terials of maximum enzymic activity from the pancreas and from malt, yield all of the eight forms of nitrogen distinguishable by the Van Slyke method, in proportions within the range of variation shown by such typical protein substances as casein, edestin, hair, and hemoglobin.

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A COMPARISON OF THE OBSERVED AND COMPUTED HEAT PRODUCTION OF CATTLE.[1]

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The first investigation by modern methods of the long-standing problem of the source of animal heat was that of Rubner.[2]

The quantities actually determined in Rubner's experiments were the total nitrogen of the excreta, the respiratory carbon dioxide and the heat produced. The carbon of the visible excreta was computed from their nitrogen, and the absence of carbon compounds, other than carbon dioxide, in the respiration was assumed. From the total excretion of carbon and nitrogen, the catabolism of protein and fat was computed, and from the latter the equivalent amount of heat, using Rubner's well-known factors; it being assumed that there was no material catabolism of carbohydrates. In the aggregate of experiments covering 45 days, the actual heat production, as determined by Rubner's form of animal calorimeter, differed from the amount computed from the body catabolism as follows:

	Cals.
Computed heat production	17406.0
Observed heat production	17349.7
Difference	—56.3 = —0.32%

Laulanié[3] has reported similar comparisons on several different species, by what appear to have been somewhat less rigorous methods. These likewise show a close agreement, the observed differing from the computed heat production in the aggregate of all the experiments reported in full by +0.31%.

The most extensive investigations on this subject are those of Atwater and Benedict upon men. Their experiments are distinguished by the accuracy of their technic and by the fact that all the factors involved were,

[1] Investigations at the Institute of Animal Nutrition of The Pennsylvania State College, in coöperation with the Bureau of Animal Industry of the U. S. Department of Agriculture.

[2] *Z. Biol.*, 30, 73 (1894).

[3] *Arch Physiol.*, 1898, 748.

so far as possible, directly determined. In 30 experiments reported up to the year 1902,[1] and in which the Pettenkofer type of respiration apparatus was employed, the aggregate observed heat production differed from that computed by only —0.05%, the observed heat production tending to be slightly greater than the computed value in the experiments in which there was a gain by the body, and slightly less in those in which there was a loss. Subsequent experiments, in which the oxygen consumption of the subject was determined, while not showing such a very close agreement as the earlier ones, nevertheless substantially confirmed them. In eleven experiments by Benedict and Milner,[2] aggregating 24 days, the observed differed from the computed heat production by +0.6%. In eighteen later experiments by Benedict,[3] mostly on fasting individuals, the corresponding difference was —0.7%.

These various investigations have established beyond reasonable doubt that, in the case of carnivora and of man, the same equivalences between chemical energy, heat energy and mechanical energy obtain in the animal body as elsewhere. It is perhaps a justifiable assumption that the same thing is true of the energy transformations in herbivora, but, with the exception of a few experiments by Laulanié on guinea pigs, rabbits and ducks, the investigations just summarized did not include this large class of animals, so important in their relation to the human food supply and its conservation.[4] For various reasons, therefore, direct investigations upon herbivorous animals, and in particular upon ruminants, appear desirable.

In the first place, while the fundamental nutritive processes may be assumed to be substantially the same in carnivora, omnivora and herbivora, the nature of the feed consumed by the latter introduces a number of possible modifying factors. Thus the carbohydrates include, along with the starches and sugars, numerous other members of the group, belonging both to the C_6 and C_5 series, especially the less soluble hexosans and pentosans. The nitrogenous ingredients of the feed, too, in addition to true protein, include a great variety of other substances whose physiological significance is but partially understood. The relatively insoluble carbohydrates (woody fiber) render the feed of herbivora bulky, requiring a complicated alimentary canal and doubtless an increased measure of digestive work, while the comparatively low digestibility of the feed results in the excretion of correspondingly bulky feces. Very extensive fermentations of the carbohydrates also occur, especially in the capacious first stomach

[1] U. S. Dept. Agr., Office of Experiment Stations, *Bulletins* 109 *and* 136; *Memoirs Nat. Acad. Sci.*, 8, 1235.

