possibly enamel, although this was not measured. These results are similar to Mallek et al.[16]. 1st molar and incisor germs of 1-, 5-, 10-, 15- and 20-day-old rat pups were removed from control and protein-energy malnourished rat pups, minced, and cultured for 4 h in media with and without CT. CT-treated incisors and molars from the 5-day-old protein-deprived rats had increased Ca uptake compared with controls. Ca uptake was also significantly higher in the CT-treated control group than the untreated control group. The present study detected an increased uptake of Ca by intact healthy 1-day-old mouse molars, an effect no observed by Mallek et al. Their failure to detect a change in the 1-day-old rat molar could have been due to the shortness of incubation (4 h vs 2 days) and the difference in the manner in which the tissue was incubated (minced vs intact).

1 A.G.E. Pearse, Proc. R. Soc., Lond. *170*, 71 (1968).
2 F.E. Newsome, R.K. O'Dor, C.O. Parkes and D.H. Copp, Endocrinology *92*, 1102 (1973).
3 P.F. Hirsch, G.F. Gauthier and P.L. Munson, Endocrinology *73*, 244 (1963).
4 D.M. Kallio, P-R. Garant and C. Minkin, in: Calcium, Parathyroid Hormone, and the Calcitonins, p.383. Ed. R.V. Talmage and P.L. Munson. Excerpta Medica, Amsterdam 1972.
5 J.L. Matthews, J.H. Martin, E.J. Collins, J.W. Kennedy and E.L. Powell, in: Calcium, Parathyroid Hormone, and the Calcitonins, p.375. Ed. R.V. Talmage and P.L. Munson. Excerpta Medica, Amsterdam 1972.
6 J. Freidman and L.G. Raisz, Science *150*, 1465 (1965).
7 S.A. Grubb, T.C. Markham and R.V. Talmage, Calcif. Tissue Res. *24*, 201 (1977).
8 S.H. Doppelt and R.V. Talmage, Clin. Orthop. *118*, 242 (1976).
9 H. Norimatsu, C.J. Vander Weil and R.V. Talmage, Clin. Orthop. *139*, 250 (1979).
10 A.B. Borle, Endocrinology *85*, 194 (1969).
11 J.J. Reynolds, Exp. Cell Res. *47*, 42 (1967).
12 D.J. Wigglesworth, Exp. Cell Res. *49*, 211 (1968).
13 G.K. Turner Associates, Manual of Fluorometric Clinical Procedures, 1977.
14 P.S. Chen, Jr, T.Y. Toribaru and H. Warner, Analyt. Chem. *28*, 1756 (1956).
15 J. Schour and M.M. Massler, in: The Rat in Laboratory Investigation, p.104. Ed. E.J. Farris and J.Q. Griffith. Hafner Publishing Co., New York 1971.
16 H.M. Mallek, T. Nakamoto, E. Nuchtern and S.A. Miller, J. dent. Res. *58*, 1921 (1979).

Open field locomotion by zinc deficient adult male mice

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Summary. Adult male mice maintained on a zinc-free diet display a statistically significant increase in open field locomotion compared to controls. However, excess zinc (100 times the established recommended daily allowance) does not produce a change compared to controls.

All animals require zinc adequate diets for proper development and maintenance of body functions. When denied zinc for a long time, an animal becomes zinc deficient, manifested by symptoms such as hair loss[1,2], fissuring of the soles[3], disrupted bone metabolism[4], skin lesions[5], and growth retardation[6]. However, little information exists on the behavioral effect from zinc deficiency. Rats denied zinc for 7 weeks displayed decreased exploratory activity[7] and performed poorly on behavioral tests[8–11]. The present study attempts to show the influence of zinc deficiency on the open field behavior of adult male mice.

Adult male mice (Institute of Cancer Research strain; 25–30 g; 18–20 animals per group) were housed in a room with 12 h light cycles over a 6-week experimental period. The pool was divided into 3 groups (control, zinc deficient, and zinc supplemented) each based upon the amounts of zinc animals received. Control mice received a standard zinc adequate diet. Zinc deficient mice received a diet identical to the control diet except the zinc was extracted from it (Teklad Test Diets, Madison, Wisconsin). The zinc deficient mice received zinc-free water. We housed these mice in plastic cages with zinc-free plastic caps on water bottles. Zinc supplemented (excess) mice received the standard zinc adequate diet and dissolved zinc sulfate (Mallindrodt Chemical Co., St. Louis, Missouri) in the drinking water in an amount 100 times the established recommended daily allowance (3 mg/kg, dry weight) for mice[2]. Our 6-week plan for each group allowed the mice to develop body zinc depletion. After weighing each animal, we observed open field locomotion by placing them into a 19×25 cm cage with the bottom divided into 6 cm^2 and tabulated the number of lines crossed in a 5-min period.

In the table, we observe that the zinc deficient mice traversed a mean of 182.9 ± 19.6 squares compared to 112.8 ± 6.1 for the control, a statistically significant increase (p 0.005). On the otherhand, while the zinc supplemented mice traversed more squares than the control, specifically 137.6 ± 15.8, statistically they remained unchanged (p 0.5) as compared to control. Apparently, zinc deficient mice exhibit hyperactivity as demonstrated by their increased exploration. Unlike rats, zinc deficiency in mice produces increased exploratory activity. We also observed over the 6-week period that zinc deficient mice displayed abnormal behavior (compared to control or zinc supplemented) such

Open field locomotion by adult male mice

Mice	Weight	Open field test Squares traversed in 5 min	p-value
Control	41.4 ± 1.0	112.8 ± 6.1	-
Zinc deficient	31.8 ± 0.9	182.9 ± 19.6	0.005
Zinc supplemented	43.1 ± 0.9	137.6 ± 15.8	0.5

Mean ± SE. p-probability value 18–20 mice/group.

as continuous jumping and running while in their cages. Finally, we observed that the zinc deficient animals showed a mean final body weight of 31.8 ± 0.9 compared to 41.4 ± 1.0 g for control animals. This is in agreement with investigators who have found zinc deficiency to result in growth cessation and weight loss[12,13].

