ring-barking, mechanical clearance and the use of arboricides, are all expensive. Strang favours an alternative to cattle ranching, that is the cropping of wild herbivores.

Game ranching offers a number of advantages over cattle grazing. In particular the wild herbivores are able to exploit the full spectrum of natural primary production rather than being dependent on certain palatable species. Most of the game animals involved are browsers rather than grazers, hence they would not be adversely affected by scrub encroachment. An important argument against this solution is the difficulty of disease control in mixed communities of wild herbivores. Perhaps a greater problem is the social upheaval which would undoubtedly result from such a radical agricultural policy —a policy which has yet to be justified economically.

ENERGY RESERVES

Bio-fuel Gauge

from a Correspondent

OF all the problems facing small homoiothermic animals living in cold places, hypothermia is possibly the greatest. This is probably one of the reasons why there is an abundance of small birds and mammals in the tropics and a scarcity in Arctic and Alpine regions. Hypothermic torpor in small animals is far from uncommon, and recently it has been shown to occur in the broad-tailed hummingbird (*Selasphorus platycercus*) of North America. What is especially interesting is the series of factors bringing about its onset.

Calder and Booser (*Science*, **180**, 751 ; 1973) have examined the fluctuations in temperature of hummingbird nests during incubation in the nesting seasons of 1971 and 1972. A study site at 2,900 m elevation was established in the Elk Mountains, Gunnison County, Colorado. Thermistor probes were embedded in elastomer "eggs", and the pattern of the hen's absences from the nest was recorded by interpretation of the rapid cooling spikes on the temperature trace.

Hummingbirds cannot feed in the rain, and during one particular 24-h period in June 1972 the weather deteriorated to such an extent that the incubating females missed several of the normal, periodic feeding flights. The hens of two wired-up nests lost approximately 21 and 12% respectively of their normal feeding opportunities. In an animal with a delicately balanced energy budget this reduction in energy intake can be expected to have a profound effect on subsequent behaviour. At about 0100 h in the night following this catastrophe the air temperature fell to −1.0° C, and the temperature of nest 1 began a steady decline from 31° C to 6.5° C. It then stabilized and seemed to be regulated. The temperature of nest 2 showed a similar decline and stabilized at the same level, but the decline started almost 3 h later. In both nests normal temperature was regained by 0500 h—the time at which feeding flights normally recommenced.

The chart from nest 2 showed several sharp drops immediately before the onset of hypothermia. This recalls the "test drops" made by ground squirrels when entering hibernation (Sturmwasser, *Am. J. Physiol.*, **196**, 8 ; 1959), but they also resemble normal brief nest departures. It is therefore possible that the hen from nest 2, sensing its energy reserves were insufficient for the weather conditions, tried to feed during the night in an attempt to preclude the need for torpor.

The fascination of these observations lies in the fact that the periods of hypothermia endured by the two hens started at different times but ended simultaneously. The length of time spent in torpor seemed to be correlated with the reduction in feeding opportunities (21 and 12%) presented to hens in the previous daytime. This is not so strange, for it has long been known that the duration of torpor induced in laboratory rodents is correlated with food intake (Bartholomew, *Ecology*, **50**, 705 ; 1969). What is curious is that the reduction in number of occasions for energy intake acts as a fuel gauge to "inform" the bird of the precise moment when it should enforce the necessary economies. These economies seem to be withheld until the last possible moment, doubtless in the hope of a sudden rise in air temperature.

Cooling seems not to damage birds' eggs, but it does increase incubation time. Perhaps frequent resort to torpor is an important factor in the long incubation periods seen in hummingbirds nesting high in the Andes.

MATERIALS SCIENCE

Analysis of Surfaces

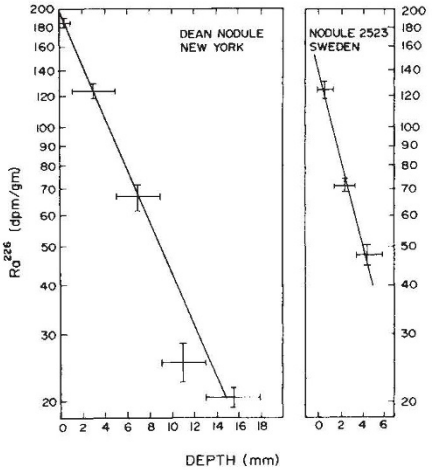
from our Materials Science Correspondent

ARGUABLY the most productive new instrument in materials science since the war has been the electron microprobe analyser. This instrument, which depends on the emission and analysis of characteristic X-rays, stimulated by a minute exploring beam of electrons impinging on a selected point on a polished specimen, has transformed the study of solidification, phase transformations, diffusion and corrosion. Its essential feature is that the chemical ana-

How Do Nodules Grow in Freshwater ?

THE question how ferromanganese nodules grow in freshwater is considered by Krishnaswami and Moore in *Nature Physical Science* next Monday (June 18). They discuss the insight cast on this problem by their study of two nodules, one a sphere 2 cm in diameter from Lake Alstern, Sweden, and the other a saucer shaped concretion about 2 cm thick from Oneida Lake, New York.

If the growth rates of the deposits are in the range 100 to 1,000 mm per 10^3 yr, ^{228}Ra (half life 6.7 yr) and ^{210}Pb (half life 22.3 yr) should be ideal for measuring the rate of accretion. Surprisingly, however, the appropriate analysis of these two nodules yields accretion rates of only 1 to 3 mm per 10^3 yr, with ages around 6,500 yr, similar to those reported for iron–manganese nodules from Lake George, New York.



Variation of ^{226}Ra with depth in the two nodules.

Taken at face value, then, these data suggest that sediment around the nodules accumulates 1,000 times faster than the nodules grow. How, then, do the nodules maintain their position at the sediment/water interface? Perhaps active currents play a part in keeping the nodules exposed, which would also explain why nodules are abundant where wave action is strong and fine sediment absent. Or perhaps there is another interpretation.

Krishnaswami and Moore point to three possible sources of error in their approach: first, the ^{226}Ra concentration in the lakes may be increasing; second, radium may migrate to the outside of the nodules during growth (although no such effect is observed for barium); and third, ^{226}Ra may be diffusing inwards, producing an apparent radioactive decay with depth. But if the nodules are as old as they seem to be, they should certainly provide valuable information on the trace element history of the water in which they formed.