cause of the disease is still unknown and even if it should be found to be an infective agent it would appear that the composition of the grass has an important role in the aetiology of the disease. The diet of stabled horses is usually rich in carbohydrate and there is need for investigation into the physiological changes that take place when they are suddenly switched from a limited quantity of a carbohydrate rich diet to unlimited grazing on pasture.

The diseases I have mentioned are those most prevalent in Scotland. Most farmers have at some time to pay heed to the potential dangers of their pastures as far as livestock is concerned.

I have tried to stress our lack of knowledge of the chemical composition of pasture and of its variation under differing soil and weather conditions. I have tried to stress how the chemical composition of pasture may play a causal or major role in the aetiology of many animal diseases and how, if we are to elaborate preventive or curative measures, our knowledge of pasture must be extended.

There is, therefore, real and immediate need for the formation of a group of experienced organic chemists and plant physiologists to work in close collaboration with soil chemists and nutrition and disease research workers, and it is hoped that in the near future a research institute or agricultural college will bring such a team together.

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Mineral Deficiency Conditions in Sheep on Scottish Hill Grazings

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Cobalt

The film "Vinquish in Hill Sheep" is presented to depict various aspects of a cobalt deficiency disease in 44 south Ayrshire hill flocks (Dunlop and McCallien, 1941). The earliest reference to the condition in this area is that of Aiton (1811), although Hogg (1807) had previously observed that it was confined, at that time, to the west of Scotland where it was distinguished in different shires by the names of "pining," "daising" and "vinquish".

The following symptoms as they occur in ewes and lambs are shown in the film: emaciation, rough staring fleeces, watering eyes, anaemic

mucous membranes of the eyes and gums, listless movement and collapse. The correlation between geological formation and the occurrence of the disease, its world wide distribution and the synonyms in use in different countries are shown by diagrams.

The further development of the symptoms over a 10-day period in an animal receiving 10 mg. doses of Fe daily, and the complete recovery of a moribund animal receiving 1 mg. of Co per day over the same period, are illustrated by direct photography.

The methods of prophylaxis now adopted, namely, the administration of 5 ml. of a solution containing 100 mg. cobalt at monthly intervals during the summer months and the provision of a mineral mixture containing cobalt in specially constructed boxes on the grazing, have eliminated the disease from the affected area.

Parasitic Worm Infestation

Previous to 1940 helminthological examination of the stomach and intestines of affected sheep in this area had shown that they carried a moderate worm burden. It was believed, however, that this did not wholly account for the poor condition of the animals. Since then the provision of cobalt salts to the flocks has become general and, while the condition of the stocks is now satisfactory, the possibility remained that some animals might still be harbouring a number of worms.

In 1943 a number of young lambs were dosed, first on June 28th and again on July 29th, with one 5 g. tablet of phenothiazine. An equal number remained undosed and served as controls. All the animals were weighed, and samples of the faeces obtained for worm counts on June 26th. The groups grazed together until August 21st when they were again weighed. The results are presented in Table 1.

TABLE 1

THE EFFECT OF TREATMENT WITH PHENOTHIAZINE ON WEIGHT GAINS IN LAMBS

Breed	Treatment	No.	Weight, lb.	
			Initial	Gain
Crossbred ..	Phenothiazine	23	54·0	24·7
	No phenothiazine	27	52·3	26·8
Blackface ..	Phenothiazine	12	47·7	24·0
	No phenothiazine	12	51·2	25·3

Statistical examination of the results showed that the differences between the groups were scarcely significant, the chances that they were so being 17 to 1. Although the gain in weight of the treated group was less than that of the untreated, it cannot be concluded that dosing with phenothiazine was definitely harmful.

Examination of faecal samples from a number of the lambs, obtained at the beginning of the experiment, showed the presence of only 100 worm eggs or less per g. Further experiments by the College on 12 hill farms in various counties of the south west of Scotland gave similar results.

Dosing with cobalt on hill farms where deficiency symptoms arise appears to be all that is necessary to maintain the animals in health and

ensure that parasitic worms are kept under control. These findings are in agreement with previous work on the influence of the nutritional state of the sheep on its susceptibility to infestation with the stomach worm (Fraser and Robertson, 1933).

Fertility

It was observed by Hogg (Ettrick Shepherd, 1829–31) that "few of the ewes that are affected in the autumn (with pining) have lambs next year or they have them far too late to be of any value". The low fertility of some flocks in south Ayrshire directed attention to Hogg's observation. In many of these the lambing season is protracted and there is frequently a large percentage of barren ewes.

Marked improvement in the fertility rate was observed in a number of flocks after the provision of salt mixtures containing cobalt on their grazings. The results obtained on one badly affected farm are given in Table 2.

