Results.					
	Dry Matter.		Ash.		Nitrogen.	
	Inclusive of Ash.	Exclusive of Ash.	In Fresh Substance.	In Dry Matter.	In Fresh Substance.	In Dry Matter.
Norfolk White Turnips, grown by mineral manures only	9.37	8.74	0.627	6.69	0.146	1.56
Norfolk White Turnips, grown by mineral manures and ammoniacal salts.....	8.42	7.79	0.630	7.48	0.175	2.08
Norfolk White Turnips, grown by mineral manures and rape-cake	7.78	7.14	0.639	8.21	0.183	2.36
Norfolk White Turnips, grown by mineral manures rape-cake and ammoniacal salts	7.88	7.17	0.703	8.92	0.252	3.20
Foods eaten by Series 4.						
Long Red Mangold, No. 1	12.94	11.94	1.002	7.74	0.30	2.36
Long Red Mangold, No. 2 ...	13.14	12.16	0.979	7.45	0.28	2.18
Mean.....	13.04	12.05	0.990	7.59	0.29	2.27
Barley	81.84	79.51	2.32	2.84	1.45	1.78
Malt.....	95.39	92.78	2.60	2.73	1.62	1.70
Malt-dust	93.76	85.06	8.70	9.28	4.10	4.38
Oil-cake	89.74	83.60	6.12	6.82	5.26	5.87

TABLE II.

Summary Table of the Per-centage Composition of Sheep Foods (continued).

Series 5.						
Foods eaten by Hants and Sussex Downs.						
Description of Food.	Mean Per-centage Results.					
	Dry Matter.		Ash.		Nitrogen.	
	Inclusive of Ash.	Exclusive of Ash.	In Fresh Substance.	In Dry Matter.	In Fresh Substance.	In Dry Matter.
Swedish Turnips, Lot 1	9.81	9.20	0.607	6.19	0.231	2.36
Swedish Turnips, Lot 2	10.32	9.73	0.607	5.87	0.301	2.61
Oil-cake	87.54	80.84	6.70	7.65	4.98	5.70
Clover-hay	81.24	72.82	8.42	10.36	2.03	2.51

TABLE II. (continued.)

Eaten by Cotswolds.						
Description of Food.	Mean Per-centage Results.					
	Dry Matter.		Ash.		Nitrogen.	
	Inclusive of Ash.	Exclusive of Ash.	In Fresh Substance.	In Dry Matter.	In Fresh Substance.	In Dry Matter.
Swedish Turnips, Lot 1	10.88	10.37	0.504	4.63	0.18	1.66
Swedish Turnips, Lot 2	10.70	10.12	0.579	5.41	0.28	2.63
Swedish Turnips, Lot 3	12.60	11.84	0.758	6.00	0.27	2.21
Oil-cake	87.54	80.84	6.70	7.65	4.99	5.70
Clover-hay.....	83.66	76.46	7.20	8.60	2.24	2.68
Eaten by Leicesters; and by Cross-bred Ewes and Wethers, [Leicester and South Down].						
Swedish Turnips, Lot 1	10.89	10.38	0.520	4.79	0.23	2.15
Swedish Turnips, Lot 2	11.88	11.26	0.623	5.23	0.25	2.14
Oil-cake	86.32	78.52	7.80	9.04	5.05	5.86
Clover-hay, Lot 1.	80.48	72.38	8.10	10.06	2.73	3.40
Clover-hay, Lot 2.	80.08	71.90	8.18	10.17	2.73	3.42

TABLE III.

Summary Table of Per-centage Composition of the Pig Foods.

Eaten by Series 1.						
Description of Food.	Mean Per-centage Results.					
	Dry Matter.		Ash.		Nitrogen.	
	Inclusive of Ash.	Exclusive of Ash.	In Fresh Substance.	In Dry Matter.	In Fresh Substance.	In Dry Matter.
Egyptian Beans	88.30	83.57	4.72	5.35	4.24	4.80
Lentils, Lot 1.	87.30	82.42	4.87	5.58	4.52	5.18
Lentils, Lot 2.	86.62	81.64	4.98	5.75	4.56	5.26
Indian meal, Lot 1.	89.70	88.33	1.37	1.53	1.72	1.92
Indian meal, Lot 2.	89.89	88.61	1.28	1.42	1.95	2.17
Bran	84.79	78.77	6.02	7.10	2.61	3.08
Barley.....	81.86	79.72	2.14	2.61	1.83	2.24
Eaten by Series 2.						
Egyptian Beans	88.17	84.45	3.72	4.22	4.21	4.78
Lentils, Lot 1.	89.42	86.44	2.98	3.33	4.54	5.08
Lentils, Lot 2.	89.97	85.10	4.87	5.41	4.18	4.65
Barley, Lot 1.	82.38	80.19	2.19	2.66	1.82	2.21
Barley, Lot 2.	80.95	78.77	2.18	2.69	1.83	2.26
Barley, Lot 3.	82.53	80.48	2.05	2.48	1.55	1.88
Bran	85.08	78.67	6.41	7.53	2.62	3.08

nitrogenous constituents of Food per 100 lbs. live weight of animal (quantities stated in lbs., tenths, &c.).

Series 1.—Five sheep in each pen, 14 weeks.

Pen Nos.	Limited Food.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-Nitrogenous Organic Substance.			Total dry Organic Substance.
			In limit-ed Food.	In ad libi-tum Food.	In total Food.	In limit-ed Food.	In ad libi-tum Food.	In total Food.	
1.	Oil-cake	Swedish Turnips	1.63	0.82	2.46	2.75	7.10	9.85	12.31
2.	Oats	ditto	0.88	0.69	1.57	4.76	6.61	11.36	12.93
3.	Clover-chaff	ditto	0.69	0.94	1.64	3.99	9.13	13.12	14.76
4.	Oat-straw chaff	ditto .....	...	1.07	1.07	...	9.82	10.17	11.24
Means			1.071	0.882	1.68	3.83	8.16	11.13	12.81

Series 2.—Five sheep in each pen, 19 weeks.

1.	Oil-cake	Clover-chaff	1.64	2.14	3.78	2.55	10.38	12.93	16.71
2.	Linseed	ditto	1.26	1.95	3.21	3.19	9.47	12.66	15.87
3.	Barley	ditto	0.50	2.08	2.58	3.83	9.96	13.79	16.37
4.	Malt	ditto	0.44	2.08	2.52	3.98	10.04	14.02	16.55
Means			0.96	2.06	3.02	3.39	9.96	13.35	16.38

Series 3.—Five sheep in each pen, 10 weeks.

1.	Barley	Mangold-wurtzel	0.44	1.26	1.70	3.53	7.06	10.59	12.29
2.	Malt and malt-dust	ditto	0.43	1.20	1.64	3.32	6.80	10.12	11.76
3.	Barley (steeped).....	ditto	0.43	1.65	2.08	3.35	9.24	12.60	14.68
4.	Malt and malt-dust (steeped)	ditto	0.40	1.36	1.77	3.09	7.60	10.70	12.47
5.	Malt and malt-dust (extra quantity)...	ditto	0.52	1.36	1.89	3.97	7.66	11.63	13.52
Means			0.44	1.37	1.82	3.45	7.67	11.13	12.94

Series 4.—Six sheep in each pen, 10 weeks; no limited Foods.

1.	Norfolk White Turnips, mineral manures only	1.20	10.30	11.50
2.	Norfolk White Turnips, mineral manures and ammoniacal salts	1.51	9.24	9.75
3.	Norfolk White Turnips, mineral manures and rape-cake.....	1.64	8.86	10.50
4.	Norfolk White Turnips, mineral manures, rape-cake and ammoniacal salts	2.14	7.60	9.74
Means		1.62	9.00	10.37

TABLE IV. (continued).

Series 5.—Different breeds of sheep.

Pen Nos.	Limited Food.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-nitrogenous Organic Substance.			Total dry Organic Substance.		
			In limit-ed Food.	In ad libi-tum Food.	In total Food.	In limit-ed Food.	In ad libi-tum Food.	In total Food.			
Forty Hants Downs, twenty-six weeks		Oil-cake and Clover-chaff.	Swedish Turnips	2.27	1.12	3.39	5.43	5.63	11.06	14.45	
Forty Sussex Downs, twenty-six weeks				2.31	1.06	3.37	5.64	5.35	10.99	14.36	
Forty-six Cotswolds, twenty weeks				2.27	1.14	3.41	5.37	6.65	12.02	15.43	
Forty Leicesters, twenty weeks				2.30	1.07	3.37	4.70	6.46	11.16	14.53	
Forty Cross-bred Ewes, twenty weeks.....				2.39	1.09	3.48	4.91	6.60	11.51	14.99	
Forty cross-bred Wethers, twenty weeks.....				2.41	1.12	3.53	4.96	6.73	11.69	15.22	
Means				2.32	1.10	3.42	5.17	6.23	11.40	14.83	

TABLE V. Experiments with Sheep.—Consumption of Nitrogenous and Non-nitrogenous constituents of Food to produce 100 lbs. increase in live weight of animal (quantities stated in lbs.).

Series 1.—Five sheep in each pen, 14 weeks.