[2] U. S. Dept. Agr., Office of Experiment Stations, *Bull.* 175, 262.

[3] "Influence of Inanition on Metabolism," Carnegie Institution of Washington, *Publication* 77, 512.

[4] Compare *Popular Science Monthly*, November, 1911, p. 496.

of ruminants, with production of large amounts of carbon dioxide and methane and sometimes of hydrogen. Finally, the excretory products of the urin include hippuric acid, a rather notable proportion of ammonia, and considerable amounts of non-nitrogenous matter of unknown nature. In view of all these differences, an investigation into the sources of animal heat in the herbivora seems not without scientific interest.

In the second place, the economic aspect of the question, already alluded to, is not without importance. Agricultural animals are transformers of chemical energy, storing up portions of it in forms available for man's nutrition. The fundamental laws governing these transformations, therefore, are of material economic significance.

In the third place, while the newer method of comparing the nutritive values of feeding stuffs for farm animals introduced by Kellner—his so-called "starch values," which are essentially energy values—does not, in terms, assume identical energy equivalences within and without the body. Confidence in its results will, nevertheless, depend largely upon whether or not they may be found in accord with the law of the conservation of energy.

Beginning in 1902, there have been made each year at this institute a number of balance experiments on mature or nearly mature cattle (steers), in which the income and outgo of carbon, hydrogen, nitrogen and energy have been determined and the results of which, therefore, permit a comparison of the observed with the computed heat production.

The experiments have been made with an Atwater-Rosa respiration calorimeter of the earlier type, consisting of a Pettenkofer respiration apparatus, the chamber of which constitutes also an animal calorimeter. The more important details of the apparatus have already been described[1] and a somewhat complete account of the experimental methods employed and of the check tests made has also been published.[2] On the basis of check tests with burning alcohol, the error of a single experiment is estimated at 0.5% for the CO_2 determination, and at 1.0% for the heat measurement.

	Body protein.[3]	Body fat.[4]
Carbon	52.54	76.5
Hydrogen	7.14	12.0
Nitrogen	16.67	..
Sulfur	0.52	..
Oxygen	23.12	11.5
	100.00	100.0

[1] U. S. Dept. Agr., Bureau of Animal Industry, *Bull.* **51**, 23–25; U. S. Dept. Agr. Expt. Sta., *Rec.* **15**, 1037 (1903–4); U. S. Dept. Agr., Bureau of Animal Industry, *23d Annual Report*, pp. 263–270.

[2] U. S. Dept. Agr., Bureau of Animal Industry, *Bull.* **128**, 200–22.

[3] Köhler, *Z. physiol. Chem.*, **31**, 479 (1900).

[4] Schulze and Reinecke, *Landw. Vers. Stat.*, **9**, 97 (1867).

From the balance of nitrogen and carbon, the gain or loss of protein and fat is computed in the usual manner, using the preceding figures for the composition of body protein and body fat, respectively.

The energy equivalent to the gain or loss is computed by the use of the usual factors, *viz.*, 5.7 cals. per gram of protein and 9.5 cals. per gram of fat. The heat production is computed by subtracting the energy of the gain by the body (or adding the energy of the loss) from the difference between income and outgo of chemical energy, as in the following illustration:

	Cals.	Cals.
Energy of feed	.....	22,486
Energy of feces	7,359	....
Energy of urin	1,217	....
Energy of CH_4	1,848	....
Energy of brushings	123	....
Total energy of excreta		10,547
		11,939
Energy of gain	...	1,699
Computed heat production	...	10,240
Observed heat production	...	10,174

Aside from experimental errors, such a comparison as the foregoing includes certain other sources of error, to which attention should be called.

The computation of the energy equivalent of the gain by the animal assumes that it consists wholly of protein and fat—in other words, that the stock of body glycogen remains unchanged. The experiments were, in every case, begun after the ration in question had been fed for 17 days consecutively. In those cases in which there was a gain it seems safe to assume that, by the end of that time, the glycogen content of the animal had come into approximate equilibrium with the feed supply, and that the gain did actually consist substantially of protein and fat. With sub-maintenance rations, on the other hand, there is to be considered the possibility of a continuous loss of glycogen for some time, in which case the estimates for the energy equivalent of the loss may be too large by an unknown amount.