TABLE 2

EFFECT OF A MINERAL MIXTURE CONTAINING COBALT ON THE FERTILITY OF EWES ON A SOUTH AYRSHIRE HILL FARM WHERE LAMBING COMMENCED ON APRIL 10TH

Details of lambing	1938–40 Untreated	1941–43 Treated
No. of lambing ewes	600	600
Still to lamb, May 1	125	67
May 15 ..	44	6
June 15 ..	17	0
Barren	4	1

The rams remained with the flock throughout the winter.

Low fertility is observed also on farms outside the recognized areas where disease symptoms appear. The average data for one such farm over 32 years are presented in Table 3. In November 1942 each breeding

TABLE 3

EFFECT OF COBALT TREATMENT ON THE FERTILITY OF EWES ON A PERTHSHIRE HILL FARM WHERE LAMBING COMMENCED ON APRIL 15TH

Details of lambing	Average for 1910–42 Untreated	1943 Treated
No. of lambing ewes	140	140
Still to lamb, May 7	36	0
Barren ewes	45	6

The rams were removed from the breeding flock on January 1st.

ewe in the flock received an oral dose of 100 mg. cobalt before the rams were turned out. The results obtained at the 1943 lambing are included in the table.

There was clear evidence that a cobalt deficient state in the autumn gives rise to anoestrus in ewes, and these ewes are found to be barren the following year.

Further work is being continued on this problem to determine all those areas in the west of Scotland where anoestrus due to cobalt deficiency is common.

Copper

The disease "swayback" in lambs has been shown to be nutritional in origin and may be prevented by adding supplements of copper salts to the diet of the pregnant ewes (Dunlop and Wells, 1938).

In Scotland affected areas of hill grazings are limited in extent. They occur in the following localities:

Dumfriesshire:	The Devil's Beef Tub and Auldgirth
Kirkcudbrightshire:	Carsphairn
Ayrshire:	Maybole, Girvan and New Cumnock
Lanarkshire:	Lead Hills
Argyllshire:	Isle of Islay and Appin
Stirlingshire:	Campsie Fells.

The disease occurs also on low ground grazings and in certain years may be very severe (Alexander, 1882). Outbreaks have been investigated recently on newly re-seeded pastures which have received heavy dressings of lime. Such outbreaks have been sufficiently numerous to require the adoption of preventive treatment of all breeding flocks grazing on such land during pregnancy.

Insufficient data are available at present to indicate the whole train of events leading to the production of the disease in the offspring of the ewes. In addition to low copper content of the pasture and excessive liming, lead also has been incriminated in certain areas in Australia (Bennetts, 1935) and in England (Dunlop and Wells, 1938).

The occurrence of the disease in the vicinity of the Carsphairn lead mines and the Lead Hills lends support to the hypothesis that lead in certain areas may be a factor in the aetiology. That a high correlation may exist between the lead content of the pasture and the severity of the disease in the vicinity of lead mines is evident from the data in Table 4.

TABLE 4

CORRELATION BETWEEN THE LEAD CONTENT OF PASTURE AND THE INCIDENCE OF SWAYBACK

Incidence per cent.	No. of farms	Pb content of pasture		Cu content of pasture p.p.m.
		Mean p.p.m.	Range	
30 to 60	3	398	300 to 545	26
10 to 30	3	138	130 to 145	27
0 to 10	3	99	86 to 122	22
0	1	58	—	20

Experiments to induce the disease on grazings where it occurs sporadically by dosing the ewes with lead salts in amounts up to 0·5 g. Pb per day

during the last 6 weeks of pregnancy gave negative results. While administration of copper over this period to ewes on affected grazings prevents the appearance of the disease in the offspring (Dunlop, Innes, Shearer and Wells, 1939), it is unlikely that symptoms will develop in the progeny of normal ewes drafted on to the worst affected grazings for so short a period before lambing.

On the other hand, as shown by Innes and Shearer (1940), there is a marked relationship between the copper stores in the liver and the incidence of the disease. This is also evident in Table 5.

TABLE 5

RELATION OF INCIDENCE OF SWAYBACK TO COPPER AND LEAD STORES IN THE LIVER OF LAMBS

Group	No. of observations	Pb content of liver*		Cu content of liver*	
		Mean p.p.m.	Range	Mean p.p.m.	Range
Normal lambs born in S. Derbyshire flocks ..	19	1·98	0·0 to 4·9	22·5	2·2 to 71·0
Normal lambs in the affected area of N. Derbyshire	12	6·34	1·8 to 16·0	5·25	1·9 to 19·0
Cases of swayback ..	9	2·81	1·5 to 6·9	0·77	0·2 to 1·9

* The analyses of lead and copper were carried out in the County Analyst's Laboratory, Derby.

This evidence shows that *in certain districts*: (*a*) The incidence of the disease is related to the amount of lead in the pasture; (*b*) there is no relationship between the incidence of the disease and the copper content of the pasture; (*c*) lambs which succumb to swayback have extremely low copper reserves in the liver compared with healthy lambs on the same grazing or in flocks free from swayback; (*d*) there is no relationship between the lead content of the lamb's liver and the occurrence of the disease.

