Daily intakes of manganese, copper, zinc and cadmium by New Zealand women

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1. A total of 179 duplicate diets were collected by twenty-three women consuming their habitual diet. Twelve of the subjects were living in a residential hall for students, the others were living in their own homes or in flats. Collection periods varied from 3 to 21 d.

2. Average daily intakes were: manganese 2·7 mg; copper 1·5 mg for diets not containing liver, 7·6 mg for fifteen diets containing liver; zinc 10·0 mg; cadmium 21 μg for diets not containing liver, 27 μg for fifteen diets containing liver.

3. The intakes were compared with values for adults from other countries and with current recommended dietary allowances or estimated minimum requirements. Mn intakes were typical for non-vegetarian Western diets. Cu and Zn intakes may have been marginally low. The intakes of Cd were low.

4. Daily intakes of protein (71 g), fat (83 g), carbohydrate (224 g) and energy (8·1 MJ) from 129 of the diets were similar to recent values obtained for New Zealand women.

5. Subjects living in the residential hall had higher intakes of all nutrients than subjects living in their own homes or flats.

Until recently, the only information on the daily intake of trace elements by New Zealand people came from the analysis of constant diets of four young women participating in a balance study (McLeod & Robinson, 1972; Robinson, McKenzie, Thomson & van Rij, 1973). The concentrations of manganese, copper, zinc and cadmium in some New Zealand foods is now known (Guthrie, 1975) but the lack of information on recent food intake and dietary patterns make it difficult to estimate from food concentrations the intakes of the trace elements for people of different ages.

The intakes of Mn, Cu, Zn and Cd now presented were obtained directly by the analysis of duplicate diets, collected by women living in Dunedin.

EXPERIMENTAL

Subjects

The subjects were twenty-three apparently healthy women aged 19–50 years (mean 24 years) and weighing 52–78 kg (mean 62 kg). Twelve of the subjects were living in a residential hall, which was closely associated with the University of Otago School of Home Science, Dunedin. The kitchen at the hall was used for the teaching of quantity meal preparation and food service administration to prospective dietetic trainees. The subjects living in the hall ('institutional') were all students and were generally younger (19–21 years) than the subjects (20–50 years) who were living in their own homes or in flats ('non-institutional').

Collection of diets

Duplicate portions of all food and beverages consumed were collected for periods of 3–21 d in previously cleaned and weighed polyethylene containers. The containers were kept refrigerated throughout the day and were delivered to the laboratory the next morning. The subjects consumed their habitual diets and used their customary utensils and tableware. All subjects kept detailed dietary records during the collection period. A total of 179 duplicate diets were collected, of which seventy-four diets were from the residential hall.

As no significant difference was found between duplicate diets collected by one subject by visual inspection or by weighing for 7 d, the duplicate portions were determined by inspection only. Mean (± SD) daily intakes from the seven 'weighed' diets were: 2·9 ± 1·1 mg Mn, 0·9 ± 0·2 mg Cu, 10·9 ± 4·3 mg Zn, 10 ± 2 μg Cd, with mean (± SD) daily intakes from the seven 'visually-prepared' diets of 2·8 ± 1·3 mg Mn, 0·8 ± 0·2 mg Cu, 10·9 ± 4·3 mg Zn, 10 ± 2 μg Cd.

Preparation for analysis

After weighing, the food composites were homogenized in a large stainless-steel Waring blender. Deionized water was added to ensure complete homogenization. No detectable contamination occurred during this procedure. The total homogenized '24 h' diets were dried to constant weight under infra-red lamps.

Analytical methods

Mn, Cu, Zn and Cd in the dried samples were determined by atomic absorption spectroscopy (Guthrie, 1975) using an atomic absorption spectrophotometer (Model AA-5; Varian Techtron Pty Ltd, Springvale, Victoria, Australia). Non-atomic absorbance for Cd was corrected by using a hydrogen continuum lamp.

Replicates of one '24 h' diet and the amounts of added minerals recovered were determined at regular intervals.