Pen Nos.	Limited Food.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-nitrogenous Organic Substance.			Total dry Organic Substance.
			In limit-ed Food.	In ad libi-tum Food.	In total Food.	In limit-ed Food.	In ad libi-tum Food.	In total Food.	
1.	Oil-cake	Swedish Turnips	111	56	167	181	469	650	817
2.	Oats		55	48	103	259	395	684	787
3.	Clover-chaff		43	59	102	223	513	736	838
4.	Oat-straw chaff .....		...	102	102	...	881	913	1015
Means			70	66	118	231	565	746	864

Series 2.—Five sheep in each pen, 19 weeks.

1.	Oil-cake.....	Clover-chaff.....	138	183	321	219	884	1103	1424
2.	Linseed.....		112	177	289	291	853	1144	1433
3.	Barley		45	190	235	353	916	1269	1504
4.	Malt		49	217	266	412	1045	1457	1723
Means			86	192	278	319	925	1244	1521

TABLE V. (continued).

Series 3.—Five sheep in each pen, 10 weeks.									
Pen Nos.	Limited Food.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-nitrogenous Organic Substance.			Total dry Organic Substance.
			In limited Food.	In ad libitum Food.	In total Food.	In limited Food.	In ad libitum Food.	In total Food.	
1.	Barley	Mangold-wurtzel	31	87	118	243	488	731	850
2.	Malt and malt-dust	ditto	29	82	111	220	457	677	788
3.	Barley (steeped) ...	ditto	25	96	121	194	536	730	851
4.	Malt and malt-dust (steeped)	ditto	32	104	136	237	584	821	958
5.	Malt and malt-dust (extra quantity)...	ditto	35	91	126	265	511	776	903
Means			30	92	123	232	515	747	870

Series 4.—Six sheep in each pen, 10 weeks; no limited Food.			
Pen Nos.	Limited Food.	Complementary or ad libitum Food.	Total dry Organic Substance.
1.	Norfolk White Turnips, mineral manures only	192	1819
2.	Norfolk White Turnips, mineral manures and ammoniacal salts	153	1083
3.	Norfolk White Turnips, mineral manures and rape-cake	324	2006
4.	Norfolk White Turnips, mineral manures, rape-cake and ammoniacal salts	Lost weight.	Lost weight.
Means		223	1636

Series 5.—Different breeds of sheep.										
Pen Nos.	Limited Food.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-nitrogenous Organic Substance.			Total dry Organic Substance.	
			In limited Food.	In ad libitum Food.	In total Food.	In limited Food.	In ad libitum Food.	In total Food.		
1.	Forty Hants Downs, twenty-six weeks ...	Oil-cake and Clover-chaff.	Swedish Turnips.	124	62	186	300	312	612	798
2.	Forty Sussex Downs, twenty-six weeks ...			129	60	189	318	302	620	809
3.	Forty-six Cotswolds, twenty weeks			111	55	166	260	322	582	748
4.	Forty Leicesters, twenty weeks			127	59	186	261	358	619	805
5.	Forty cross-bred Ewes, twenty weeks			127	58	185	260	350	610	795
6.	Forty cross-bred Wethers, twenty weeks ...			127	59	186	261	355	616	802
Means			124	59	183	277	333	610	793	

TABLE VI.

Experiments with Pigs.—Weekly consumption of Nitrogenous and Non-nitrogenous constituents of Food per 100 lbs. live weight of animal (quantities stated in lbs., tenths, &c.).

Series 1.—Three pigs in each pen, 8 weeks.									
Pen Nos.	Limited Food, per head, per day.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-nitrogenous Organic Substance.			Total dry Organic Substance.
			In limited Food.	In ad libitum Food.	In total Food.	In limited Food.	In ad libitum Food.	In total Food.	
1.	None	Bean and Lentil meal .....	...	8.84	8.84	...	17.6	17.6	26.4
2.	Indian meal	ditto	0.83	7.30	8.13	5.5	14.3	19.8	27.9
3.	Bran	ditto	1.32	6.39	7.71	5.0	12.8	17.8	25.5
4.	Indian meal and Bran	ditto	2.14	4.73	6.87	10.6	9.4	20.0	26.9
Means			1.07	6.82	7.89	5.3	13.5	18.8	26.7
5.	None	Indian meal .....	...	2.91	2.91	...	19.3	19.3	22.2
6.	Bean and Lentil meal	ditto	1.95	2.60	4.55	3.9	17.2	21.1	25.7
7.	Bran	ditto	1.21	2.74	3.95	4.6	17.9	22.5	26.4
8.	Bean and Lentil meal, and Bran	ditto	3.05	2.15	5.20	8.1	14.0	22.1	27.3
Means			1.55	2.60	4.15	4.1	17.1	21.2	25.4
9.	Bean and Lentil meal	Bran	3.34	1.85	5.19	6.7	7.0	13.7	18.9
10.	Indian meal	ditto	1.44	2.46	3.90	9.4	9.3	18.7	22.6
11.	Bean and Lentil meal, and Indian meal...	ditto	3.23	1.73	4.96	10.4	6.6	17.0	22.0
12.	None	Bean and Lentil meal, Indian meal, Bran, each ad libitum	...	6.12	6.12	...	20.1	20.1	26.2
Means			2.00	3.04	5.04	6.6	10.8	17.4	22.4
Means of the 12 pens			1.54	4.15	5.69	5.3	13.8	19.1	24.8

Series 2.—Three Pigs in each pen, 8 weeks.									
Pen Nos.	Limited Food.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-nitrogenous Organic Substance.			Total dry Organic Substance.
			In limited Food.	In ad libitum Food.	In total Food.	In limited Food.	In ad libitum Food.	In total Food.	
1.	None	Bean and Lentil meal .....	...	6.69	6.69	...	14.5	14.5	21.2
2.	3 lbs. Barley meal ...	ditto	1.23	7.06	8.29	7.3	15.3	22.6	30.9
3.	1 lb. Bran	ditto	0.66	8.07	8.73	2.5	17.5	20.0	28.7
4.	3 lbs. Barley meal, 1 lb. Bran	ditto	1.95	4.85	6.80	10.1	10.5	20.6	27.4
Means			0.96	6.67	7.63	5.0	14.4	19.4	27.0

TABLE VI. (continued.)

Pen Nos.	Limited Food, per head, per day.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-nitrogenous Organic Substance.			Total dry Organic Substance.
			In limited Food.	In ad libitum Food.	In total Food.	In limited Food.	In ad libitum Food.	In total Food.	
5	None	Barley Meal .....	...	3.91	3.91	...	23.6	23.6	27.5
6	1 1/2 lb. Bean, and 1 1/2 lb. Lentil meal	ditto	2.81	2.36	5.17	6.1	13.9	20.0	25.2
7	1 lb. Bran	ditto	0.61	3.45	4.06	2.3	20.9	23.2	27.3
8	1 1/2 lb. Bean, 1 1/2 lb. Lentil meal, and 1 lb. Bran	ditto	2.98	1.66	4.64	7.2	10.0	17.2	21.8
Means.....			1.60	2.84	4.44	3.9	17.1	21.0	25.4
9.	None	Mixture of 1 part Bran, 2 parts Barley meal, and 3 parts Bean and Lentil meal.....	...	6.65	6.65	...	20.6	20.6	27.2
10.	None	Duplicate of pen 9 .....	...	7.03	7.03	...	21.9	21.9	28.9
11.	None	Mixture of 1 part Bran, 2 parts Bean and Lentil meal, and 3 parts Barley meal .....	...	5.86	5.86	...	21.4	21.4	27.3
12.	None	Duplicate of pen 11 .....	...	6.02	6.02	...	22.1	22.1	28.1
Means.....			...	6.39	6.39	...	21.5	21.5	27.9
Means of the 12 pens.....			0.85	5.30	6.15	2.9	17.7	20.6	26.8
Means of the 24 pens.....			1.19	4.73	5.92	4.1	15.8	19.9	25.8

TABLE VII.

Experiments with Pigs.—Consumption of Nitrogenous and Non-nitrogenous constituents of Food, to produce 100 lbs. increase in live weight of animal (quantities stated in lbs.).

Series 1.—Three pigs in each pen, 8 weeks.

Pen Nos.	Limited Food, per head, per day.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-nitrogenous Organic Substance.			Total dry Organic Substance.
			In limited Food.	In ad libitum Food.	In total Food.	In limited Food.	In ad libitum Food.	In total Food.	
1.	None	Bean and Lentil meal .....	...	138	138	...	275	275	413
2.	Indian meal.....	ditto	12	102	114	77	201	278	392
3.	Bran	ditto	28	133	161	105	267	372	533
4.	Indian meal and Bran	ditto	38	83	121	185	166	351	472
Means.....			19	114	133	92	227	319	452

TABLE VII. (continued.)

