both pools were isolated in other similar experiments; both formed precipitates with polyhaptenic antigens.

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[1] Lerman, L. S., *Proc. U.S. Nat. Acad. Sci.*, **39**, 232 (1953).

[2] Campbell, D. H., Luescher, E., and Lerman, L. S., *Proc. U.S. Nat. Acad. Sci.*, **37**, 575 (1951).

[3] Alm, R. S., Williams, J. P., and Tiselius, A., *Acta Chem. Scand.*, **6**, 826 (1952).

[4] Lowry, O. H., Rosebrough, N. J., Farr, A. L., and Randall, R. J., *J. Biol. Chem.*, **193**, 265 (1951).

[5] Pauling, L., Pressman, D., and Grossberg, A. L., *J. Amer. Chem. Soc.*, **66**, 784 (1944).

Nosean as a Tracer Mineral

EIGHT miles south of Land's End stands the well-known Wolf Rock with its important lighthouse. The rock itself is a phonolite, the only one of its kind on the whole of the coast of the British Isles. Its petrography was accurately described by J. J. Harris Teal in 1888 ("British Petrography", Dulau and Co., London).

For our purpose the all-important mineral is nosean, a somewhat soluble sodium aluminium silicate with sodium sulphate; but fortunately it is found in two stages. It occurs as phenocrysts which are useless for the present purpose because of their solubility in sea-water, and it also occurs as inclusions in the felspar sanidine, as minute grains which are thus hermetically sealed within this colourless mineral which is practically as resistant to sea-water as quartz itself. Actually, one can boil small flakes of the sanidine in fairly strong hydrochloric acid without the nosean being destroyed.

Thus the nosean would appear to constitute an ideal tracer mineral for investigating the direction of deep, or bottom, sea-water drift around the British Isles.

Owing to the kindness of Major H. W. Hall, who readily placed his motor yacht *Manihine* at my disposal, we were able to carry out the first test on July 22.

Only one sample has been worked out so far, and that was one taken five miles east of the Wolf Rock at a depth of forty fathoms. It was thought that the work would entail a laborious microscopic examination of the bottom sand grains with the use of density fluids for floating off the sanidine flakes with the nosean. This, however, was found to be unnecessary in this case, for small pebbles of phonolite (about a third of an inch across) were readily separated out with a hand lens. These were crushed and the nosean enclosed in the sanidine recognized without difficulty.

Obviously, if pebbles of the phonolite are carried five miles away by the deep-water drift the minute flakes may be carried even hundreds of miles. Phonolite from the Wolf Rock has been broken up, and the nosean in conjunction with the sanidine is at once recognizable in flakes which are small enough to go through a 200-mesh sieve.

The refractive index of the sanidine is, of course, below that of the canada balsam, while that of the nosean is below that of the sanidine. This, coupled with the low density of the phonolite itself (2·54), makes the work comparatively simple and gives an indisputable diagnosis.

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Milk Yield of Hill Ewes

IN the early stages the growth of the lamb is largely dependent on the milk yield of its dam. In hill sheep, where the environment constitutes the limiting factor to production, a study of the milking capacity of the ewe would seem to be of special interest, as it forms a large part of the lamb's environment at a most important period of growth.

Comparatively little work has been done on the lactation of non-dairy breeds of sheep, especially hill sheep. Some of the most extensive studies made on this problem are those by Bonsma in South Africa[1] and Wallace in Cambridge[2], although the sheep studied were not under natural conditions. Studies of the milk yields of sheep on pasture have been made by Barnicoat *et al.*[3] in New Zealand.

In the spring of 1953, an experiment was started at the University College of North Wales to study the milk-yielding capacity of Welsh Mountain ewes, both under their normal hill conditions and after being drafted to the lowland.

Previous workers have usually obtained estimates of the ewe's milk yield by weighing the lamb before and after suckling at various intervals in a weekly 24-hr. period. Between sucklings the ewes and the lambs were separated. At Bangor, however, the separation of the ewe from the lamb was regarded as likely to be a disturbing factor, which might seriously affect milk yield, and an attempt was made to devise a method whereby the lamb was prevented from suckling, and at the same time allowing both ewes and lambs to go out on pasture together in between suckling periods. This was achieved by fitting the ewes with a harness which effectively prevented the lamb from reaching the ewe's udder, and at the same time was both comfortable for the ewe and easy to manipulate at suckling time.

A pilot experiment using eight pedigree Welsh Mountain sheep kept on the lowland was first carried out early in the year to develop the required technique. The experiment proper was started early in April using thirty-two randomly selected hill ewes with single ewe lambs on 'ffridd' or 'inbye' land at about 1,000 ft. above sea-level. Mean daily yields during the six weeks of the experiment were $31{\cdot}79 \pm 6{\cdot}04$ oz. for the hill ewes compared with 47 oz. for the pedigree ewes during a shorter period. A preliminary analysis of this year's results gave a high correlation coefficient ($r = +0{\cdot}79$) between the milk yield of the ewe and the growth of the lamb during the first month, demonstrating the importance of the dam's milk yield to the young lamb. Significant correlations were also obtained between the milk yield of the ewe and the birth weight of the lamb ($r = +0{\cdot}51$) and the weight of the ewe at tupping time ($r = +0{\cdot}36$). Although there appeared to be a correlation between milk yield and some fleece characters these were not highly significant, and further work is needed to prove any relationship.

These results, of course, being for one season only, must be confirmed and extended by further work before any conclusions are reached.

