Dietary Reference Intakes:

Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc

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The Food and Nutrition Board of the Institute of Medicine, The National Academies, recently released the fourth in a series of reports presenting dietary reference values for the intake of nutrients by Americans and Canadians (1). The overall project is a comprehensive effort undertaken by the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes (DRI Committee) of the Food and Nutrition Board, Institute of Medicine of the National Academies, with the active involvement of Canadian scientists[1].

The development of Dietary Reference Intakes (DRIs) expands and replaces the series of Recommended Dietary Allowances, which have been published since 1941 by the Food and Nutrition Board of the National Academy of Sciences, and the Recommended Nutrient Intakes (RNIs) of Canada. Earlier reports (2,3,4) in the series providing DRIs for some vitamins and elements have been described previously (5,6), along with details on the framework and definitions of each category (5).

Dietary Reference Intakes (DRIs) are reference values that are quantitative estimates of nutrient intakes to be used for planning and assessing diets for healthy people. They include RDAs as goals for intake by individuals but also present three new types of reference values (Figure 1).

In the earlier reports AIs, rather than RDAs, were proposed for all nutrients for infants to age 1 year and for calcium, vitamin D, fluoride, pantothenic acid, biotin, and choline for persons of all ages (Tables 1,2). RDAs for the other nutrients were also provided (Tables 1,2). In this new report, AIs for vtamin K, chromium, and manganese are proposed, with RDAs being provided for vitamin A, copper, iodine, iron, molybdenum, and zinc (Tables 1,2). Although the evidence was reviewed, no quantitative recommended intakes were given for arsenic, boron, nickel, silicon, or vanadium.

HIGHLIGHTS OF THE REPORT

Infant Recommendations

For most of the micronutrients included in this new report, AIs rather than RDAs are being proposed for infants to age 1 year. EARs and RDAs, however, are proposed for iron and zinc for infants 7 to 12 months of age because the level of iron and zinc in human milk does not meet the needs of older infants and because factorial data are available to estimate the average requirement and from that derive an RDA.

Adequate for What?

A critical point in reviewing the recommendations for intake is to note the specific criterion or functional outcome that was used as the benchmark for adequacy. Three of the categories of DRIs are defined by specific criteria of nutrient adequacy (the EAR, the RDA, and the AI); the fourth is defined by a specific indicator of excess if one is available. A key question is: "Adequate for what?" In some cases, a continuum of benefits may be ascribed to various levels of intake of the same nutrients. Thus, each EAR and AI is described in terms of the selected criterion or criteria of adequacy (Figure 2). For example, the RDA for vitamin A is based on maintaining a minimum store of vitamin A in hepatic tissue; a lower RDA would result if the criterion chosen to be used in Canada and the United States had been night blindness. Iron requirements are based on maintaining minimal levels of iron stores, rather than the lower amounts needed to prevent anemia.

Tolerable Upper Intake Levels

UL values have been established for nutrients for which adequate data were available (Tables 3, 4). The adverse effects that identified and characterized these nutrients are listed in Table 5. For vitamin K, arsenic, chromium, and silicon, there are insufficient data for developing a UL. This does not mean that there is no potential for adverse effects resulting from high intakes from all sources; for example, arsenic in water is a known poison. However, at levels below what is known to cause acute toxicity, little data is available. When data about adverse effects are extremely limited, extra caution may be warranted. Similarly, the valence state for chromium found in foods, chromium III, was the only form evaluated. Thus, adverse effects associated with ingesting other valence states of chromium, such as chromium VI, or with picolinic acid, were not reviewed. Because of lack of suitable data, ULs of many of the nutrients reviewed could not be established for infants. This

Recommended Dietary Allowance (RDA): the average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97 to 98 percent) healthy individuals in a particular life stage and gender group.
Adequate Intake (AI): a recommended intake value based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of healthy people that are assumed to be adequate—used when an RDA cannot be determined.
Tolerable Upper Intake Level (UL): the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects for almost all individuals in the general population. As intake increases above the UL, the potential risk of adverse effects increases.
Estimated Average Requirement (EAR): a daily nutrient intake value that is estimated to meet the requirement of half of the healthy individuals in a life stage and gender group.

FIG. 1. Dietary Reference Intakes

[1] Full texts of reports are available at www.nap.edu.