Pen Nos.	Limited Food, per head, per day.	Complementary or ad libitum Food.	Nitrogenous Organic Substance.			Non-Nitrogenous Organic substance.			Total dry Organic Substance.
			In limited Food.	In ad libitum Food.	In total Food.	In limited Food.	In ad libitum Food.	In total Food.	
5.	None	Indian Meal.....	...	57	57	...	378	378	435
6.	Bean and Lentil meal	ditto	31	42	73	62	275	337	410
7.	Bran	ditto	18	40	58	68	264	332	390
8.	Bean and Lentil meal, and Bran	ditto	43	30	73	114	195	309	382
Means.....			23	42	65	61	278	339	404
9.	Bean and Lentil meal	Bran	127	71	198	255	268	523	721
10.	Indian meal.....	ditto	48	82	130	311	309	620	750
11.	Bean and Lentil meal, and Indian meal	ditto	74	40	114	240	151	391	505
12.	None	Bean and Lentil meal, Indian meal, Bran, each ad libitum .....	...	107	107	...	350	350	457
Means.....			62	75	137	202	269	471	608
Means of the 12 pens.....			35	77	112	118	258	376	488
Series 2.—Three pigs in each pen, 8 weeks.									
1.	None	Bean and Lentil meal .....	...	146	146	...	317	317	463
2.	3 lbs. Barley meal	ditto	20	117	137	120	254	374	511
3.	1 lb. Bran.....	ditto	12	140	152	43	305	348	500
4.	3 lbs. Barley meal, 1 lb. Bran.....	ditto	36	89	125	186	192	378	503
Means.....			17	123	140	87	267	354	494
5.	None	Barley meal .....	...	64	64	...	385	385	449
6.	1 1/2 lb. Bean and 1 1/2 lb. Lentil meal	ditto	50	41	91	107	245	352	443
7.	1 lb. Bran.....	ditto	10	56	66	38	341	379	445
8.	1 1/2 lb. Bean, 1 1/2 lb. Lentil meal, and 1 lb. Bran	ditto	64	36	100	157	215	372	472
Means.....			31	49	80	75	297	372	452
9.	None	Mixture of 1 part Bran, 2 parts Barley meal, and 3 parts Bean and Lentil meal .....	...	117	117	...	362	362	479
10.	None	Duplicate of pen 9 .....	...	110	110	...	342	342	452
11.	None	Mixture of 1 part Bran, 2 parts Bean and Lentil meal, and 3 parts Barley meal .....	...	88	88	...	320	320	408
12.	None	Duplicate of pen 11 .....	...	87	87	...	321	321	408
Means.....			...	101	101	...	336	336	437
Means of the 12 pens.....			16	91	107	54	300	354	461
Means of the 24 pens.....			25	84	109	86	279	365	474

A glance at the Tables as a whole must show, that in all comparable cases there is much more of uniformity of amount in the total columns of non-nitrogenous than in those of nitrogenous substance, both as to the quantities consumed to a given weight of animal within a given time, and to those required to produce a given weight of increase. The deviations from this general regularity in the amount of non-nitrogenous substance consumed under equal circumstances, are indeed, in most cases such, that when examined into they tend the more clearly to show, that the uniformity would be considerably more strict if the amounts only of the really available respiratory and fat-forming constituents could have been represented, instead of, as in the case of these Tables, that of the gross or total non-nitrogenous substance consumed. For, in reading the actual figures of the Tables, allowance has to be made both for those of the non-nitrogenous constituents of the food which would probably become at once effete, and also for the different respiratory and fat-forming capacities of the portions of them which are digestible and available for the purposes of the animal economy. It must further be remembered, that even after all due allowance has been made for the sources of discrepancy just referred to, the amounts which we may suppose to be so corrected must still cover all variations, whether arising from differences of external circumstances—from individual peculiarities in the animals themselves—from the different amounts stored up in them according to the adaptation of the respective foods—as well as from the many other uncontrollable circumstances which must always interfere with any attempts to bring within the range of accurate numerical measurement the results of those processes in which the subtle principal of animal life exerts its influence. Bearing, then, all those points in mind which must tend to modify the true indications of the actual figures in the Tables, it appears to us, that the coincidences in the amounts of available respiratory and fat-forming constituents consumed by a given weight of animal, under equal circumstances, within a given time, and also in those required under equal circumstances to produce a given amount of increase in weight, must be admitted to be much more striking and conclusive than *à priori* we could have expected to find them. With this general uniformity, however, as to the amounts of non-nitrogenous substance consumed under given circumstances, or for a given result, those of the nitrogenous constituents are found to vary, under the same circumstances, in the proportion of from 1 to 2 or 3.

In illustration of our statements let us examine the Tables for a moment somewhat more in detail.

In Table IV. we have the amounts of the two classes of constituents respectively, which were consumed weekly per 100 lbs. live weight of animal, in the case of five different series of experiments with sheep. In all cases the experiments extended over a period of many weeks, and in some even of several months. Each series comprised several pens, to each of which (except in Series 4, in which there were no limited foods) there was allotted a different description of fixed or limited food, the *ad libitum* or complementary food being (except in series 4) the same throughout the several pens of the same series, but different in the different series. In the Series 1, 2, 3 and 4, there were five or six sheep in each pen; in Series 5, from 40 to 50 sheep in each pen.

In Series 1, the complementary or *ad libitum* food was Swedish turnips, and the limited foods were—

- In pen 1, oil-cake.
- In pen 2, oats.
- In pen 3, clover-chaff.
- In pen 4, oat-straw chaff.

The oat-straw chaff of pen 4 was given as adding to the otherwise only succulent matter of the turnip, the *bulk* of solid matter which seems to be demanded particularly by ruminant animals. So small a quantity of this straw was eaten, however, that it need scarcely enter into our calculations. Turning to the results of pens 1, 2 and 3, it is seen that the weekly consumption of non-nitrogenous matter per 100 lbs. live weight of animal is, with the oil-cake as limited food, 9.8 lbs.; with the oats, 11.3 lbs.; and with the clover-chaff, 13.1 lbs. Now, of these three descriptions of food, the oil-cake would contain by far the most of oleaginous matter, the respiratory and fat-forming capacity of which is about twice and a half as great as that of the starch series of compounds which would more abound in the oats. Hence we find that a less actual weight of non-nitrogenous substance was consumed with the oil-cake than with the oats. But to the reason just given, to which a part of the result was doubtless due, we might add that there was a comparatively large and somewhat excessive amount of nitrogenous matter consumed in the oil-cake pen, a part of which at least might serve the respiratory and fat-forming functions. Then, again, in pen 3, where clover-chaff was the limited food, the animals would consume a much larger amount of effete woody fibre than with either the oil-cake or the oats; in this pen therefore a larger gross weight of non-nitrogenous substance must be eaten to yield the same equivalent of that which is available for respiratory or fat-forming purposes than with either of the other foods. When therefore, allowance has been made for the different quantities and capacities of the available constituents in the several foods, it will be seen, that the equivalents of the available non-nitrogenous constituents consumed in the different cases, are in reality much more nearly identical, than the figures as they stand in the Table would indicate. But if we now turn to the column of the nitrogenous substance consumed under the same circumstances, we find that it varies, comparing one pen with another in this first series, nearly as much as from 1 to 2½.

In the second series (Table IV.) we have clover-chaff as the *ad libitum* or complementary food in all the pens, instead of Swedish turnips as in Series 1; and again, with the much larger amount of effete woody fibre, we have a larger gross amount of the non-nitrogenous substance consumed. The average of the four pens of this Series 2 is indeed almost identical with the amount where clover-chaff was employed in Series 1. Again, comparing one pen with another in this clover-chaff series, we have with the larger amounts of oleaginous matter supplied in the linseed and oil-cake, less of gross non-nitrogenous substance taken than with the barley or the malt, in which there is a proportionally larger amount of the starch series of compounds. When due allowance is made, then, for the different respiratory and fat-forming capacities of the several foods, we have again a closer coincidence than would at first sight appear, in the equivalents of the non-nitrogenous substances consumed in the different pens of this second series—as also when we compare this series with the former one. Turning now to the column of the nitrogenous substances consumed in this second series, we see that the gross amounts vary more than in those of the non-nitrogenous; and more indeed than, according to any knowledge we at present possess, could be accounted for by a consideration as to the state in which the nitrogen existed in the several pens. Comparing now the result of the one series with those of the other, although in the two cases the description of the larger portion of the food is widely different, and we have found that there is nevertheless considerable coincidence in the amounts of non-nitrogenous substance consumed, yet the columns of nitrogenous substance throughout the two series show a very great variation in the quantities of these consumed—amounting, indeed, in

the extreme cases, to as much as from one to three and a half. There can be little doubt that the method of estimating the amount of available nitrogenous substance from the per-centage of nitrogen must be more or less faulty, both in the case of the succulent turnips of the first series, and in that of the also unripened produce—clover-chaff—of the second; but whether or in what degree the differences in the amounts consumed in the two series would be lessened by corrections due to this source of discrepancy, we have not the means of accurately deciding.

In the third series, which consisted of five pens, mangold-wurtzel was the complementary food; and the limited foods were barley and malt, respectively, in different states and proportions in the several pens. Throughout this series the proportion of nitrogenous to non-nitrogenous constituents varied but little in the limited foods, and being also constant in the complementary foods of the several pens, we have but little difference in this series in the amounts respectively of either class of constituents when comparing pen with pen. Comparing the results of this series with those of the others, however, we observe that there was a very close coincidence between the amounts of available non-nitrogenous substance consumed; but in those of the nitrogenous substances there is little in common when thus taking at one view the results of the several series.