Calcium, Phosphorus and Vitamin D

"Bent Leg"

In Scotland on a number of grazings where ram lambs are reared, especially those of the Blackface breed, difficulty is experienced after the New Year in maintaining the animals in normal health and condition. The disease known as "bent leg" finally manifests itself and renders the animals almost valueless in the sale ring.

The condition was produced experimentally at the Rowett Institute by Elliot and Crichton (1926). It is fairly widespread in Scotland but occurs principally in ram lambs after they have been drafted from hill grazings to rich arable pasture. Numerous cases have been reported from Lanarkshire and the Carse of Gowrie.

The occurrence of rickets in hoggets in New Zealand (Fitch, 1943) during the same season of the year prompted further investigation into the nature of "bent leg". In New Zealand the blood picture in the ram lambs showed that blood calcium and phosphorus were depressed to about half their normal values.

The analysis of the blood of a number of animals in a naturally occurring outbreak investigated during the early spring months of 1943 gave the results shown in Table 6.

TABLE 6

BLOOD VALUES FOR HILL RAM LAMBS ON ARABLE PASTURE AFFECTED WITH "BENT LEG"

Hogg No.	Condition	Serum Ca mg. per 100 ml.	Serum P mg. per 100 ml.
Affected animals			
1	Worst affected	8·9	6·4
2	Tibia bent	9·3	5·0
3	Bent at fetlocks	8·3	5·7
4	Knock kneed	7·2	4·4
Other animals on same pasture			
5	Clinically normal	9·8	6·0
6	,, ,,	9·0	4·4
Normal animals on permanent pasture			
7	Normal	13·0	6·0
8	,,	10·8	6·3
9	,,	12·7	5·6
10	,,	12·5	5·9

It is evident, therefore, that "bent leg" in Scotland is not the same disease as rickets in hoggets as described by Fitch.

Work by Auchinachie and Fraser (1932) showed that a calcium supplement and vitamin D as cod liver oil had a marked prophylactic effect on "bent leg" produced experimentally.

"Croitich" or "Creutuch"

"Croitich" or "creutuch", another disease of hill sheep referred to as rachitic in nature, occurs during midsummer. Cases are most prevalent in July. Affected animals gradually assume a stiff, stilted gait and appear to walk on their toes with short uneasy steps. The disease appears to be similar to "cruban" in cattle as described by McNab (1803). Affected animals "become poor, exhausted and scarcely able to move while their hind-legs are contracted towards their fore-feet as if they were drawn by cords".

MacLelland (1875) reported that "those affected by this disease are found on the tops of the hills, the poor feeding and constant exposure being the supposed cause of it. A change to lower and better pastures generally effects a cure but the sheep require to be watched as they have a singular tendency to return to the old feeding ground on the top of the hill". Observant shepherds, however, report that animals frequently show the first symptoms of the disease on the lower grazings. Their presence on the top of the hill is explained by the stiff, stilted gait which becomes progressively more marked and renders descent down hill most difficult. It is necessary that they continue to graze up hill to the tops where they eventually remain unable to move further.

Cases begin to develop about the end of June and a number of ewes may be seen to be affected in mid-July at clipping time. After the

fleece has been removed the symptoms rapidly disappear and there may be few, if any, fresh cases that year.

The aetiology of the condition is still obscure. The short seasonal occurrence of the disease, the location of affected animals and the low morbidity have not encouraged any extensive research work. The classification of the disease as "rachitic" by some workers appears to be based on the similarity of the symptoms to those of other conditions. It is noteworthy, however, that ewes which become affected nurse the biggest lambs in the flock. The removal of the fleece may allow the actinic rays of the sun to penetrate to the skin of the animal and thus alleviate the negative calcium and phosphorus balance of a heavy lactation.

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Discussion

Professor S. J. Watson (Edinburgh and East of Scotland College of Agriculture, Edinburgh), opener: These two papers by Dr. Stewart and Dr. Dunlop demonstrate our lack of knowledge of the composition of grass and pasture. An extensive team is required for the study of this subject. When methods of analysis have been agreed, the work is just begun, and there is no final answer in analysis; we must know the availability of the constituents to animals. Again, a review of the literature shows that analyses do not agree; there are fluctuations in composition due to season and growth. Further, the composition when signs of disease appear may not represent the composition when the trouble began. There are also difficulties in getting representative samples. Sheep may not graze the whole of an area. Herbage that causes disease may not cause any when fed to stock elsewhere.

Then there is the question, what is a deficiency? In swayback, copper therapy is used, but there is no copper deficiency; in molybdenum excess, copper is curative but not deficient according to our inadequate standards. Diseases that occur on pasture most commonly affect the ruminant. Sufficient importance has not been attached to this fact. Has this association some connexion with the microflora of the rumen? Molybdenum, for instance, will stimulate the growth of certain strains of bacteria in the rumen. We know little about conditions in the rumen