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Figure 2
Nutrient Functions and the Indicators Used to Estimate Requirements[ab]

Nutrient	Function	Criterion(ia) of Adequacy
Vitamin A (RDA)	Required for normal vision, gene expression, reproduction, embryonic development, and immune function	Maintenance of adequate body vitamin A stores as indicated by liver biopsy
Vitamin K (AI)	Coenzyme in blood coagulation and bone metabolism	Based on intake
Arsenic	No biological function in humans although animal data indicate requirement	No recommendation
Boron	No clear biological function established in humans has been identified, although data in animal indicate a role	No recommendation
Chromium (AI)	Potentiates the action of insulin	Based on estimated intake per 1,000 kcal
Copper (RDA)	Component in numerous metalloenzymes acting as oxidases to achieve the reduction of molecular oxygen	Plasma copper concentration, serum ceruloplasmin concentration, erythrocyte superoxide dismutase activity, and platelet copper concentration
Iodine (RDA)	Component of the thyroid hormones, thyroxine and triiodothyronine	Thyroid iodine accumulation and turnover and iodine balance.
Iron (RDA)	Component of hemoglobin and numerous enzymes	Factorial model based on basal iron losses, menstrual losses, fetal requirements in pregnancy, increased requirement during growth, and/or increased tissue and storage iron
Manganese (AI)	Involved in the formation of bone and in enzymes involved in amino acid, cholesterol, and carbohydrate metabolism	Based on intake
Molybdenum (RDA)	Cofactor for enzymes involved in catabolism of sulfur amino acids, purines and pyridines.	Molybdenum balance
Nickel	No clear biological function in humans has been identified. May serve as a cofactor of metalloenzymes.	No recommendation
Silicon	No biological function in humans has been identified. May be involved in bone function based on animal studies.	No recommendation
Vanadium	No biological function in humans has been identified.	No recommendation
Zinc (RDA)	Component of multiple enzymes involved in maintenance of the structural integrity of proteins and in the regulation of gene expression	Factorial analysis based primarily on the minimal amount of absorbed zinc necessary to match total daily zinc excretion; secondary indicator was physical growth response to zinc supplementation.

[a]RDA=Recommended Dietary Allowance.
[b]AI=Adequate Intake.

Table 1 Dietary Reference Intakes: Recommended Intakes for Individuals, Vitamins
Food and Nutrition Board, The Institute of Medicine, National Academies

Life Stage Group	Vitamin A (μg/d)[a]	Vitamin C (mg/d)	Vitamin D (μg/d)[b,c]	Vitamin E (mg/d)[d]	Vitamin K (μg/d)	Thiamin (mg/d)	Riboflavin (mg/d)	Niacin (mg/d)[e]	Vitamin B_6 (mg/d)	Folate (μg/d)[f]	Vitamin B_{12} (μg/d)	Pantothenic Acid (mg/d)	Biotin (μg/d)	Choline[g] (mg/d)
Infants														
0-6 mo	400*	40*	5*	4*	2.0*	0.2*	0.3*	2*	0.1*	65*	0.4*	1.7*	5*	125*
7-12 mo	500*	50*	5*	5*	2.5*	0.3*	0.4*	4*	0.3*	80*	0.5*	1.8*	6*	150*
Children														
1-3 y	**300**	**15**	5*	**6**	30*	**0.5**	**0.5**	**6**	**0.5**	**150**	0.9	2*	8*	200*
4-8 y	**400**	**25**	5*	**7**	55*	**0.6**	**0.6**	**8**	**0.6**	**200**	1.2	3*	12*	250*
Males														
9-13 y	**600**	**45**	5*	**11**	60*	**0.9**	**0.9**	**12**	**1.0**	**300**	1.8	4*	20*	375*
14-18 y	**900**	**75**	5*	**15**	75*	**1.2**	**1.3**	**16**	**1.3**	**400**	2.4	5*	25*	550*
19-30 y	**900**	**90**	5*	**15**	120*	**1.2**	**1.3**	**16**	**1.3**	**400**	2.4	5*	30*	550*
31-50 y	**900**	**90**	5*	**15**	120*	**1.2**	**1.3**	**16**	**1.3**	**400**	2.4	5*	30*	550*
51-70 y	**900**	**90**	10*	**15**	120*	**1.2**	**1.3**	**16**	**1.7**	**400**	2.4[h]	5*	30*	550*
>70 y	**900**	**90**	15*	**15**	120*	**1.2**	**1.3**	**16**	**1.7**	**400**	2.4[h]	5*	30*	550*
Females														
9-13 y	**600**	**45**	5*	**11**	60*	**0.9**	**0.9**	**12**	**1.0**	**300**	1.8	4*	20*	375*
14-18 y	**700**	**65**	5*	**15**	75*	**1.0**	**1.0**	**14**	**1.2**	**400**[i]	2.4	5*	25*	400*
19-30 y	**700**	**75**	5*	**15**	90*	**1.1**	**1.1**	**14**	**1.3**	**400**[i]	2.4	5*	30*	425*
31-50 y	**700**	**75**	5*	**15**	90*	**1.1**	**1.1**	**14**	**1.3**	**400**[i]	2.4	5*	30*	425*
51-70 y	**700**	**75**	10*	**15**	90*	**1.1**	**1.1**	**14**	**1.5**	**400**	2.4[h]	5*	30*	425*
>70 y	**700**	**75**	15*	**15**	90*	**1.1**	**1.1**	**14**	**1.5**	**400**	2.4[h]	5*	30*	425*
Pregnancy														
≤18 y	**750**	**80**	5*	**15**	75*	**1.4**	**1.4**	**18**	**1.9**	**600**[j]	2.6	6*	30*	450*
10-30 y	**770**	**85**	5*	**15**	90*	**1.4**	**1.4**	**18**	**1.9**	**600**[j]	2.6	6*	30*	450*
31-50 y	**770**	**85**	5*	**15**	90*	**1.4**	**1.4**	**18**	**1.9**	**600**[j]	2.6	6*	30*	450*
Lactation														
≤18 y	**1,200**	**115**	5*	**19**	75*	**1.4**	**1.6**	**17**	**2.0**	**500**	2.8	7*	35*	550*
19-30 y	**1,300**	**120**	5*	**19**	90*	**1.4**	**1.6**	**17**	**2.0**	**500**	2.8	7*	35*	550*
31-50 y	**1,300**	**120**	5*	**19**	90*	**1.4**	**1.6**	**17**	**2.0**	**500**	2.8	7*	35*	550*