In the fourth series we have no supply of limited food. In all the four pens Norfolk-white turnips only were given *ad libitum*. Those supplied to the different pens, were, however, respectively grown by very different manures, and differed in all cases very much in ultimate composition and other qualities. Thus, the per-centage of dry substance and the state of maturity were greatest in the turnips of pen 1, and diminished in the order of the pens, they being in pen 4 the worst in both these respects. On the other hand, the per-centage of water, of mineral matter, and of nitrogen, and the degree of unripeness or unfitness for food, were in the inverse order. The turnips eaten in pen 1 were, however, too ripe, and what is called "pithy"; and those were in the best condition which were supplied to pen 2.

In this series there was, with a probably generally lower amount of effete matter, at the same time a generally less amount of non-nitrogenous substance consumed—though most where the turnips were known to be too ripe and *pithy*. In pen 4 there was a very small amount of non-nitrogenous substance taken; but there is no doubt that here the limit to consumption was fixed by the unfitness of the turnips as food, and not by their high value in this respect; for these turnips were very succulent and unripe, and notwithstanding they contained a very high per-centage of nitrogen, all the animals fed upon them lost weight. Taking the circumstances into account, then, we have as much uniformity in the amounts of non-nitrogenous constituents consumed as we could expect, both among the several pens of the series, and in comparing this series with the rest. In the column of nitrogenous constituents, on the other hand, there is nothing to indicate any uniformity of demand for the supply of them, whether we compare pen with pen, or the results of this series with those of the others. It might perhaps be objected, from what we have already said of the varying qualities of the turnips used in this series, that the nitrogenous compounds themselves would exist in the different lots in a more or less assimilable condition; and hence probably some of the differences in the amounts consumed. Doubtless there were differences in this respect in the different lots, but it is seen that there is nearly twice as much of nitrogen consumed in one pen as in another; and we cannot suppose that by any such method of correction as has been suggested, so large a difference as this, or even that the whole of the lesser ones observed in the other cases, could

be thus accounted for. It is worthy of observation, however, that in this series the amounts of the nitrogenous constituents consumed are in an inverse ratio to those of the non-nitrogenous; and if we are to calculate, that in the case of a defect of the latter or an excess of the former, a notable portion of the nitrogenous constituents would serve as respiratory material, such an assumption in the present case would tend yet more clearly to show the closer dependence of *consumption* upon respiration, than upon the supplies by the food of the plastic elements of nutrition, as such.

In the next and last series of experiments to be noticed with *sheep*, as far as possible the same description of foods is used throughout; but animals of different breeds and weights and other admitted qualities are now the subject of experiment in the several pens. The breeds which have thus been compared are,—the Hampshire Down, Sussex Down, Cotswold, Leicester, Half-bred Wethers (Leicester and Southdown), and Half-bred Ewes (Leicester and Southdown). In all these experiments oil-cake and clover-chaff were the limited foods, and Swedish turnips the complementary food. About 1 lb. per head per day of each of the limited foods was given to the Hampshires; and taking this allowance as the standard, the other breeds had quantities of these foods exactly in proportion to their weights. There were from 40 to 50 sheep in each lot; and each experiment extended over several months. The experiments were, however, not all made in the same season; the turnips were therefore of different growths; and the oil-cake and clover-chaff, though chosen as nearly as possible of similar quality, were not always from the same stocks. These circumstances, then, as well as the intrinsic differences in the breeds themselves, if any, might be supposed perhaps to have some share in any variations in result. We see, however, that there is nevertheless a very striking coincidence in the amounts of constituents consumed to a given weight of animal among the different breeds. But what is more to the purpose, the amounts of non-nitrogenous substance consumed to a given weight of animal by these different breeds, and at different times, are, after making, as before, due allowance for the probable different equivalents of the foods, exactly consistent with the indications of the other series with all their varied foods. This result, then, further shows that in all, the respiratory and fat-forming exigencies of the animals have fixed the limit to their consumption of food; and also that these requirements have, on an average, and under somewhat similar circumstances, a pretty constant relationship to their weights. With this general coincidence in the amount of non-nitrogenous substance consumed to a given weight of animal in the several pens of this series, there could not, of course, with foods of similar composition in all, be much variation in the amounts of the nitrogenous constituents taken under the same circumstances. Of these, however, we have throughout this series twice or thrice as much as in many cases of the other series, which would not happen if the demand for them had been the guide to *consumption*; nor shall we afterwards find that the *increase in weight* obtained was by any means proportional to this large amount of nitrogenous substance consumed.

In our experiments with sheep, then, whether with different descriptions of food, or with different breeds of the animal, *the amount of food consumed would seem to be regulated by the quantities which it supplied of the non-nitrogenous rather than by those of the nitrogenous constituents.*

So much, then, for the bearing of our sheep experiments upon the question of the amount of food consumed according to its composition: but before entering upon a consideration of the results of these same experiments in relation to the second question, namely, that of the *increase produced*, it

will be well to see how far the experiments with pigs afford us similar indications in relation to the former one.

The pig requires much less of mere *bulk* in his food than the ruminant animal. Indeed, the food of the Pig, when on a liberal fattening diet, consists generally, weight for weight, of a much larger proportion of digestible or convertible constituents, and contains much less of effete woody fibre than that of the sheep. Thus, whilst the food of the fattening sheep is principally composed of grass, hay and roots, with a comparatively small proportion of cake or corn, that of the fattening pig comprises a larger proportion of corn, which contains a comparatively small amount of indigestible woody fibre, and is comparatively abundant in starch, sugar, &c., and in highly nitrogenous compounds. Notwithstanding the generally richer character of his food, however, the fattening pig is found to consume a much larger quantity of dry substance in relation to his weight than the sheep. We should at least expect, therefore, that he would yield a greater proportion of increase, and this he is found to do. Such, indeed, is the greediness of the animal, and so much larger is the proportion of the food which he will consume beyond that which is necessary for the respiratory function, or for the formation of flesh, and which is therefore employed in storing up fat, that the amounts of non-nitrogenous matter consumed must obviously, in his case, have a less close numerical relationship to the requirements of the respiratory system than in that of the sheep. Hence, no doubt, is in part the reason that the exact indications of the figures of the Tables are, on the whole, not so consistent as with the sheep. The experiments with the pigs however, bear testimony in the same direction as those with the sheep on the question now in discussion, and the evidence they afford on the point is, indeed, very conclusive.

In the arrangement of the pig experiments the selection of the foods was made rather according to composition than to cost. In the first series (see Tables VI. and VII.) the foods chosen were—

A mixture of equal parts of bean and lentil meal as a *highly nitrogenous food*.

Indian corn meal, as the *comparatively non-nitrogenous food*. And—
Bran, as containing a considerable amount of woody fibre.

The series comprised twelve pens, in each of which three pigs were placed. In the first four pens, the bean and lentil mixture constituted the *ad libitum* food; in one of these it was given alone, and in the others with a limited amount of one or both respectively of the other two descriptions of food. In the second set of four pens, the Indian corn meal was the *ad libitum* food; and it, in its turn, was in one case given alone, and in the others with a certain amount of the other or limited foods. In the third set of pens, bran was the *ad libitum* food; the other two then constituting the fixed or limited food. In this way there was secured a great diversity in the proportion of the nitrogenous to the non-nitrogenous constituents of the food in the several pens; and as the animals were allowed to fix for themselves the limit of their consumption, the results afford us the means of judging, whether in doing this, their natural instincts have led them to any uniformity in relation to their weights, in the amounts taken of either of these classes of constituents.

In Table VI. are given the amounts of the nitrogenous and non-nitrogenous constituents respectively, consumed *weekly by every 100 lbs. live weight of animal*. In this Table we see at a glance, that although there are some apparent discrepancies, yet the figures in the column of non-nitrogenous constituents are much more uniform than in that of the nitrogenous ones. And, as to the few apparent deviations from this uniformity, we think it

will be much more reasonable to attempt to explain, or even considering the nature of the subject, to admit as inexplicable, a few discrepant cases, than to reject on their account the general testimony of much more numerous, more consistent, and otherwise sufficiently conclusive results. Thus in the first set of four pens in this series, there is, upon the whole, a less amount of the non-nitrogenous constituents consumed than in the second; and this lessened amount of non-nitrogenous constituents consumed in the former is seen to be coincident with excessive consumption of the nitrogenous ones, and it is even the less the greater that excess. It is also worthy of remark, too, that in pens 5 to 8, where there was this larger amount of non-nitrogenous substance consumed, it was supplied chiefly by Indian corn meal, which, containing more oily matter than that of the foods in pens 1 to 4, would also possess a higher respiratory and fat-forming capacity, weight for weight, than that in the other cases. We may here suppose, that perhaps a surfeit of the nitrogenous substances put a limit to the further consumption of non-nitrogenous constituents which would otherwise have been taken; or, that being in excess, the nitrogenous substances have substituted other respiratory material; and it is consistent with such a supposition, that with the less amount of non-nitrogenous constituents consumed, where the nitrogenous are in excess, there is nevertheless a larger amount consumed of *total* organic substance than where there is more of the non-nitrogenous constituents.

That a larger amount of the complementary food was consumed when it consisted of the comparatively low nitrogenized Indian meal, was not due only to a craving for a supply of nitrogen which a less quantity would not have yielded, would appear, among other considerations, from the fact, that when, after a time, the pigs in pen 5, where Indian meal alone was given, had become affected with large tumours breaking out on their necks, their breathing and swallowing becoming at the same time difficult, we, in order to test the question as to whether this arose from a defect of nitrogen or from other causes, supplied them with a trough of *mineral* substances: they soon recovered from their complaint, and eventually proved to be among the fattest and best of the entire series of pigs; at least, a dealer in pork with a practised eye, purchased by preference one of these animals from among the whole set of carcasses. The mineral mixture that was supplied to them was composed of twenty parts coal ashes, four parts common salt, and one part superphosphate of lime; and for it they seemed to exhibit considerable relish.

