Magnesium Deficiency
I. The Femur in Acute Magnesium Deficiency (36149)

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Duckworth *et al.* (1) demonstrated a decrease in percentage ash of the leg bones of magnesium-deficient young growing albino rats. Clark (2) and Clark and Belanger (3) on the other hand, using adult rats which had been maintained on a magnesium-deficient diet, reported no decrease in the percentage ash of the femur. Indirect evidence of the effect of magnesium on bone has been supplied by histological studies. Bernick and Hungerford (4) demonstrated an arresting of the proliferating cartilage of the epiphyseal plate, which was later confirmed by Clark and Belanger (3). By the use of tetracycline labeling on magnesium-deficient bones, Trowbridge and Jenks (5) demonstrated a reduction in appositional bone formation.

This report describes the effect of magnesium deficiency on the mineral in bone.

Materials and Methods. Twelve 100 g male rats of the Sprague-Dawley strain were divided into two groups. Both groups were placed on triple distilled deionized water and were fed Heggtveit low, magnesium test diets purchased from General Biochem (Cat. No. 170489). The diets of the control group were supplemented with 500 ppm Mg in the form of $MgSO_4$ (Analytical Reagent Grade).

When an experimental animal appeared to be near terminal stages of the deficiency, it and its control were anesthetized with ether and killed by cardiac puncture. The appendicular skeletons were dissected out along with the head and vertebral column. The femurs were Grenz rayed and scanned by γ-ray absorption densitometry as described by Cameron and Sorenson (6, 7). The scans were made cross-sectionally at 1 mm intervals. The femurs were then sectioned into thirds, the bone marrow was removed and the bone sections were defatted in 1:1 mixture of ether:ethanol. The bones were then weighed, ashed at 550° and reweighed.

Results. A. γ-Ray absorption densitometry. The γ-ray absorption densitometry of the control femurs produced a characteristically shaped curve. There are three main areas of significance in the control curves. They are: (A) a small initial peak at the proximal end of the bone; (C) a second larger peak at the distal end; and (B) a left-skewed depression. These three areas of the control curves were used for comparison with the experimental curves (Fig. 1).

Femurs from the experimental animals showed alteration in the γ-ray absorption curves. In general, the curves reflected a decrease in the overall size of the experimental femurs; this was particularly apparent with animal number 162. All but one of the curves showed a decrease in peak C, and two showed decreases in peak A. The region of the left-skewed depression in the curves was also altered in the experimental femur. The depression was less marked when bone length was comparable to the control femurs. The decrease was so marked that the experimental curve rose above its control curve in several cases, as illustrated in Fig. 1. The individual curves were expressed in Table I as values of the heights of peaks A and C and the depression B base line, and as the ratios A/B and C/B.

B. Grenz ray examination. An examination of the Grenz rays of the excised bones of the legs revealed differences in the radiological appearance of bones from several areas. The proximal epiphyseal plate of the experimental tibias was more sharply defined than the controls (Fig. 2). In the diaphysis of the

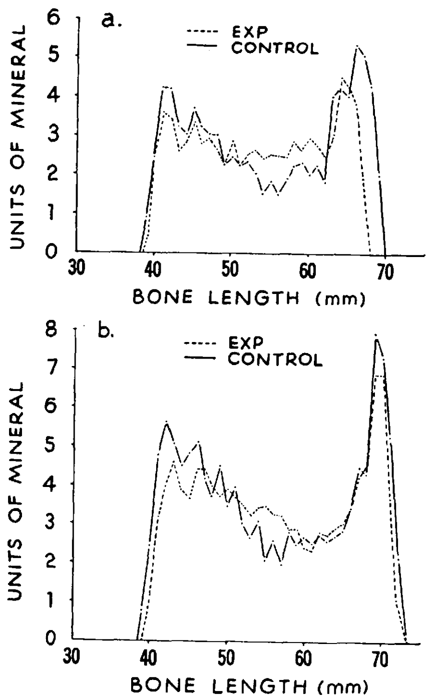

FIG. 1. γ-Ray absorption densitometry scans: (a) animals on diets for 15 days (141E & 142C); (b) animals on diets for 29 days (177E & 178C).

experimental femurs, the endosteal surface of the cortical bone appeared uneven. The trabeculation in the distal condyles and patella was more apparent in the deficient animals than in the controls. The observation

TABLE I. Values for A, B, and C of the γ-Ray Absorption Densitometry Scans.

Animal no.[a]	A	B[b]	C	A/B	C/B
141E	3.65	2.48	4.54	1.47	1.83
142C	4.29	1.46	5.36	2.93	3.67
148E	4.15	2.44	5.45	1.70	2.23
149C	4.29	1.65	6.16	2.60	3.73
162E	3.91	1.83	4.95	2.13	2.70
163C	4.86	2.15	7.05	2.26	3.28
173E	5.12	2.21	6.66	2.32	3.01
174C	5.10	2.24	6.98	2.28	3.12
177E	4.62	2.55	6.86	1.81	2.70
178C	5.71	2.54	8.03	2.25	3.16
184E	5.11	2.96	6.42	1.73	2.17
185C	5.53	2.03	6.99	2.72	3.44

[a] The letters **E and C** in the animal number stands for experimental or control.

