

as to which the Indians declare that the island was once the cemetery for the neighboring mainland, and therefore will not allow the mounds to be explored.

Subsequently, near the village of San Miguel. Mr. Miller examined and photographed the ruins of an old church, surrounded by a pavement of smooth, flat stones, carefully laid in cement, but now cov-



RUINS OF A TEMPLE ON THE ISLAND OF COZUMEL.

ered with earth. The inhabitants say that this pavement extends for half a mile around the church, and that a broad, paved way once led from the church to the water, a mile away.

ERRORS IN DIGESTION EXPERIMENTS.

HENNEBERG and Stolmann, in their *Beiträge zur rationellen fütterung der wiederkäuer*, published in 1860, reported practically the first determinations of the digestibility of the proximate constituents of cattle-foods. Since that time, a large number of similar determinations upon various fodders, and with the several species of domestic animals, have been made, chiefly, if not entirely, by the German experiment-stations. In these determinations the method employed by Henneberg and Stolmann, and which is here given in outline, has been universally followed.

The food of the animal is weighed, suitable account being taken of any portion left uneaten, and a sample of the food is subjected to chemical analysis. The solid excrement of the animal, which consists for the most part of the undigested portions of the food, is also carefully collected, weighed, and analyzed.

From these data, it is a simple matter to compute how much dry matter or how much of any particular ingredient of the food the animal received, and what part of this failed to be digested.

This method of experiment evidently will give directly the digestibility of any fodder which can be made the exclusive food of the animal. In the case of material like grain, meal, and the concentrated fodders in general, the matter is not quite so simple. In this case it is first necessary to determine the digestibility of a sample of hay, or other coarse fodder. This done, the animal is given a mixture of this coarse fodder and the concentrated fodder in question, and the amount of this mixture which is digested is determined. Then, on the assumption that the same proportion of the coarse fodder was digested in the second trial as

in the first, we calculate how much of the concentrated fodder must have been digested in order to yield the results observed upon the mixture.

Certain sources of error have been ignored in the general statement given above. Thus the excretion is always more or less irregular from day to day: and the excreted matter contains, in addition to undigested food, more or less intestinal mucus, and remnants of digestive juices, which, though small in amount relatively, are not entirely to be neglected. Then it has recently been shown that some portions of the food fail to appear in the excreta, because they suffer a fermentation in the alimentary canal, rather than because they are digested in any proper sense. This is particularly the case with cellulose (see *Science*, No. 100, p. 11). Finally, the methods of analysis in use for fodder and excrement are not in all respects capable of giving sharply defined results.

Another class of errors, the small unavoidable errors of weighing and chemical analysis, usually less considered, may grow to very considerable dimensions when multiplied many

times in computing the composition of large amounts of fodder from that of small samples. In some recent digestion experiments made by the writer at the Wisconsin agricultural experiment-station, a computation was made of the influence of these analytical errors, with results very similar to those arrived at by Kühn¹ in a paper on the effect of cooking and other methods of preparation, upon the digestibility of wheat-bran.

In both cases it was assumed that no material loss of either fodder or excrement had occurred. In view of the care taken in the conduct of the experiments, this assumption seems justified. It at least does not magnify the probable error. It was likewise assumed that the sampling was free from error. In the writer's experiments, analyses of four samples of the same hay agreed so closely as to justify the assumption. In short, the computations were confined to the effect of *analytical errors* upon the results.

With these explanations, we give below a statement of the errors to which the several determinations were found to be subject:—

Probable errors.—Hay.

	Kühn's experiments.	Armsby's experiments.
	<i>Per cent.</i>	<i>Per cent.</i>
Dry matter	—	± 0.08
Organic matter	± 0.1	—
Proteine (N × 6.25)	± 2.1	± 1.15
Crude fibre	± 1.9	± 0.62
Fat (ether extract)	± 2.5	—

It should, perhaps, be added, that the results of a digestion experiment are usually expressed in per cent of the amount fed. The above results mean, that if, for example, 50% of the proteine fed was found to have been digested, the true amount in the writer's experiments was probably not less than 48.85% nor more than 51.15%.

That the probable error appears smaller in the writer's experiments is largely due to the methods of calculation employed. No strict rules can be followed in such a computation, but a considerable field must be left for the exercise of good judgment. Kühn wished to avoid making the error appear too small: the writer, with a somewhat different purpose in view, wished to avoid exaggerating it. It is plain that in both experiments a reasonable degree of accuracy was attained.

Next let us turn to the results upon by-fodders. Here, owing to the method necessarily

employed (see above), the errors are, so to speak, concentrated in the by-fodder, as the following statement shows:—

Probable errors.—By-fodders.

	Kühn's experiments. ¹	Armsby's experiments.	
	Bran.	Malt sprouts.	Cottonseed-meal.
	±	±	±
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Dry matter	—	0.5	0.5
Organic matter	0.6	—	—
Proteine	7.7	2.8	1.6
Crude fibre	7.2	6.8	31.0
Fat	25.6	—	—

¹ Calculated by the writer.

It is evident from these results that determinations of the digestibility of concentrated fodders are subject to a somewhat considerable error. When they contain but little of an ingredient, the relative error may be very large, as in the case of the crude fibre of the cottonseed-meal, while, if the ingredient is present in larger amount, as in the malt sprouts and bran, the relative error is reduced.