NOTE: This table (taken from the DRI reports, see www.nap.edu) presents Recommended Dietary Allowances (RDAs) in **bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). RDAs and AIs may both be used as goals for individual intake. RDAs are set to meet the needs of almost all (97 to 98 percent) individuals in a group. For healthy breastfed infants, the AI is the mean intake. The AI for other life stage and gender groups is believed to cover needs of all individuals in the group, but lack of data or uncertainty in the data prevent being able to specify with confidence the percentage of individuals covered by this intake.

[a]As retinol activity equivalents (RAEs). 1 RAE=1 μg retinol, 12 μg β-carotene, 24 μg α-carotene, or 24 μg β-cryptoxanthin in foods. To calculate RAEs from REs of provitamin A carotenoids in foods, divide the REs by 2. For preformed vitamin A in foods or supplements and for provitamin A carotenoids in supplements, 1 RE=1 RAE.

[b]Cholecalciferol. 1 μg cholecalciferol=40 IU vitamin D.

[c]In the absence of adequate exposure to sunlight.

[d]As α-tocopherol. α-Tocopherol includes RRR-α-tocopherol, the only form of α-tocopherol that occurs naturally in foods, and the 2R-stereoisomeric forms of α-tocopherol (RRR-, RSR-, RRS-, and RSS-α-tocopherol) that occur in fortified foods and supplements. It does not include the 2S-stereoisomeric forms of α-tocopherol (SRR-, SSR-, SRS-, and SSS-α-tocopherol), also found in fortified foods and supplements.

[e]As niacin equivalents (NE). 1 mg of niacin=60 mg of tryptophan; 0-6 months=preformed niacin (not NE).

[f]As dietary folate equivalents (DFE). 1 DFE=1 μg food folate=0.6 μg of folic acid from fortified food or as a supplement consumed with food=0.5 μg of a supplement taken on an empty stomach.

[g]Although AIs have been set for choline, there are few data to assess whether a dietary supply of choline is needed at all stages of the life style, and it may be that the choline requirement can be met by endogenous synthesis at some of these stages.

[h]Because 10 to 30 percent of older people may malabsorb food-bound B_{12}, it is advisable for those older than 50 years to meet their RDA mainly by consuming foods fortified with B_{12} or a supplement containing B_{12}.