Mean (± SD) concentrations (μg/g dry matter (DM)) for eighty replicates of the '24 h' diet were: 6·4 ± 0·4 Mn, 3·4 ± 0·3 Cu, 40·3 ± 1·8 Zn, 0·036 ± 0·006 Cd. Mean (± SD) values for recovery of added Mn, Cu, Zn, Cd in fifty replicates were respectively: 0·99 ± 0·04, 0·96 ± 0·03, 1·00 ± 0·02, 1·01 ± 0·03.

The accuracy of the method was checked by analysis of eight replicates of bovine liver (standard reference material 1577) from the National Bureau of Standard (NBS), Washington, DC, USA. Mean (± SD) values (μg/g DM) found were: 10·2 ± 0·3 Mn, 180 ± 1 Cu, 130 ± 3 Zn, 0·28 ± 0·02 Cd. 'Certified NBS' mean (with 0·95 confidence limits) values (μg/g DM) were: 10·3 ± 1·0 Mn, 193 ± 10 Cu, 130 ± 10 Zn, 0·27 ± 0·04 Cd.

Nitrogen, crude fat, ash and total carbohydrate (by difference) were determined in 129 diets. The dried samples were analysed for N by the micro-kjeldahl method and for crude fat by Soxhlet extraction. The protein content of the diets was calculated as N × 6.25. The Atwater factors were used to calculate the metabolizable energy content of the diets (Southgate & Durnin, 1970).

RESULTS

Dietary patterns

Three meals were served each day at the residential hall, where the meals were carefully planned from both an aesthetic and nutritional viewpoint. 'In-between' snacks were the only foods eaten which were not provided by the hall. With the 'non-institutional' subjects, personal preference for food was the major determinant in the selection of the daily diet. These subjects were involved in the purchase, preparation, cooking and serving of the foods eaten.

The dietary records kept by the subjects revealed differences in meal patterns between the 'institutional' and 'non-institutional' subjects, with the major difference being the amount of animal protein consumed. Sixty of the seventy-four 'institutional' diets contained a cooked breakfast or a cooked lunch, including fish, minced meat, bacon, sausages, saveloys or eggs, or both; this was in addition to a serving of meat at the main meal of the day. Only

Table 1. *Daily intakes of 'dry' food (dry matter basis), protein, fat, carbohydrate and energy of New Zealand women living in a residential hall ('institutional') or living in their own homes or flats ('non-institutional')**

(Mean values and standard deviations for 129 diets, except 'dry' food values which are for 179 diets)

	'Dry' food (g)		Protein (g)		Fat (g)		Carbohydrate (g)		Energy (MJ)	
Diet	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
'Institutional'	397	108	89	23	87	23	242	73	8·8	2·0
'Non-institutional'	374	73	61	13	81	26	215	46	7·7	1·7
Total	384	89	71	22	83	25	224	58	8·1	1·9

* For details of subjects, see p. 55.

Table 2. *Concentrations (µg/g dry matter) of manganese, copper, zinc and cadmium in* 179 *'24 h' duplicate diets from twenty-three New Zealand women* living in a residential hall ('institutional') or living in their own homes or flats ('non-institutional')*

(Mean values and standard deviations)

		Mn		Cu† Without liver		Cu† With liver		Zn		Cd† Without liver		Cd† With liver	
Diet	No. of diets	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
'Institutional'	74	7·6	2·2	4·9	2·4	20·0	9·1	29·9	10·0	0·05	0·03	0·09	0·04
'Non-institutional'	105	7·0	2·4	3·3	1·6	25·7	7·6	23·9	10·0	0·06	0·05	0·08	0·04
Total	179	7·2	2·3	3·9	2·1	22·7	8·6	26·4	10·4	0·05	0·04	0·08	0·04

* For details of subjects, see p. 55.
† Fifteen diets contained liver; eight were 'institutional' diets, and seven were 'non-institutional' diets.

seventeen of the 105 'non-institutional' diets included this second source of animal protein for breakfast or lunch, or both. Fish, eggs or sausages replaced the serving of meat at the main meal of the day only in the 'non-institutional' diets.

Daily intakes of macro-nutrients

Protein intakes ranged from 24–133 g/d, with a mean value of 71 g/d (Table 1). The 'institutional' diets contained more protein ($P < 0·001$; Student's t test) than the 'non-institutional' diets, confirming the observations from the dietary records. Total food intake was marginally greater ($P < 0·05$) from the 'institutional' diets than from the 'non-institutional' diets. The mean fat intake was 83 g/d, with a range of 28–106 g/d. Mean intakes of carbohydrate and energy were 224 g/d and 8·1 MJ/d, respectively. Both carbohydrate and energy intakes were greater ($P < 0·01$) from the 'institutional' diets.