In both Kühn's and the writer's experiments, however, a second source of uncertainty was discovered in the fact that the same animal may digest the same fodder to a somewhat different extent at different times. The writer's experiments show one unmistakable example of this, and Kühn's several.

Now, as stated above, the calculation of the digestibility of a concentrated fodder is based on the assumption of unaltered digestibility of the coarse fodder. If this assumption is not true, the whole of the error thus introduced will, by the method of computation employed, attach to the concentrated fodder. The following statement shows what very considerable errors may arise from this source, combined with the analytical errors above noted:—

Possible errors.

	Kühn's experiments.	Armsby's experiments.	
	Bran.	Malt sprouts.	Cottonseed-meal.
	±	±	±
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Dry matter	11.5	4.3	4.7
Organic matter	9.6	—	—
Proteine	15.4	5.7	3.2
Crude fibre	91.5	10.9	52.4
Fat	36.1	—	—

¹ Lande, versuchs-stationen, xxix. 1.

The experiments which we have been considering compare favorably as to methods and care with previous experiments of the same sort; and it does not seem unwarranted to conclude that those, also, are subject to errors of somewhat the same magnitude. It appears plain that we can, with proper care, determine the digestibility of the total ration fed with a very satisfactory degree of accuracy; but it seems equally plain that we cannot compute from that result the digestibility of any single fodder composing the ration with the hope of obtaining any thing more than approximately correct figures. The data which we have for the digestibility of the concentrated fodders are of more or less value for practical purposes, since they are usually the average of several determinations; but for scientific purposes such determinations are of very doubtful value.

H. P. ARMSBY.

AN ANTHROPOMETRIC LABORATORY.

In the February number of the *Journal of the Anthropological Institute of Great Britain and Ireland*, Mr. Francis Galton describes the laboratory which he established at the International health exhibition to familiarize the public with simple methods of measuring and recording many of the physical characteristics of man. The instruments in action dealt with keenness of sight, color-sense, judgment of eye, hearing, highest audible note, breathing-power, strength of pull and squeeze, swiftness of blow, span of arms, height standing and sitting, and weight. Some other apparatus not in actual use, such as a balance to determine delicacy of touch, was exhibited.

All these instruments were so contrived as to economize the time of the attendant; so that, although each person measured was in the laboratory about twenty minutes, he consumed but seven minutes of the attendant's time. Thus it was possible to measure ninety persons daily, and cover the running expenses of the laboratory with a tax of threepence each. Of course, the reduction of expense to a minimum gives a much broader field for work, especially in introducing periodic systematic measurements into schools, which is one of the ultimate objects of this demonstration.

Keenness of sight, or power of accommodation of the eye, was measured by means of an original instrument of a flat, sickle-shape, upon which were set upright, at regular intervals, small blocks of wood, covered below with printing in diamond type, and having printed at the top in large type the distance in inches from the eye-piece. The number of inches at which the diamond-type is legible is an expression of the accommodating power. This test showed, that, of 850 persons, forty per cent had both eyes equally effective, while sixty per cent had a notable

difference in the power of the two eyes. The average difference between the two eyes was two inches; but the average strength of the right and left eye was almost exactly the same. The color-test was Holmgren's light-green test, nicely arranged to economize time. Judgment of the eye in dividing a line into halves, and in setting a movable arm square upon a board, were tested in ingenious ways, which doubtless among children would express the native quality, but oftentimes among adults would be only a measure of facility acquired by occupation. The highest audible note was measured by five whistles, set to emit 10,000, 20,000, 30,000, 40,000, and 50,000 vibrations per second respectively. Of 317 males between forty and fifty years of age, a hundred per cent heard the first whistle, to four per cent who heard the last. In this, as in every other particular, the males excel the females.

The spirometer used consists of a counterpoised vessel suspended in water, which rises as air is breathed into it, and shows the number of cubic inches of displacement by a scale at its side. The breathing-capacity increases rapidly in early youth, becomes stationary between twenty and thirty, or a little later, and thenceforward steadily declines. Up to the age of twenty, the breathing-capacity has been the same for both sexes; but at that age that of the males becomes half as great again, — a ratio which is maintained throughout after-life. Unexpectedly, it appears that there is no close relation between the breathing-capacity and the strength of pull or of squeeze. The latter, which were estimated by means of Salter's instruments for the purpose, show that the left hand is about six per cent weaker than the right, and that women are weaker than men. Of the 1,657 adult women measured at the laboratory, the strongest could exert a strength of squeeze of but eighty-six pounds, or about that of an average man.

For the first time, swiftness of blow was measured, either of a blow delivered with the fist straight at a pad upon one end of a flat bar running freely between guides, or of a pull, by holding a stirrup attached by a string to a similar bar, and striking out into space. The swiftness is registered by means of a spring with pencil attached, which is set free, and vibrates transversely as soon as the bar begins to move. The results of this measurement are not discussed.

A curious fact, which came to light on comparing the height sitting with the height standing, is, that in women an increase in stature is accompanied by a disproportionate increase in the length of the legs, while in men, for all statures up to six feet, the ratio between height sitting and height standing is the same, 54:100.

During the continuance of the laboratory, 9,337 persons were measured, of whom 4,726 were adult males, and 1,657 were adult females. The results of all these measurements are not fully discussed, nor has Mr. Galton perfected his ideal of a laboratory. Among other measurements which will be added to the list, are those of the head, its maximum length and breadth with graduated calipers, and its maxi-