[i]In view of evidence linking folate intake with neural tube defects in the fetus, it is recommended that all women capable of becoming pregnant consume 400 μg from supplements or fortified foods in addition to intake of food folate from a varied diet.

[j]It is assumed that women will continue consuming 400 μg from supplements or fortified food until their pregnancy is confirmed and they enter prenatal care, which ordinarily occurs after the end of the periconceptional period—the critical time for formation of the neural tube.

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Table 2 Dietary Reference Intakes: Recommended Intakes for Individuals, Elements
Food and Nutrition Board, The Institute of Medicine, National Academies

Life Stage Group	Calcium (mg/d)	Chromium (μg/d)	Copper (μg/d)	Fluoride (mg/d)	Iodine (μg/d)	Iron (mg/d)	Magnesium (mg/d)	Manganese (mg/d)	Molybdenum (μg/d)	Phosphorus (mg/d)	Selenium (μg/d)	Zinc (mg/d)
Infants												
0-6 mo	210*	0.2*	200*	0.01*	110*	0.27*	30*	0.003*	2*	100*	15*	2*
7-12 mo	270*	5.5*	220*	0.5*	130*	**11**	75*	0.6*	3*	275*	20*	**3**
Children												
1-3 y	500*	11*	**340**	0.7*	**90**	**7**	**80**	1.2*	**17**	**460**	**20**	**3**
4-8 y	800*	15*	**440**	1*	**90**	**10**	**130**	1.5*	**22**	**500**	**30**	**5**
Males												
9-13 y	1,300*	25*	**700**	2*	**120**	**8**	**240**	1.9*	**34**	**1,250**	**40**	**8**
14-18 y	1,300*	35*	**890**	3*	**150**	**11**	**410**	2.2*	**43**	**1,250**	**55**	**11**
19-30 y	1,000*	35*	**900**	4*	**150**	**8**	**400**	2.3*	**45**	**700**	**55**	**11**
31-50 y	1,000*	35*	**900**	4*	**150**	**8**	**420**	2.3*	**45**	**700**	**55**	**11**
51-70 y	1,200*	30*	**900**	4*	**150**	**8**	**420**	2.3*	**45**	**700**	**55**	**11**
>70 y	1,200*	30*	**900**	4*	**150**	**8**	**420**	2.3*	**45**	**700**	**55**	**11**
Females												
9-13 y	1,300*	21*	**700**	2*	**120**	**8**	**240**	1.6*	**34**	**1,250**	**40**	**8**
14-18 y	1,300*	24*	**890**	3*	**150**	**15**	**360**	1.6*	**43**	**1,250**	**55**	**9**
19-30 y	1,000*	25*	**900**	3*	**150**	**18**	**310**	1.8*	**45**	**700**	**55**	**8**
31-50 y	1,000*	25*	**900**	3*	**150**	**18**	**320**	1.8*	**45**	**700**	**55**	**8**
51-70 y	1,200*	20*	**900**	3*	**150**	**8**	**320**	1.8*	**45**	**700**	**55**	**8**
>70 y	1,200*	20*	**900**	3*	**150**	**8**	**320**	1.8*	**45**	**700**	**55**	**8**
Pregnancy												
≤18 y	1,300*	29*	**1,000**	3*	**220**	**27**	**400**	2.0*	**50**	**1,250**	**60**	**13**
10-30 y	1,000*	30*	**1,000**	3*	**220**	**27**	**350**	2.0*	**50**	**700**	**60**	**11**
31-50 y	1,000*	30*	**1,000**	3*	**220**	**27**	**360**	2.0*	**50**	**700**	**60**	**11**
Lactation												
≤18 y	1,300*	44*	**1,300**	3*	**290**	**10**	**360**	2.6*	**50**	**1,250**	**70**	**14**
19-30 y	1,000*	45*	**1,300**	3*	**290**	**9**	**310**	2.6*	**50**	**700**	**70**	**12**
31-50 y	1,000*	45*	**1,300**	3*	**290**	**9**	**320**	2.6*	**50**	**700**	**70**	**12**

NOTE: This table presents Recommended Dietary Allowances (RDAs) in **bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). RDAs and AIs may both be used as goals for individual intake. RDAs are set to meet the needs of almost all (97 to 98 percent) individuals in a group. For healthy breastfed infants, the AI is the mean intake. The AI for other life stage and gender groups is believed to cover needs of all individuals in the group, but lack of data or uncertainty in the data prevent being able to specify with confidence the percentage of individuals covered by this intake.