Mn, Cu, Zn and Cd contents of diets

The concentrations of the trace elements in the daily diets are shown in Table 2. The majority of diets with a Mn content greater than 11 µg/g DM included wholemeal bread, wheat germ, silver beet (*Beta vulgaris* var. cicla) or bran products, all foods known to be rich in Mn (Guthrie, 1975). Tea consumption was low in the subjects whose diets contained the

Table 3. *Daily intakes of manganese, copper, zinc and cadmium from analysis of duplicate diets collected by twenty-three New Zealand women* living in a residential hall ('institutional') or living in their own homes or flats ('non-institutional')*

(Mean values and standard deviations)

		Mn (mg)		Cu† (mg) Without liver		Cu† (mg) With liver		Zn (mg)		Cd† (μg) Without liver		Cd† (μg) With liver	
Diet	No. of diets	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
'Institutional'	74	3·0	1·0	1·9	0·9	6·5	3·7	11·6	3·7	19	12	28	9
'Non-institutional'	105	2·6	0·9	1·2	0·7	9·1	2·5	8·9	4·0	22	16	27	13
Total	179	2·7	1·0	1·5	0·8	7·6	3·3	10·0	4·1	21	14	27	11

* For details of subjects, see p. 55.
† Fifteen diets contained liver; eight were 'institutional' diets, and seven were 'non-institutional' diets.

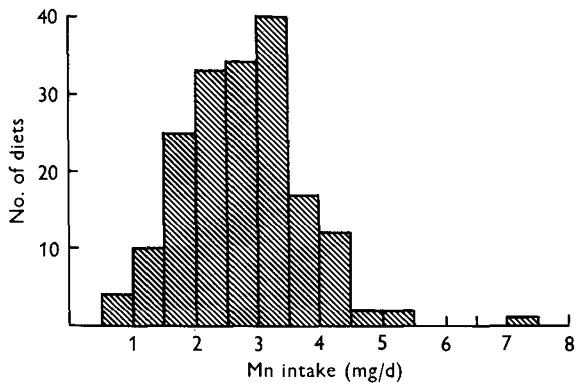

Fig. 1. Daily intakes of manganese (mg) from 179 duplicate diets collected by twenty-three New Zealand women living in a residential hall or living in their own homes or flats (for details of subjects, see p. 55).

highest Mn content, the maximum being 2 cups/d. Only one subject in the study was a regular tea-drinker, consuming on average 6–7 cups/d. The Mn content (8·8–10·6 μg/g DM) of her diets was consistently higher than the mean value.

The Cu content of the fifteen diets containing liver was significantly higher ($P < 0{\cdot}001$) than that of diets which did not contain liver. All the diets containing liver had a Cu content greater than 11 μg/g DM. Excluding the diets containing liver, the 'institutional' diets had more Cu ($P < 0{\cdot}001$) than the 'non-institutional' diets.

Zn contents were also higher ($P < 0{\cdot}001$) in the 'institutional' diets compared to the 'non-institutional' diets.

The diet that had the highest Cd content (0·41 μg/g DM) included several oysters. The diet with the second highest Cd content (0·21 μg/g DM) contained two oysters. The fifteen diets containing liver had a higher Cd content ($P < 0{\cdot}01$) than the diets which did not contain liver.

Negative correlations for 'dry' food intake (DM basis) *v.* Mn, Cu, Cd ($P < 0{\cdot}05$) and Zn ($P < 0{\cdot}01$) contents were found.