In pens 9, 10 and 11, a comparatively small quantity of the more digestible foods was allowed, the complementary food being in these cases bran; and as we have before said the digestive apparatus of the pig is not adapted for a large amount of bulky woody substance. Here the animals consumed a less amount of non-nitrogenous substance in proportion as the bran predominated in their food; and they at the same time also increased and fattened much less than those in the other pens. In fact, until 3 lbs. per head per day of the limited foods were allowed instead of only two, as was at first given, several of the pigs lost weight and became unwell; being as it were paralysed (gouty?), and almost deprived of the use of their legs. There can be little doubt that the proportion of woody matter in the bran, which food only they had at full command, was too great for the convenience of their stomachs; and that hence, after their respiratory requirements had been fulfilled, a limit was put to further consumption to serve the mere purpose of fattening.

In pen 12, the several foods, namely, the bean and lentil mixture, the Indian meal, and the bran, were each put into a separate trough, and the animals were allowed to take of all or any of them *ad libitum*. Were it not

consumed, the figures at the same time include the amounts which have been expended in the respiratory process.

Looking down the entire columns of Table V., it is at once seen that wherever clover-chaff was employed, that is to say, wherever there was a large amount of innutritious woody fibre, the gross amount of non-nitrogenous substance consumed to produce a given amount of increase is always great. The analysis of the excrements of this series showed, indeed, that there was, in relation to the non-nitrogenous matter consumed in the food, a very much larger proportion of it voided by the animals than in the case of the series where the amount of woody fibre in the food was less. This, therefore, must be allowed for in comparing the figures in the column. It will at once be seen, when due allowance has thus been made, that the amounts of *available* non-nitrogenous substance consumed to produce a given weight of increase, are at any rate much more nearly uniform than are those of the nitrogenous constituents. Of the differences which will still remain after the allowance for woody fibre has been made, many can be again reduced by a consideration of the different equivalents of the remaining *available* non-nitrogenous constituents; as for instance, when in comparable cases these contain, in one instance, more of oil, and in another more of the starch series of compounds. A less amount of the former than of the latter is required to produce the same resulting increase in the animal; and again, less of the starchy series than of some of the peculiar products of the root crops.

In the column showing the proportion of the total nitrogenous substance consumed to increase produced (Table V.), we have a much wider range of difference than in that of the non-nitrogenous, and much wider, indeed, than can be explained away by such considerations as have above been alluded to in reference to the latter. It is true that these figures cannot, any more than in the column of the non-nitrogenous constituents, be taken as showing absolutely proportional nutritious values of the matters represented; for as we have before observed the figures assume the whole of the nitrogen of the food to exist in the form of proteic compounds, which obviously would not be the case with the succulent and unripened produce, such as the roots and clover-chaff; and hence, this consideration must more affect the correctness of the statement of nitrogenous constituents consumed for a given result in the sheep experiments than in those with the pigs, where the foods employed were ripened seeds. But, as we have observed, the differences in the figures in the Table would seem to be too great to be satisfactorily accounted for by the correction of any errors arising from this cause.

Looking at this Table V. rather more in detail, we see, taking the first two pens in Series 1, which are comparable so far as the description of the *ad libitum* food is concerned, that whilst the non-nitrogenous substance consumed to produce 100 lbs. increase in weight is very nearly equal in the two cases, yet that of the nitrogenous constituents varies in the two in the proportion of from three to two; but a difference in the nature of the nitrogenous substance cannot be supposed to have made a difference so great in the amount of constituents consumed to produce a given result. On the other hand, the higher *capacity* of the oleaginous matter of the oil-cake than of the starch, &c., of the oats, is sufficient further to lessen the but small difference in the amounts of the non-nitrogenous substance in the two cases. In pens 2, 3, and 4, of the first series of sheep, we have all but identical amounts of gross nitrogenous substance consumed for a given amount of increase; but this would be of the most highly elaborated kind in pen 2 with the oats, and the least so in pen 4, with turnips only; and in the latter, besides having less of *available nitrogenous* substance, the respiratory and fat-forming *capacity* of the non-nitrogenous

substance in the exclusive turnip diet would be less than in the other instances; and hence the larger amount consumed for a given result.

Turning to the results of the second series, with clover-chaff instead of turnips as the *ad libitum* food, we have, with the larger amount of woody fibre, which would become at once effete, much more gross non-nitrogenous matter consumed to produce 100 lbs. of increase than in Series 1. This is less, however, in pens 1 and 2, with the large proportion of oleaginous matter, than in pens 3 and 4. There is, moreover, in this second series, with this greater amount of non-nitrogenous matter consumed for a given effect than in Series 1, a much larger amount also of the *nitrogenous* constituents; the gross amount of the latter, indeed, in this second series, is twice, and even sometimes thrice as great as in Series 1.

In the next series, namely, Series 3, with barley and malt in different states and proportions as limited food, and mangold-wurtzel as the complementary food, we have, upon the whole, about the same amounts of non-nitrogenous substance required to produce the same result as in series 1, with, besides, a small quantity of grain or other limited food and Swedish turnips as the complementary food, which latter are in great degree comparable with the mangold-wurtzel; and of course, as in Series 1, the average amount is very different from that in the second series with the large proportion of clover-chaff. Looking to the three total columns, namely, of nitrogenous, of non-nitrogenous, and of total organic constituents consumed, although it is true the differences are not great, and perhaps such as might be covered by differences in the composition of the increase, yet it may be noticed, that larger amounts, both of non-nitrogenous and of total organic substance, were consumed to produce the same result the larger the proportion in the latter of the nitrogenous constituents.

In Series 4, we have a more marked instance of the result last noticed. But, apart from the question as to whether the increase of the fattening animal has a closer relationship with the amount of the *true proteic compounds*, or, within certain limits, of the available non-nitrogenous constituents of its food, we have here a striking illustration of the inapplicability on other grounds of the *per-centage of nitrogen* as the measure of feeding value, or indeed of any analytical method, unless a detailed determination of the *proximate compounds*, when succulent products, such as in this instance, the roots, are the subjects of the experiment. Thus, in the fourth pen of this series, where there was by far the largest amount of nitrogen consumed, the animals lost weight; and in the other three pens, the productiveness of the food is in the inverse order of the amounts of nitrogen taken in the food. This arose of course from the different states of maturity, and the consequent state of elaboration of the constituents of the various turnips, the produce of the different manures. Indeed, we believe that an unusually high per-centage of nitrogen in succulent produce is frequently a pretty sure indication of immaturity and innutritious qualities. Comparing the results of this series with those of the others, we have, considering how small would be the proportion of inert woody fibre in the unripe turnips, about twice as much dry substance (in pens 1 and 3 at least) consumed to produce a given amount of increase—a difference which could, at any rate in only a small degree, be accounted for by any difference in the capacities of the digestible and available portions of the foods in the cases thus compared.

Considering only the ostensible similarity of the foods in the several pens constituting the 5th and last series of experiments with sheep, there is, perhaps, no more of coincidence in the amounts that have been required to produce a given increase in the different pens, than, judging from previous results, we might have anticipated. From what we know, however, of the

varying character of the several breeds as fatteners, greater differences might have been expected; for, in some cases a less or larger proportion of the gross increase would be solid substance than in others; whilst this solid substance itself would be composed of more or less of fat or lean—circumstances which obviously imply the appropriation in the increase, of varying amounts and proportions of the constituents of the food consumed. Then, again, though nominally the same, there were unavoidably slight differences in the qualities of the food used in the different cases, and the experiments themselves were not all conducted in the same season; that with the Hampshire and Sussex Downs being made in the winter of 1850-51, that with the Cotswolds in 1851-52, and with the Leicesters and half-breeds in 1852-53. There is also, upon the whole, a very general coincidence in the amounts of non-nitrogenous and total organic substance, consumed to produce a given amount of increase in this series with the different breeds, and the Series 1 and 3. At least the general coincidence throughout these several series is quite as close as the variations in the foods could lead us to look for. But in the column of nitrogenous substance the agreement between this series and the others is by no means so obvious; nor, so far as we know, can the want of agreement in the cases thus compared together be accounted for by differences in the composition and applicability of the nitrogenous constituents themselves.

Reviewing then the whole of the experiments with sheep,—if we consider that it is the results obtained under the subtle agency of animal life that we are seeking to measure and express in figures, and if we also bear in mind the various sources of modification to which our actual figures must be submitted in order to attain their true indications, we think that it cannot be doubted, that beyond a limit below which few, if any, of our current fattening food-stuffs are found to go, it is their available non-nitrogenous constituents rather than their richness in the nitrogenous ones, that measure both the amount consumed to a given weight of animal, within a given time, and the increase of weight obtained.