[b] The B value is chosen as the lowest point on the curve.

confirms the decrease in peak C of the adsorption curves.

C. Percentage ash. The percentage ash of each of the three sections of femurs indicates no significant change in mineralized osteoid tissue in the Mg-deficient animals (Table II).

Discussion. The Grenz rays of the femur suggest that there is something occurring in the bone other than simple arresting of growth. The nonsmooth medullary cavity indicated that the bone remodeling process was altered due to either abnormal mineral deposition or to abnormal breakdown of bone. The percentage ash indicates that the ratio of mineral to osteoid is within normal limits.

The measurement of the attenuation of γ-ray beam provides a direct measurement of bone mineral per millimeter of length along the bone. The γ-absorption scans of the femurs confirm the picture seen in the Grenz rays. The scans suggest that there is marked reduction of osteoclastic activity because the

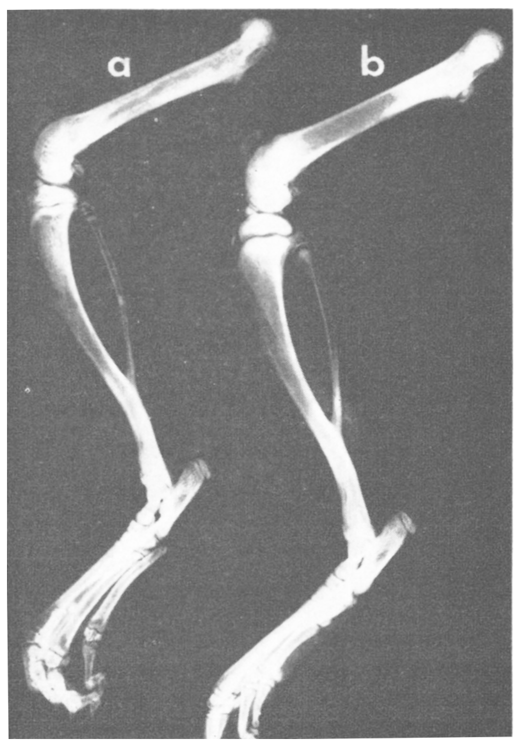

FIG. 2. A comparative Grenz ray of animals on diets for 29 days: (a) experimental animal, 177E; (b) control animal, 178C.

TABLE II. Percentage Ash of the Sectioned Femurs.

Animal no.[a]	(days) On diet	Wt at sacrifice (g)	Ash of femur sections (%)[b]		
			Proximal	Diaphysis	Distal
141E	15	151	45.9 (9)	60.0 (12)	41.8 (10)
142C	15	184	47.8 (8)	67.5 (12)	40.0 (9)
148E	19	184	48.5 (9)	59.4 (10)	35.9 (10)
149C	19	209	53.3 (10)	54.3 (11)	50.0 (8)
162E	22	162	52.5 (9.5)	62.7 (10)	46.7 (8)
163C	22	286	52.9 (9)	62.5 (13)	48.8 (10)
173E	28	183	53.2 (9)	62.4 (12)	48.2 (9)
174C	28	279	55.4 (12)	60.7 (13)	46.8 (8)
177E	29	233	54.3 (10)	63.3 (12)	48.8 (10)
178C	29	248	55.4 (10)	63.4 (12)	51.2 (10)
184E	35	241	55.0 (10)	64.5 (12)	48.8 (10)
185C	35	282	55.7 (12)	63.9 (12)	50.5 (10)

[a] The letters E and C in the animal no. stands for experimental or control.
[b] The length (mm) of the femur section is given in parentheses.

left-skewed depression indicates more mineral per unit length than the control. In addition, there is an increase in bone density, both mineral and matrix phases, which is demonstrated by the normal percentage ash. Clark and Belanger's (3) finding of dense immature matrix would tend to support these observations.

The γ-absorption scans along with the Grenz rays provide evidence for an effect of acute magnesium deficiency on osteoblast and chondroblast activity, suggested by the histological appearance of cells (1, 3, 4). The effect is also demonstrated by a more pronounced decrease in peak C than in peak A.

Acute magnesium deficiency thus seems to alter the activity of different bone cell types. The magnitude and mechanism of the alteration require further experimentation for clarification.

1. Duckworth, J., Godden, W., and Warnock, G. M., Biochem. J. 34, 97 (1940).
2. Clark, I., Amer. J. Physiol. 34, 97 (1940).
3. Clark, I., and Belanger, L., Calcif. Tissue Res. 1, 204 (1967).
4. Bernick, S., and Hungerford, G., J. Dent. Res. 44, 1317 (1965).
5. Trowbridge, H., and Jenks, P., J. Calif. Dent. Ass. 44, (1968).
6. Cameron, J., and Sorenson, J., Science 142, 230 (1963).
7. Sorenson, J., and Cameron, J., J. Bone Joint Surg. (Amer.) 49, 481 (1967).

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