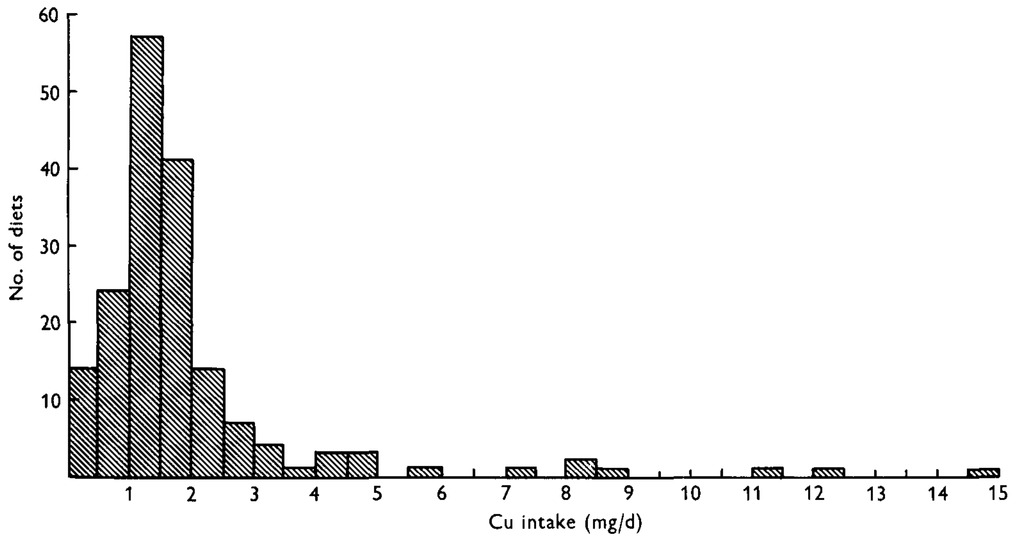

Fig. 2. Daily intakes of copper (mg) from 179 duplicate diets collected by twenty-three New Zealand women living in a residential hall or living in their own homes or flats (for details of subjects, see p. 55).

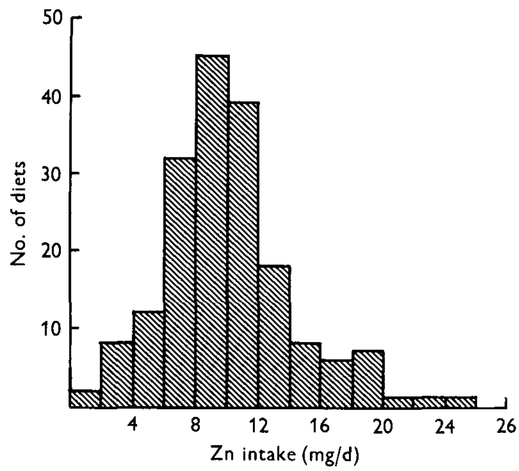

Fig. 3. Daily intakes of zinc (mg) from 179 duplicate diets collected by twenty-three New Zealand women living in a residential nall or living in their own homes or flats (for details of subjects, see p. 55).

Daily intakes of Mn, Cu, Zn, and Cd

The daily intakes of the trace elements are shown in Table 3 and Figs. 1–4. Mn intakes ranged from 0·8 to 7·1 mg/d with a mean value of 2·7 mg/d. The diets of subjects from the residential hall contained more Mn ($P < 0.05$) and Zn ($P < 0.01$) than the 'non-institutional diets. In the eleven 'non-institutional' diets in which fish was the major dish, Zn intakes were low with a mean value of 5·6 mg/d (range 1·7–9·1 mg/d). The 7 d on which sausages were the major dish also gave low intakes of 1·6–9·8 mg Zn/d. The over-all mean Zn intake was 10 mg/d.

Cu intakes were markedly higher ($P < 0.001$) when the diets included liver. Non-liver-containing diets of subjects from the residential hall provided more Cu ($P < 0.001$) than the 'non-institutional' diets. The lowest Cu intake was 0·1 mg/d.

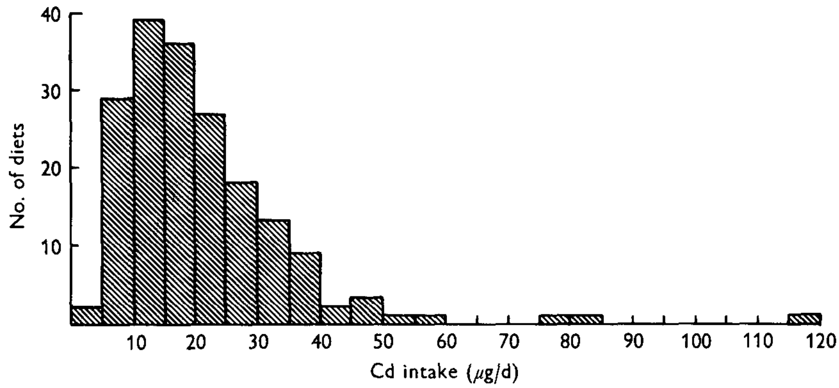

Fig. 4. Daily intakes of cadmium (µg) from 179 duplicate diets collected by twenty-three New Zealand women living in a residential hall or living in their own homes or flats (for details of subjects, see p. 55).