Whereas no hypothesis has been previously suggested for the increased activity level in zinc deficiency, it is well established that zinc participates in at least 18 metalloenzyme[14] systems and is essential for normal protein synthesis through its direct effect on deoxyribonucleic acid polymerase[15]. It seems likely that in a state of zinc deficiency, various biochemical pathways may be disrupted resulting in decreased production of metabolites such as CNS neurotransmitters whose function is primarily in primarily inhibitory. Future studies might measure the concentration of these neurotransmitters in zinc deficient CNS tissue and compare these levels to those found in control animals.

1 I. Diamond, H. Swenerton and L.S. Hurley, J. Nutr. *101,* 77 (1971).
2 National Research Council. Agricultural Board, Committee on Animal Nutrition, Subcommittee on Laboratory Animal Nutrition. Nutrient Requirements of Domestic Animals. No. 10. Nutrient Requirements of Laboratory Animals, 2nd edn, p. 33. National Academy of Sciences, Washington, D.C. 1972.
2 L.M. Zielsdorf and C.S. Witt, J. Am. Pod. Ass. *68,* 17 (1978).
4 C.J. Condon and R.M. Freeman, Ann. intern. Med. *73,* 531 (1970).
5 M. Greaves and T.R. Boyde, Lancet 2, 1019 (1967).
6 W.J. Pories and W.H. Strain, in: Zinc Metabolism, p. 378. Ed. A.S. Prasad. Thomas, Springfield, Ill. 1966.
7 D.F. Caldwell, D. Oberleas, J.J. Clancy and A.S. Prasad, Proc. Soc. exp. Biol. Med. *133,* 1417 (1970).
8 D.F. Caldwell, D. Oberleas and A.S. Prasad, Nutr. Rep. Int. *7,* 309 (1973).
9 E.S. Halas and H.H. Sandstead, Pediat. Res. *9,* 94 (1975).
10 D.M. Lokken, E.S. Halas and H.H. Sandstead, Proc. exp. Biol. Med. *144,* 680 (1973).
11 H.H. Sandstead, G.J. Fosmire, J.M. McKenzie and E.S. Halas, Fedn Proc. *34,* 86 (1975).
12 Subcommittee on Zinc, Committee on Medical and Biological Effects of Environmental Pollutants, *Zinc,* p. 173. University Park Press, Baltimore, Md. 1979.
13 Subcommittee on Zinc[12], p. 531.
14 J.M. Orten and O.W. Neuhaus, in: Human Biochemistry, p. 549. C.M. Mosby & Co., St. Louis, Mo. 1975.
15 Subcommittee on Zinc[12], p. 300.

Thermogenic response as the function of extravascular influx of infused noradrenaline

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Summary. The dynamic and static phases of the thermogenic response to i.v. infused noradrenaline (NA) do not reflect the arterial concentration of NA; according to the equation presented here they are a function of the influx rate.

Thermogenesis of cold-acclimatized rats in the cold is accompanied by enhanced arterial concentration of noradrenaline (NA)[1,2]. Furthermore, injection[3] or infusion[4] of NA evokes a thermogenic response in the same animals placed in the thermoneutral zone. In spite of the fact that thermogenesis is stimulated by NA, the magnitude of the thermogenic response is not controlled by the arterial concentration of NA[5]. In the present report we have derived an equation, describing (under the 2 generally-accepted assumptions that: A) the thermogenic response is a classical function of inner-receptor-concentration of NA; B) the receptor acting NA is removed enzymatically) the inner concentration of NA as the function of extravasal influx of i.v. infused NA. We thus obtained an approximation of experimental thermogenic values.

Material and methods. Male Sprague-Dawley albino rats were acclimatized to cold by a standard procedure. Before each experiment in a barbital-sedated rat of 341 g average weight the external jugular vein was cannulated for infusion of NA. The aorta was catheterized via the carotid artery for measuring arterial concentration of NA and blood pressure. Plasma concentration of NA was measured radioenzymatically[6]; blood pressure by the direct route, using a transducer. Total thermogenesis was measured as the oxygen consumption by an open circuit method, using a paramagnetic oxygen analyser.

Results. Changes in the functional inner NA concentration (c) are given by the difference between influx (i) and efflux (e) NA rate into and from inner space:

$$V\dot{c} + e = i \qquad (1)$$

where V = constant volume of the inner space

$$c = c_{min}\Delta c$$
$$e = e_{min}\Delta e$$
$$i = i_{min}\Delta i$$

It follows from the condition of initial steady-state that:

$$e_{min} = i_{min}$$

Then

$$V\Delta\dot{c} + \Delta e = \Delta i \qquad (2)$$

For transformation to the relative form, the following variables are defined:

$$c_r = \Delta c/K;\ e_r = \Delta e/\Delta e_{max};\ i_r = \Delta i/\Delta e_{max}$$

where K is a constant with the size of concentration.