But we have still to examine the results of the experiments with pigs as to the latter point, namely, that of the relationship of the *increase produced* to constituents consumed; and owing partly to the peculiarities of the animals, and partly to the nature of the foods employed, the actual figures themselves even (see Table VII.) bear out the view that has been maintained more obviously at first sight, than those relating to the sheep. Thus, casting the eye down the column of total non-nitrogenous substance consumed, and more particularly that of the total organic matter, we see with but few exceptions, a strikingly close coincidence in the amounts required to produce 100 pounds of gross increase throughout the two series of twenty-four pens, and as many different dietaries. Some of the exceptions, such as those where a large quantity of bran was used, are at once explained by a consideration of the more obvious qualities of that substance; and many of the minor differences by that of the different capacities of those portions of the foods which would be digestible and available for the purposes of the animal economy; and in this way, as we have already noticed when speaking on the first question, we must account for the generally larger amount consumed with the barley meal in Series 2, than in the comparable cases with the Indian corn in Series 1.

Looking to pens 1 and 2 of Series 1, where the food consisted chiefly of the highly nitrogenous Leguminous seeds, we have comparatively very small amounts of non-nitrogenous substance required to produce a given amount of increase; a result which at first sight appears to lead to conclusions opposite to those from the experiments as a whole. If we look down the column of *total organic substance*, however, we observe that the amounts

of it in the second section of Series 1, where the Indian corn predominated, and where the nitrogenous constituents consumed were only about half as great as in the pens 1 and 2, are generally as small, or even smaller, than in these two pens. It is not, then, that there was in reality a very great productiveness in gross increase from a given amount of food in these two pens, but rather only that with the large supply of available nitrogenous constituents in the Leguminous seeds, a certain amount of the non-nitrogenous constituents have been substituted by it. It was observed, too, that although all the pigs were very fat, excepting the few with an excessive allowance of bran, yet those apparently *grew* more, where, with no deficiency of other matters, the nitrogenous constituents were very liberally supplied. Hence the gross increase obtained might be somewhat more nitrogenous with the large supply of nitrogenous food; but it would in that case, according to some experiments of our own, contain a larger proportion of water, and less of solid matter, than where more *fat* had been produced.

But, with the very great regularity of non-nitrogenous equivalent consumed throughout this large series of pig experiments to produce a given amount of increase, we have, in the column of total nitrogenous substance, on the other hand, a difference in the amounts required, in the proportion of from one to two, or three, or even more; though, since all the foods used in these experiments were ripened vegetable products, a very trifling error, if any, can arise from representing, in all cases, the whole of the nitrogen as existing as proteine compounds. And, there is throughout, a generally larger amount of total organic substance required to yield a given amount of gross increase, the larger the proportion in that substance of the nitrogenous constituents.

It is seen, as has been already noticed, that where the amount of nitrogen consumed in these pig experiments to produce a given amount of gross increase is comparatively large, it is where a large proportion of the Leguminous seeds have been employed. Some writers who have taken the percentage of nitrogenous compounds as the measure of feeding value, have recognised, and endeavoured to explain in various ways, the fact that the records of practical feeding experiments do not award to the Leguminous seeds a feeding value in proportion to their richness in nitrogen; and they have concluded, that it is the accepted indications of the practical experiments, and not the theoretical conclusions, that are at fault. Thus it has been objected against the teachings of such experiments, that the variations in the composition of the same description of food used in different cases has not been determined; that the test has been the gross increase or loss in weight; that the increase may be only fat formed from starch, &c.; that the loss in weight, if any, may be the result of activity, and not of defective diet; that the food in the different cases has been employed in different states, that is, coarse or fine, raw or prepared; that the animals have been variously circumstanced as to temperature, exposure, and activity; that individual animals have very various tendencies to increase and so on. Now we believe that not one of all these objections can vitiate the comparisons which we have made, unless indeed, in some degree, the one which refers to the difficulty of determining whether the gross increase obtained be composed chiefly of fat formed from the starch and oily series of compounds; or whether of flesh from the nitrogenous ones. We believe, indeed, from the many direct experiments which we have made, that in reality, the composition of our domestic animals generally, but especially that of the gross increase of the so-called "fattening" animals, consists of a much larger proportion of fat than is usually supposed. We have instituted very extensive and laborious investigations in regard to this point, the details, or even the general results of which must be reserved for

some future occasion ; before closing this paper, however, we propose to call attention to a mere summary statement of one of these experiments. But, apart from the considerations involved in the question of the varying composition of increase, or from the fact that our own feeding experiments (which, so far as we are aware, are the largest comparable series bearing upon the point) afford testimony in the same direction, we think there is evidence of another kind of the probable correctness of the decisions of practical experiments which have thus been objected to. Thus the comparative prices of the Leguminous seeds and the Cereal grains, may be taken as a pretty safe condemnation of the measurement of feeding value according to their percentage of nitrogenous constituents. In matters of this kind, indeed, especially when staple and generally used articles of food are concerned, the market is one of our shrewdest judges, as we shall presently endeavour a little further to illustrate.

Whilst speaking of the comparative feeding values of the Leguminous seeds and the Cereal grains, we may casually allude to some other considerations of much interest bearing upon this question, which, however, we cannot in any degree adequately discuss in this place.

As a general rule, it may be said, that weight for weight, the Leguminous seeds contain about twice as much of the nitrogenous constituents as the Cereal grains. We have elsewhere shown, that in a Leguminous crop, under equal circumstances of soil and season, an acre of land will frequently yield twice or thrice as much of nitrogenous constituents as in a Cereal grain ; and again, that in the latter an *increase* of produce is not obtained except at the cost of more nitrogen in the manure than is contained in that increase. How is it, we would ask, if this be the case, and if really these foods are valuable in proportion to their richness in nitrogenous constituents, that according to the usual state of the market, we can obtain, for a given sum, about twice as much nitrogenous substance in the Leguminous seeds as in the Cereal grain ; or how is it, on the other hand, that the Leguminous crop does not, much more than is in fact the case, supersede the Cereal grain in the field, the feeding shed, or even on the table ? We have, it is true, much yet to learn of those minor differences of composition to which is due the greater or less adaptation to the instinctive wants of the system of the various constituents of which our staple articles of food are made up, but we think that in no considerations of this kind could we seek an adequate solution of our question. On the other hand, we believe that in the Leguminous seeds the due proportion of the non-nitrogenous to the nitrogenous constituents is not observed. It is obvious, if this be the case, that in the use of the Leguminous seeds, instead of the Cereal grains, more than was requisite of nitrogen would be taken into the system before the adequate supply were attained of the non-nitrogenous or respiratory materials ; nor, as the markets go, would the relative prices of these seeds and grains be found to interfere with a somewhat lavish use and expenditure of nitrogen in the former.

In the facts which are here briefly stated, we have surely very curious and interesting matter for reflection ; and we have brought to our view a striking instance of the mutual adaptations which are everywhere traceable in the practical operation of natural laws. Thus, then, we have said, that under given circumstances, the Leguminous crop will give a much larger acreage yield of nitrogen than the Cereal grain ; and that an increase of produce of the latter is not obtained except at the cost of more nitrogen in the manure than is obtained in this increased produce ; whilst in point of fact, in the ordinary practice of rotation in this country, the growth of the Leguminous corn or fodder crop, with its large per-centage and actual amount of nitrogen, is itself frequently either the direct or indirect source of the nitrogenous ma-

nure by which the increased Cereal is obtained ; and again, this Cereal, obtained at the *cost* of, but with its lessened *produce* of nitrogen, is found in practice to be of equal, or of a more highly feeding value than the more highly nitrogenized Leguminous product which perhaps has been expended to produce it. It would thus appear, therefore, that the demands of the respiratory function which again, more than any other, regulate the consumption of food, would, in point of fact, not be satisfied in the use of the Leguminous diet unless by a consumption or expenditure of an amount of nitrogen beyond that which the due balance of the constituents of food would seem to require ; whilst on the other hand, in the use of the Cereal grain, its better proportion of respiratory to nitrogenous constituents has only been attained by the sacrifice of nitrogen expended in its growth. It would seem, therefore, that whether we would seek our supplies of respiratory food in the direct use of the highly nitrogenized Leguminous seeds, or in the better balanced diet of the Cereal grains, in either case the end is attained only at the cost or expenditure of nitrogen ; in the one case, by the consumption of a larger amount of it in the food than the due balance of constituents would seem to require, whilst in the other this due balance has not been attained without a loss of nitrogen during growth. The claims of health and natural instinct generally leave little doubt which alternative should be adopted, in the case of human food at least ; and it becomes us, therefore, to investigate and understand the practical bearings of these curious and interesting facts ; for upon the principles they involve depend much for their success those fundamental practices of the farm,—the feeding of our stock, for their *double products of meat and manure*, and the adaptation of our rotations.

It would appear, then, from our experiments, that taking our current food-stuffs as we find them, it is their supply of the *non-nitrogenous*, rather than of their nitrogenous constituents, which guides both the amount of food consumed, and of increase produced by a fattening animal. When we consider the nature of the respiratory process, and the large share which its demands must necessarily have upon the consumption of food, it can scarcely appear surprising that *consumption*, at least, should be chiefly regulated by the supply in the food of compounds rich in carbon and hydrogen, rather than nitrogen. That the amount of *increase* produced should also bear a closer relationship to the supply of these constituents than to that of the latter, does not perhaps at first sight seem so obvious, especially if we supposed, as some writers on this subject have done, that the amount of nitrogen in the current food of man and other animals was frequently insufficient to supply the amount required for the production or restoration of the nitrogenous products of the animal organism. We believe, however, that a closer examination of the facts would show that this exceedingly rarely happens ; and we think, moreover, as we have already intimated, that in fact, that portion of nitrogen which is stored up in the *increase* of a growing, and especially of a "fattening" animal, is much less than is usually supposed. We cannot in any degree adequately discuss this question in this place ; but when maintaining a greater relative importance of the *non-nitrogenous* constituents of food than is usually accorded to them, it seems somewhat pertinent briefly to adduce some evidence in confirmation of our conclusions on this point.