Table 4. *Statistical significance of correlation coefficients† for intakes of manganese, copper, zinc and cadmium with intakes of 'dry' food (dry matter basis), protein, fat, carbohydrate and energy for twenty-three New Zealand women living in a residential hall or living in their own homes or flats.*

	Mn	Cu	Zn	Cd
'Dry' food	***	***	***	*
Protein	***	***	***	NS
Fat	***	NS	*	*
Carbohydrate	***	***	**	NS
Energy	***	NS	**	NS

NS, not significant.
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.
† All correlations were positive.

The two diets that contained oysters provided the highest intakes of Cd (118 and 81 µg/d). No significant differences in Cd intakes were observed between 'institutional' and 'non-institutional' diets, or between liver- and non-liver-containing diets.

The intakes of all the trace elements measured were positively correlated with 'dry' food intake (Table 4).

DISCUSSION

The diets collected by the women in the present study appeared to provide intakes of protein, fat, carbohydrate and energy which were typical for New Zealand women. The mean energy intake of 8·1 MJ/d was identical to that found for women students at the University of Otago using a 1 d, 'activity-associated, dietary-recall and food-model' system (K. Christie, personal communication). It was similar to the 7·9 MJ/d reported for sixty-seven women surveyed in Milton, New Zeland (K. Christie, personal communication). The proportions of total energy derived from fat and from carbohydrate were identical to those found in a household survey in Carterton, New Zealand (Davidson & Gilmore, 1970). The proportion of energy derived from protein (0·15) was slightly higher than in the 'Carterton' survey (0·13) but was identical to that for the 'Milton' women.

The mean Mn intake (2·7 mg/d) corresponded very closely with the 2·8 mg/d reported previously for four women in New Zealand (McLeod & Robinson, 1972) and was within the range of 2–4 mg/d provided by the majority of mixed Western diets (Belz, 1960; North, Leichsenring & Norris, 1960; Schroeder, Balassa & Tipton, 1965; Tipton, Stewart & Dickson, 1969; White, 1969; Kirkpatrick & Coffin, 1974). Intakes of less than 2 mg Mn/d were reported by Gormican (1970) and White & Gynne (1971).

The highest intakes of Mn (6·6–22·5 mg/d) were all from vegetarian-type diets (Basu & Malackar, 1940; De, 1949; De & Basu, 1949; Lang, North & Morse, 1965; Soman, Panday, Joseph & Raut, 1969). Diets of plant origin did not always ensure a high intake of Mn because of the loss of Mn during refining (Underwood, 1971). Kent & McCance (1941) reported an intake of 8·7 mg Mn/d when 0·40–0·50 of the energy intake was derived from wholemeal flour, but with the use of white flour the intake was reduced to 2·5 mg Mn/d. There was a difference of greater than fiftyfold between the highest (Basu & Malackar, 1940) and the lowest (White & Gynne, 1971) Mn intakes, which reflected the wide variation in the Mn content of different foods (Guthrie, 1975).

A recommended dietary allowance has not been established for Mn. The WHO (1972) Expert Committee on Trace Elements noted that 2–3 mg Mn/d appeared to be adequate as intakes at this level were not associated with deficiency symptoms. The actual requirement for Mn appears to be less than 2 mg/d as thirty-nine of the present diets provided less than 2 mg Mn/d and the diets were consumed by apparently healthy women.