As regards the determination of the heat actually produced, two sources of error are to be specially noted.

The first is that due to a gain or loss of matter by the body of the animal. In case of a gain, heat actually produced in the body is stored up in it, while in the contrary case heat generated in the body at some previous time is eliminated and measured along with that actually produced. In the experiments here described, the measured heat has been corrected as accurately as possible for these gains or losses, especially for that of water.

The second source of error in the determination of the heat produced is that arising from fluctuations in the body temperature of the experimental animal. It has not been found practicable thus far to take the temperature of the subject while in the calorimeter. No indications of any abnormal conditions, however, were afforded by the rectal temperature taken outside the calorimeter, and since the experiments began and ended at the same hour it has been assumed that the body temperature was the same at both times.[1]

Beginning in 1902, there have been made 57 experiments, the results of which have been computed and are available for comparison.[2] The results, so far as they relate to the subject under discussion, are contained in the following table, which includes all the experiments made up to the close of the year 1909. Each experiment covered 48 hours and was divided into four sub-periods of 12 hours each. The table shows the average results for 24 hours.

OBSERVED AND COMPUTED HEAT PRODUCTION OF CATTLE.

	Gain by animal. Cals.	Heat production in 24 hours.		Difference.	
		Computed. Cals.	Observed. Cals.	Cals.	Per cent.
Steer I, 1902	—2,741	9,243	9,215	— 28	—0.3
	— 807	10,201	10,296	+ 95	+0.9
	— 9	11,116	10,749	—367	—3.4
	+ 524	11,577	11,493	— 84	—0.7
Steer I, 1903	—3,409	11,635	11,529	—106	—0.9
	—4,179	10,123	10,123	0	0
	—2,518	10,655	10,540	—115	—1.1
	+3,791	14,181	14,652	+471	+3.2
Steer I, 1904	—5,243	11,014	10,911	—103	—0.9
	—5,374	11,185	11,736	+551	+4.7
	—1,339	11,980	11,435	—545	—4.8
	—1,086	11,727	11,318	—409	—3.6
	—2,715	11,274	10,724	—550	—5.1
	—2,770	11,066	10,875	—191	—1.8
Steer A, 1905	—1,260	8,047	8,606	+559	+6.5
	+1,117	8,826	9,149	+323	+3.5
	—2,439	5,979	6,196	+217	+3.5
	—1,271	7,285	7,356	+ 71	+1.0
Steer B, 1905	— 818	6,379	6,621	+242	+3.6
	+ 829	6,901	7,327	+426	+5.8
	—1,869	4,825	5,221	+396	+7.6
	— 535	5,346	5,434	+ 88	+1.6

[1] For further details on these two points, compare U. S. Dept. Agr., Bureau of Animal Industry, *Bull.* 128, 111–13.

[2] The computation of a considerable number of additional experiments has not been entirely completed.

OBSERVED AND COMPUTED HEAT PRODUCTION OF CATTLE—(*Continued*).