We propose, therefore, to give a very brief summary of one of our experiments, in which pigs were the subjects, which was undertaken chiefly for the purpose of ascertaining the *composition of the increase of the fattening animal* ; but to obtain also, some clear evidence in reference to the much-debated question, whether or not more fatty matter is stored up in the animal, than is contained, as such, in its food.

Taking first the question of the *composition of the increase*, we have in the following table a summary statement of the composition of the foods employed in the experiment referred to; and also of the pigs themselves, both in the store, and in the fat condition; as well as that of the *increase* in weight during the fattening process, as deduced by calculation.

Table VIII.

Summary of the Per-centage Composition of the Foods employed—of the Store Pig, and of the Fat Pig—and also of the Increase in Live Weight of the latter.

Description.	Dry Matter.		Mineral Matter (Ash)		Nitrogen.		Fatty Matter (by ether).	
	Inclusive of Ash.	Organic only.	In Fresh Substance.	In Dry Substance.	In Fresh Substance.	In Dry Substance.	In Fresh Substance.	In Dry Substance.
Egyptian Beans .	87.8	84.53	3.274	6.73	4.214	4.80	2.26	2.58
Lentils	86.96	82.03	4.926	5.66	4.487	5.16	2.23	2.56
Foreign Barley...	81.86	79.72	2.140	2.61	1.834	2.24	2.34	2.86
Bran.....	85.08	78.67	6.408	7.53	2.620	3.08	4.98	5.85
Store or Lean Pig	39.70	37.03	2.67	6.73	2.20	5.54	23.32	58.74
Fat Pig	54.74	53.09	1.65	3.01	1.75	3.19	42.20	77.09
Increase in } Live Weight }	71.83	71.39	0.436	0.61	1.33	1.85	63.44	88.32

We may briefly explain, that, for the purposes of this experiment, two pigs were selected resembling each other as nearly as possible both in weight and in every other respect. One of these was killed at once, and its composition determined by methods which we shall fully describe on some future occasion. The other pig, after it had been put up to fatten for a period of eight weeks upon weighed quantities of the foods, the composition of which is given in the upper lines of the table, and its *increase* in weight determined, was also killed, and submitted to the same methods of preparation and analysis as the former one. The composition of the two pigs—the one in the store and the other in the fat condition—thus being ascertained, that of the *increase in weight* was, as will be readily understood, simply a matter of calculation.

We learn from this table (VIII.), that rather less than 40 per cent. of the Store or Lean Pig was dry substance; of which about $2\frac{2}{3}$ rds were mineral matter. Of the remaining 37 per cent. of dry substance, 2.2 were nitrogen, equal to about 14 only of proteine compounds. There is, however, of absolute or dry *fat* in this Store or Lean Pig, about $23\frac{1}{2}$ per cent.; or nearly twice as much as of dry nitrogenous compounds.

In the Fat Pig, on the other hand, there is about 55, instead of about 40 per cent. of dry substance; of which only $1\frac{3}{4}$ rds, instead of $2\frac{2}{3}$ rds are mineral matter. Of the remaining 53 per cent. of dry substance, only 1.75, instead of 2.2, is nitrogen; and this is equal, upon the entire animal, to only 11, instead of 14 per cent. of proteine compounds. We have, however, of *fat*, instead of $23\frac{1}{2}$ per cent., about $42\frac{1}{4}$ per cent, in this Fat Pig, or nearly double as much as in the Lean one; and nearly four times as much as of dry nitrogenous compounds.

With then only about 14 per cent. of nitrogenous substance in the Lean Pig, and nearly twice as much *fat*, we have, in the fattening process, conducted only for a few weeks, the per-centage of mineral matter, reduced by about one-third, and that of the nitrogenous substances by about one-fourth; that of the *fat*, on the other hand, which in the Store Pig even, was in so

much the larger proportion, is nearly doubled in the Fat one. Thus, the increase in weight during the fattening process was found to contain as much as 72 per cent. of dry substance, of which only 0.436 is mineral matter, and only 1.33 nitrogen, equal to about $8\frac{1}{2}$ of proteine or gelatinous compounds. There is, however, about $63\frac{1}{2}$ per cent. of fat, or nearly eight times as much as of dry nitrogenous compounds. Indeed, it is seen in the table, that 88 per cent., or about eight-ninths of the entire dry increase of this Fat Pig, was pure fat.

M. Boussingault, in his 'Rural Economy,' estimates that the Ox, the Sheep, and the Pig, contain from $3\frac{1}{2}$ to 4 per cent. of nitrogen; and more recently in his paper on the Formation of Fat in the Animal Body (*Ann. de Chimie*, vol. xiv. p. 444), he supposes 4 as the probable per-centage in the Pig. He also states (Rural Economy), that M. Payen estimates the *increase* of the fattening pig to contain about 16 per cent. of nitrogenous compounds equal to about $2\frac{1}{2}$ per cent. of nitrogen. It will be observed, however, that only about half of these amounts of nitrogen were found in the direct experiments of our own which we have quoted; and it should at the same time be remarked, that the Fat Pig in our experiment was by no means so fat as is usual, at least in this country.

It is doubtless true, that other animals, as fed for the butcher, will generally contain more flesh and less fat than the pig. In a very fat sheep, however, fed for Christmas, and which was indeed too fat, we found a larger percentage of fat, and as little nitrogenous substance, as in the moderately fat pig, whose composition has been given above. Among our experiments on this subject, it was only in the case of a lean ox, that we found the nitrogen to exceed $2\frac{1}{2}$ per cent. of the entire animal; whilst in all the cases of store or lean animals, the per-centage of dry fat was much greater than that of the dry nitrogenous compounds.

The fact that fat is in so much a larger proportion than lean in the animals fed for the butcher, would seem not only to be consistent with the results of our experiments as to the great influence of the non-nitrogenous constituents of the food of these animals in the production of increase during the fattening process—but it indicates also the predominance of this non-nitrogenous character in that description of human food (butcher's meat), which is generally spoken of as the most nitrogenous, and therefore the most nutritive.

That the *fatty matter of the food* is not the only source of the fat stored up in the body of the fattening animal, is illustrated by a further consideration of the circumstances and results of this same experiment with pigs. Thus, in the following table are shown the amounts of Gross Dry Substance—of Mineral Matter—of Dry Organic Matter—of Total *Non*-nitrogenous constituents—of Nitrogenous constituents—and of Fatty Matter, stored up in the Fat Pig, for 100 lbs. of each of them consumed as food.

Table IX.

Showing the proportion of certain constituents stored up in the Fattening Pig for 100 of each of them consumed as food.

Constituents.	Consumed as Food.	Stored up in the Animal.	Expired, Perspired, or Voided.
Gross dry substance	100	15.04	84.96
Mineral matter	100	2.19	97.81
Total dry organic matter ...	100	15.59	84.41
Non-nitrogenous constituents	100	17.74	82.26
Nitrogenous constituents.....	100	8.35	91.65
Fatty matter	100	407.00	

It may be observed, that in the case of the experiment with this single pig, the amounts of nitrogenous and non-nitrogenous constituents required to produce a given amount of increase—though nearly the same as the *averages* of the 24 pens, as given at the foot of Table VII.—were greater, than in many of the cases with the better foods. Hence, the quantities of the various constituents, represented in Table IX. as stored up in this pig for 100 of each of them consumed, are less than they would be in many of the other experiments. We believe, however, that the figures in the Table (IX.) may be trusted in their general indications; and attention may therefore be called in passing to the fact, that for 100 of each consumed, there is of the total dry substance little more than 15 stored up in the animal; of the mineral matter, little more than 2 per cent; and of the nitrogenous constituents, about $8\frac{1}{3}$ rd per cent.

Again a glance at the Table shows how very much larger is that proportion of every constituent of the food—excepting *fatty matter*—which was expired, perspired, or voided, *i.e.*, which was expended in merely keeping in working order the living mechanism, than that which is stored up in the animal as increase. Of *fat*, however, it appears that there was nearly four times as much stored up in the animal, as there was of fatty matter ready formed in the food. There was then, in this experiment, a considerable *formation* of fat in the animal body.

As is seen in the Table (IX.), for every 100 lbs. of gross dry substance consumed as food, only about 15 lbs. were stored up in the animal; and about 85 lbs. expired, perspired or voided. It may be convenient here to show in a tabular form, the composition of this 15.04 of total dry increase obtained by the consumption of 100 of total dry matter as food.

Table X.