It is hoped to be able to increase the numbers used in the experiment in future, and to study the relationship of milk yield to such factors as fleece type, genetic influences, weight (both at lambing and tupping time), age, time of lambing and udder measurements. Some of the ewes included in this year's experiment will be drafted on to the lowland in order to study the effect on milk yield of the change from a poor to a good environment, as normally occurs when the hill ewe is drafted to the lowland.

Some observations have also been made on the quality of the milk, and it is hoped to extend these.

Finally, the effect of milk yield and other factors on the lamb will be studied.

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[1] Bonsma, F. N., Publication No. 48, University of Pretoria (1939).
[2] Wallace, L. R., *J. Agric. Sci.*, **38**, Part 2 (1948).
[3] Barnicoat, Logan and Grant, *J. Agric. Sci.*, **39**, Parts 1 and 2 (1949).

Influence of Inorganic Sulphate on the Copper–Molybdenum Interrelationship in Sheep

IN 1945 we published the first experimental observations[1] which showed that the storage of copper in the livers of sheep and cattle could be significantly reduced by an increase in the molybdenum intake, and we suggested that an abnormally high molybdenum intake may possibly explain, among other things, the seeming anomaly of copper deficiency in sheep-grazing pastures which show by ordinary chemical anlalysis a copper concentration within normal limits.

Since then a number of workers have studied the copper–molybdenum interrelationship in animal metabolism. Observations on this interrelationship are discussed in a number of the papers in the symposium on copper metabolism edited by McElroy and Glass[2], and more recently the literature has been reviewed by Marston[3].

Many of the observations and experimental results have been conflicting[2–4], and some workers[5] have not been able to confirm our original results.

In association with our studies on chronic copper poisoning in sheep[6,7], we have continued our observations on the effects of molybdenum on copper metabolism; and we believe that in the results of our more recent studies may lie the explanation of many of the anomalies and conflicting observations.

With sheep under experimental conditions, we have shown that, for a particular dietary regime, which included a total daily intake of 10 mgm. of copper, there is a quantitative relationship between the amount of molybdenum added to the diet and the reduction in the amount of copper stored in the liver. Under these conditions, on comparing groups of sheep on successively greater daily intakes of molybdenum, all on a diet of equal parts by weight of chaffed lucerne hay and chaffed oaten hay, it was found that progressively less copper was stored in the liver as the molybdenum intake was increased from 0·4 mgm. to 10 mgm. per day. Further increases in the molybdenum intake, up to 100 mgm. per day, had no greater effect in limiting the amount of copper stored.

On this mixed diet, the level of molybdenum maintained in the circulating blood was increased as the molybdenum intake was increased. When these chaffed hays were fed separately to sheep, all on the same molybdenum intake, it was observed that the blood-molybdenum level was approximately ten times higher in the sheep on the oaten diet than in those on the lucerne diet. A comparison of groups of sheep[8], all on intakes of 10 mgm. of molybdenum and 15 mgm. of copper per day, but fed on the separate chaffed hays or on mixtures of several different proportions of these, showed that the greatest limitation of copper storage in the liver was obtained in sheep fed on the pure lucerne diet. Molybdenum appeared to exert no limiting effect at all in sheep on the pure oaten diet, and for the several diet mixtures the amount of copper stored in the liver and the level of molybdenum in the blood were directly proportional to the amount of chaffed oaten hay in the mixture.

We thus have the apparently anomalous position that as the blood-molybdenum level is raised by increasing the molybdenum intake of sheep, all on the same mixed diet, the amount of copper stored in the liver is progressively decreased; but as the blood-molybdenum level is raised by increasing the proportion of chaffed oaten hay in the diet of sheep, all on the same molybdenum intake, the amount of copper stored in the liver is progressively increased.

In a subsequent experiment of six months duration we have shown that with two groups of sheep, both having a total copper intake of 10 mgm. per day and a molybdenum intake of 0·5 mgm. per day, one group fed on chaffed lucerne hay and the other on chaffed oaten hay, the copper content of the livers of both groups increased. However, even at this low level of molybdenum intake, the group on the lucerne diet stored significantly less copper than the group on the oaten diet; in the former there was a gain of 55 mgm., increasing during the experiment from 39 mgm. to 94 mgm., and the latter 97 mgm., increasing from 40 mgm. to 137 mgm.

With two similar groups on a molybdenum intake of 10 mgm. per day, there was a loss of 13 mgm. (from 41 mgm. to 28 mgm.) of copper from the liver in the group on the lucerne diet, but the greater intake of molybdenum did not significantly affect the rate of copper storage in the group on the oaten diet; it increased by 70 mgm. (from 38 mgm. to 108 mgm.).

By fractionation of this chaffed lucerne hay we have shown[9] that the whole of its effect on the level of molybdenum in the blood is due to its content of inorganic sulphate which is present in amounts of the order of 0·3 per cent. The chaffed oaten hay contains less than one-tenth of this amount.

To determine whether the difference in inorganic sulphate content of the two diets was also responsible for the difference between them in enabling molybdenum to exert its limiting effect on copper storage, a further experiment has been carried out. A sufficient quantity of copper sulphate and ammonium molybdate was added to the diets of three groups of sheep to bring both the copper and molybdenum intakes up to 10 mgm. per day in each group. One group was fed on chaffed oaten hay, one on chaffed lucerne hay, and the third group on chaffed oaten hay with 4·5 gm. potassium sulphate per kilogram added to