The majority of Cu intakes reported for mixed Western diets were between 1–3 mg/d (Ohlson & Daum, 1935; Leverton, 1939; Kehoe, Cholak & Story, 1940; Leverton & Binkley, 1944; Tipton *et al.* 1969; Wester, 1971, 1974; Robinson *et al.* 1973; Hartley, Dawson & Hodgkinson, 1974; Kirkpatrick & Coffin, 1974). The Cu intakes in the present study were at, or less than, the lower limit of this range. Ninety-eight of the diets contained 1–2 mg Cu/d and thirty-eight diets provided less than 1 mg Cu/d. The lowest intakes were similar to those reported by Gormican (1970) for representative hospital diets in USA and for the diets of young college women in the USA (White, 1969; White & Gynne, 1971).

The (US) National Research Council: Food and Nutrition Board (1974) reported that an intake of 2 mg Cu/d appeared to maintain balance in adults. The WHO (1973) Expert Committee on Trace Elements considered that 30 μg Cu/kg body-weight per d was adequate for the adult male but made no comment regarding the adult female. The mean intake found in this study was 33 μg Cu/kg body-weight per d, but when the fifteen diets containing liver were excluded the mean value became 24 μg Cu/kg body-weight per d. This could mean that some women in New Zealand are consuming less than the proposed adequate intake of Cu.

The mean Zn intake in the present study (10·0 mg/d) was considerably lower than the value of 18·6 mg/d previously reported for New Zealand women (Robinson *et al.* 1973). The mean protein intake of 71 g/d was also less than the value of 87 g/d reported by Robinson *et al.* (1973). Most reported values for the daily intakes of Zn (Tribble & Scoular, 1954; Bostrom & Wester, 1968; Soman *et al.* 1969; Tipton *et al.* 1969; White, 1969; Gormican, 1970; Wester, 1971; White & Gynne, 1971; Osis, Kramer, Wiatrowski & Spencer, 1972; Hartley *et al.* 1974; Kirkpatrick & Coffin, 1974) were higher than those found in the present study. The only reported values for intake for adults which were less than those found in the present study were from hospital diets in USA (Schroeder, Nason, Tipton & Balassa, 1967), from mixed Swedish diets (Wester, 1974) and from diets particularly designed to be low in Zn (McCance & Widdowson, 1942). Because of the close correlation between Zn intakes and protein intakes, variations in the latter could have accounted for some of the observed differences between the Zn intakes found in this study and reported values.

A recommended dietary allowance of 15 mg Zn/d has been established for adults (National Research Council: Food and Nutrition Board, 1974). Only twenty of the 179 diets provided more than 15 mg/d. Because of the many factors affecting Zn absorption (Becker & Hoekstra, 1971) the requirement for Zn is dependent on the amount available for absorption. The WHO (1973) Expert Committee estimated a requirement of 5·5 mg Zn/d when 0·40 of this amount was available, and 11·0 mg Zn/d when 0·20 of this amount was available. Over half the diets provided less than 11 mg Zn/d and twenty-two diets provided less than 6 mg Zn/d.

The intakes of Cd reported here were typical of a 'non-contaminated' area (Friberg, Piscator, Nordberg & Kjellstrom, 1974) and were similar to those reported from the USA (Schroeder & Balassa, 1961) and Sweden (Bostrom & Wester, 1968; Wester, 1974). With the exception of the 2 d on which oysters were eaten, the intakes were much lower than the recommended provisional tolerable weekly intake of 400–500 μg Cd (WHO, 1972).

The carefully-planned diets produced in the residential hall usually provided higher intakes of Mn, Cu and Zn than did the diets prepared by the women living in their own homes or in flats. The mean intakes of Zn (11·6 mg/d) and Cu (1·9 mg/d) of subjects from the residential hall were still considerably less than the value of 15 mg/d recommended for Zn (National Research Council: Food and Nutrition Board, 1974) and less than the value of 2 mg/d widely quoted as an adequate intake for Cu. It would appear than Zn and Cu are two elements for which intakes may be marginally low in New Zealand women.

The availability of Zn and Cu in New Zealand diets is unknown. Both fibre and phytate have been implicated in reducing the availability of dietary Zn, particularly in diets from the Middle East (Mahloudji, Reinhold, Haghshenass, Ronaghy, Spivey Fox & Halsted, 1975). In well-balanced, mixed diets, such as those consumed by the women in the present study, it is not anticipated that these two factors would adversely affect the availability of dietary Zn.

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