Mineral matter	0.09
Nitrogenous substance	1.67
Non-nitrogenous substance (fat)	13.28
Total increase	15.04
Expired, perspired or voided ...	84.96
Total dry matter consumed	100.00

It must not be concluded, however, that only 15 per cent. of the dry substance of the food was employed in the production of the 15 parts stored up in the fat pig. Thus, in Table X. we see, that, of the 15.04 of gross dry increase produced from 100 of gross dry food consumed, 13.3 were *fat*; and from Table IX. we learn, that only one-fourth of this fat could have been derived from fatty matter already formed in the food. As then only one-fourth, or about $3\frac{3}{4}$ parts of the 13.3 of pure fat, was already formed in the food, about 10 parts out of the 15 of dry animal substance produced, would be *fat formed in the body from some other constituents*. We may perhaps safely reckon, that at least $2\frac{1}{2}$ parts of starch, or the other non-nitrogenous compounds of food, would be required for the formation of one part of fat. It is true, that less than $2\frac{1}{2}$ of starch, &c., would *contain* all the constituents of one part of fat; but when we consider, that in the conversion of the starch series of compounds into fat a large quantity of oxygen is eliminated, which we may assume would not leave the body except in combination with matters that would otherwise serve the respiratory process, it would seem probable, that more than $2\frac{1}{2}$ parts of other constituents of food would be ex-

pended in the direct production in the animal body of one part of fat. At any rate, we are safe in assuming this amount for our present purpose, in the absence of more exact knowledge than is at command on the nature of the intermediate changes to which the constituents of food are subject in their passage through the body. If, then, we suppose, that the starch series—rather than the proteine compounds—of the food, served for the formation of the fat in the animal body, it follows, that about 25 parts of these were expended in the formation of the 10 parts of *produced fat*. If now we add to this amount of the non-nitrogenous constituents of the food not fat, the $3\frac{1}{3}$ rd parts which were fatty matter already formed, and also the $1\frac{2}{3}$ rd of the increase which was not fat, it would appear, that at least 30 parts of the 100 of dry substance consumed, must have been directly employed in the production of the 15 only of dry animal increase. It is obvious, too, from the nature of the chemical change by which fat would be formed from the starch series of compounds, that the extra 15 of the 30 parts of the dry substance of the food, which were expended in the direct production of the 15 of dry increase, would not serve any useful purpose in the respiratory process of the fattening animal. And, unless, indeed, we were to assume—that in the more direct use of the starch series of compounds as respiratory matter, their oxygen was eliminated only in combination with respiratory material—and that when employed in the production of *fat* it was not so—it would appear, that not only must this produced fat have been obtained at the cost of respiratory material expended by the fattening animal which produced it—but that it is, at any rate, not in the *amount* of respiratory material thus obtained, that there can be any gain in this conversion by the fattening animal of a given amount of compounds of *lower* respiratory and fat-forming capacity, into fat to serve as human food, of which it is the most concentrated of the respiratory constituents.

If, then, as we have seen, so large a proportion as nearly $\frac{1}{3}$ rd of the dry substance of the food of the fattening pig may be employed in the direct production of increase—and we have reason to suppose that frequently more than this is so employed—we think that the deviations from uniformity in the amounts of non-nitrogenous constituents consumed by a given weight of animal, within a given time, as shown in our tables, will be admitted to be even less than might have been expected in so extensive and varied a series of experiments—and to be, by no means such, as to raise any question as to whether or not, it was the supplies of the respiratory and fat-forming, rather than the flesh-forming constituents of the foods, which determined the amounts consumed.

But to recur to the question of the *formation* of fat in the animal body. We believe that such a formation, even to a considerable, and practically important extent, is demonstrated by the results of the experiments with pigs last given; and there is every reason to believe, that it is the starch and other non-nitrogenous constituents of the food that contribute mainly, if not entirely, to this formation.

At one time MM. Dumas and Boussingault maintained that the formation of fat in the animal body was improbable; and others have done so more recently. Since that time, however, both M. Boussingault and M. Persoz have instituted direct experiments in reference to this question. In the course of these experiments they found a decided *formation* of fat; and most probably from the starch series of compounds.

M. Boussingault made numerous experiments of a somewhat artificial kind with ducks; from which it appeared, that fat might be formed in the body from other non-nitrogenous constituents of food, and probably from nitroge-

nous compounds also. He also experimented with pigs, in a manner somewhat similar to that adopted by ourselves; and it is a curious circumstance, that his *store*, or *lean* pig, contained almost identically the same per-centage of fat as our own. The foods he employed were, however, far inferior in fattening quality. Hence, though his experiments extended over a much longer period of time, the per-centage of fat in his *fat* pig was scarcely 5 per cent. higher than in his lean one; whilst almost the whole of this *increased* fat had been supplied by fatty matter in the food. It was indeed mainly upon a calculation of the fat which had been supplied in the food of the *store* pig, that he found the evidence of the formation of fat in his experiments with pigs. M. Boussingault is disposed to believe, that the nitrogenous constituents of food probably have some considerable influence in the *formation* of fat in the animal body. We have ourselves called attention to the fact, that a large supply of the nitrogenous constituents of the food would seem to replace a relative deficiency of other constituents. The amount of increase is found, however, to bear a rapidly decreasing ratio to the amount of nitrogen in the food when this exceeds a somewhat narrow limit; whilst the composition of such increase would appear to contain a less proportion of fat. Whether therefore any effect of an excess of nitrogenous compounds in the production of increase be due merely to the amounts they contain of certain non-nitrogenous elements, or to the influence of the nitrogenous compounds themselves as such, in increasing the activity of some of the vital processes, and thus aiding the production of fat, or whether any increase due to the nitrogenous constituents in the food is more generally not fat at all, may be considered to be an open question.

In the experiments made by M. Persoz, geese were the animals he operated upon, and maize the food employed. He found a decided *formation* of fat; and apparently from the starch series of compounds.

We repeat, then, that we believe that the *formation of fat in the animal body*, even to a considerable and practically important extent, and most probably from the starch series of compounds, may now be considered to be clearly proved. It would appear, therefore, that the theoretical opinions of Baron Liebig on this point are fully borne out.

We have thus far only alluded to the feeding of fattening animals; and we think that the results which have been brought forward clearly indicate, that with them at least, as our current food-stuffs go, both the *amount consumed*, and the *increase produced*, are regulated more by the supplies of the more peculiarly respiratory and fat-forming constituents, than of the flesh-forming or nitrogenous ones. We have, however, calculated many human dietaries; and this branch of the subject we hope to enter upon more fully on some future occasion. We may, however, remark in passing, that from the results of this inquiry, as well as from a consideration of the management of the animal body undergoing somewhat excessive labour, as for instance, the hunting horse, the racer, the cab-horse, and the fox-hound, and also pugilists and runners, we are led to believe, that in the cases, at least of ordinary exercise of force, the exigencies of the respiratory system keep pace more nearly with the demand for nitrogenous constituents of food than is usually supposed; and in fact, that the exigencies of the animal body are much more correctly stated in the following sentences by Professor Liebig, than in those wherein he has attached so much more of importance to the amounts of the nitrogenous constituents, as the measure of the comparative value of foods.

At page 314 of the 3rd edition of his *Chemical Letters*, he says:—

“*** It is evident that the amount of nourishment required by an animal

for its support must be in a direct ratio with the quantity of oxygen taken into its system.”

And again at page 322:—

“But the waste of matter, or the force exerted, always stands in a certain relation to the consumption of oxygen in respiration; and the quantity of oxygen taken up in a given time determines in all seasons, and in all climates, the amount of food necessary to restore the equilibrium.”

A somewhat concentrated supply of nitrogen does, however, in some cases, seem to be required when the system is overtaxed; as for instance, when day by day, more labour is demanded of the animal body than it is competent without deterioration to keep up; and perhaps also, in the human body, when under excitement or excessive mental exercise. It must be remembered, however, that it is in butcher's meat, to which is attributed such high flesh-forming capacity, that we have also, in the fat which it contains, a large proportion of respiratory material of the most concentrated kind. It is found too, that of the dry substance of the *egg*, 40 per cent. is pure fat.

A consideration of the habits of those of the labouring classes who are under-rather than over-fed, will show, that they first have recourse to fat meat, such as pork, rather than to those which are leaner and more nitrogenous; thus perhaps indicating, that the first instinctive call is for an increase of the respiratory constituents of food. It cannot be doubted, however, that the higher classes do consume a larger proportion of the leaner meats; though it is probable, as we have said, that even with these as well as pork, more *fat*, possessing a higher respiratory capacity than any other constituent of food, is taken into the system than is generally imagined. Fat and butter, indeed, may be said to have about twice and a half the respiratory capacity of starch, sugar, &c. It should be remembered, too, that the classes which consume most of the leaner meats, are also those which consume the most butter, sugar, and in many cases, alcoholic drinks also.

It is further worthy of remark, that wherever labour is expended in the manufacture of staple articles of food, it has generally for its object the concentration of the *non-nitrogenous*, or more peculiarly respiratory constituents. Sugar, butter, and alcoholic drinks are notable instances of this. Cheese, which at first sight might appear an exception, is in reality not so; for those cheeses which bring the highest price are always those which contain the most butter; whilst butter itself is always dearer than cheese.

In conclusion, it must by no means be understood that we would in any way depreciate the value of even a somewhat liberal amount of nitrogen in food. We believe, however, that on the current views too high a relative importance is attached to it; and that it would conduce to further progress in this most important field of enquiry if the prevailing opinions on the subject were somewhat modified.