	Gain by animal. Cals.	Heat production in 24 hours. Computed. Cals.	Observed. Cals.	Difference. Cals.	Per cent.
Steer A, 1906	+1,368	9,249	9,339	+ 90	+1.0
	+4,305	12,882	12,872	— 10	—0.1
	—2,510	7,345	7,452	+107	+1.4
	— 287	8,165	8,209	+ 44	+0.5
Steer B, 1906	— 640	9,053	8,937	—116	—1.3
	+1,133	9,700	9,736	+ 36	+0.4
	—2,047	6,709	6,928	+219	+3.2
	— 438	7,448	7,380	— 68	—0.9
Steer A, 1907	+1,699	10,240	10,174	— 66	—0.6
	+6,341	14,090	14,140	+ 50	+0.4
	—1,655	7,766	7,773	+ 7	+0.1
	+ 628	9,407	9,493	+ 86	+0.9
Steer B, 1907	— 166	9,490	9,536	+ 46	+0.5
	+2,573	11,330	11,521	+191	+1.7
	—2,283	7,853	7,895	+ 42	+0.5
	+ 163	9,165	9,428	+263	+2.8
Steer D, 1908	—1,277	5,069	5,029	— 40	—0.8
	—1,923	4,078	4,021	— 57	—1.4
Steer E, 1908	+ 815	7,150	7,087	— 63	—0.9
	— 862	5,553	5,524	— 29	—0.5
	—1,954	5,008	4,903	—105	—2.1
	+ 728	7,437	7,687	+250	+3.2
	—1,440	5,664	5,695	+ 31	+0.5
	—1,963	4,523	4,646	+123	+2.6
Steer C, 1908	—1,955	7,169	7,046	—123	—1.7
	—2,109	6,105	5,945	—160	—2.6
	— 845	9,177	8,975	—202	—2.3
	—1,464	7,066	7,115	+ 49	+0.7
	—2,000	5,884	5,934	+ 50	+0.8
Steer F, 1909	+2,147	8,756	8,989	+233	+2.6
	— 95	7,369	7,404	+ 35	+0.5
	—1,936	6,310	6,343	+ 33	+0.5
	+ 500	10,784	11,066	+222	+2.0
	—1,186	7,697	7,731	+ 34	+0.3
	—3,148	6,846	6,718	—128	—1.9
Totals and averages, 57 experiments	—45,904	488,102	490,117	+2,015	+0.4

As might be anticipated, in view of the numerous sources of error in experiments of this sort, the results of individual trials differ considerably, in some cases, from those required by the law of the conservation of energy, the extreme percentage differences being +7.6 and —5.1.

In the aggregate of a considerable number of experiments, however, these errors would tend to compensate each other, and, in fact, the total observed heat production for the 57 trials differs from that computed by only +0.4%. This difference is of about the same order of magnitude as those observed by previous investigators, being slightly greater than Rubner's and slightly less than Laulanié's and Benedict's, although the range of error in the individual experiments is somewhat greater. Only the earlier averages of Atwater and Benedict show a materially closer agreement.

The conclusion seems warranted, therefore, that the same equivalencies between chemical energy, heat energy and mechanical energy obtain in the bodies of herbivorous animals as in those of carnivora or of man, and, as a rule, elsewhere in nature.

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NEW BOOKS.

Elementary Chemistry with Special Reference to the Chemistry of Medicinal Substances. By H. M. Gordin, Professor of Chemistry in the Schools of Pharmacy and Dentistry of the Northwestern University. Vol. I. Inorganic Chemistry. Medico-Dental Publishing Co., Chicago. Price, $3.00.

This book was written to fulfil the two-fold purpose of supplying an elementary text for medical students, and a fairly complete compendium of inorganic medicinal preparations. It gives a very complete discussion of the preparation and properties of the elements and their compounds, with many references to substances of greater pharmaceutical than chemical importance, and closes each chapter with a very satisfactory set of questions. The spirit in which one would have to teach from the book may be well summed up in a few words from the introduction to the chapter on the Periodic Table (p. 178); "It is of much greater importance to know the physical and chemical properties of an element than to decide to what family it belongs." The book would encourage learning by rote rather than acquiring any powers of reasoning. Chapters on Matter and Energy, Physical and Chemical Changes, Gas Laws, Molecular Hypothesis, Atomic Hypothesis, Chemical Formulas and Chemical Equations and Calculations serve as an introduction and are, probably by reason of their location, presented in a rather simplified form. On p. 21 one notes that "Avogadro proposed a hypothesis according to which all molecules of all gases, no matter of what elements they consist, are of the same size;" on p. 67 gypsum is given as $2CaSO_4.H_2O$; on p. 116, "The largest amount of a solute which will give a clear solution with a definit amount of the solvent is called the solubility of that solute;" on p. 119, "If the solution contains more than 20.2 per cent. of the gas, hydrogen chloride alone escapes when the solution is heated; when the solution con-