SOURCES: Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride (1997); Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B_6, Folate, Vitamin B_{12}, Pantothenic Acid, Biotin, and Choline (1998); Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids (2000); and Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc (2001). These reports may be accessed via www.nap.edu.

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Table 3
Dietary Reference Intakes (DRIs): Tolerable Upper Intake Levels (UL[a]), Vitamins
Food and Nutrition Board, The Institute of Medicine, National Academies

Life Stage Group	Vitamin A (μg/d)[b]	Vitamin C (mg/d)	Vitamin D (μg/d)	Vitamin E (mg/d)[c,d]	Vitamin K	Thiamin	Ribo-flavin	Niacin (mg/d)[d]	Vitamin B_6 (mg/d)	Folate (μg/d)[d]	Vitamin B_{12}	Pantothenic Acid	Biotin	Choline (g/d)	Carote-noids[e]
Infants															
0-6 mo	600	ND[f]	25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7-12 mo	600	ND	25	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Children															
1-3 y	600	400	50	200	ND	ND	ND	10	30	300	ND	ND	ND	1.0	ND
4-8 y	900	650	50	300	ND	ND	ND	15	40	400	ND	ND	ND	1.0	ND
Males, Females															
9-13 y	1,700	1,200	50	600	ND	ND	ND	20	60	600	ND	ND	ND	2.0	ND
14-18 y	2,800	1,800	50	800	ND	ND	ND	30	80	800	ND	ND	ND	3.0	ND
19-70 y	3,000	2,000	50	1,000	ND	ND	ND	35	100	1,000	ND	ND	ND	3.5	ND
>70 y	3,000	2,000	50	1,000	ND	ND	ND	35	100	1,000	ND	ND	ND	3.5	ND
Pregnancy															
≤18 y	2,800	1,800	50	800	ND	ND	ND	30	80	800	ND	ND	ND	3.0	ND
19-50 y	3,000	2,000	50	1,000	ND	ND	ND	35	100	1,000	ND	ND	ND	3.5	ND
Lactation															
≤18 y	2,800	1,800	50	800	ND	ND	ND	30	80	800	ND	ND	ND	3.0	ND
19-50 y	3,000	2,000	50	1,000	ND	ND	ND	35	100	1,000	ND	ND	ND	3.5	ND

[a]UL=The maximum level of daily nutrient intake that is likely to pose no risk of adverse effects. Unless otherwise specified, the UL represents total intake from food, water, and supplements. Due to lack of suitable data, ULs could not be established for vitamin K, thiamin, riboflavin, vitamin B_{12}, pantothenic acid, biotin, or carotenoids. In the absence of ULs, extra caution may be warranted in consuming levels above recommended intakes.
[b]As preformed vitamin A only.
[c]As α-tocopherol; applies to any form of supplemental α-tocopherol.
[d]The ULs for vitamin E, niacin, and folate apply to synthetic forms obtained from supplements, fortified foods, or a combination of the two.
[e]β-Carotene supplements are advised only to serve as a provitamin A source for individuals at risk of vitamin A deficiency.
[f]ND=Not determinable due to lack of data of adverse effects in this age group and concern with regard to lack of ability to handle excess amounts. Source of intake should be from food only to prevent high levels of intake.
SOURCES: Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride (1997); Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B_6, Folate, Vitamin B_{12}, Pantothenic Acid, Biotin, and Choline (1998); Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids (2000); and Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc (2001). These reports may be accessed via www.nap.edu.
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Table 4
Dietary Reference Intakes (DRIs): Tolerable Upper Intake Levels (UL[a]), Elements
Food and Nutrition Board, The Institute of Medicine, National Academies

Life Stage Group	Arsenic[b]	Boron (mg/d)	Calcium (g/d)	Chromium	Copper (μg/d)	Fluoride (mg/d)	Iodine (μg/d)	Iron (mg/d)	Magnesium (mg/d)[c]	Manganese (mg/d)	Molybdenum (μg/d)	Nickel (mg/d)	Phosphorus (g/d)	Selenium (μg/d)	Silicon[d]	Vanadium (mg/d)[e]	Zinc (mg/d)
Infants																	
0-6 mo	ND[f]	ND	ND	ND	ND	0.7	ND	40	ND	ND	ND	ND	ND	45	ND	ND	4
7-12 mo	ND	ND	ND	ND	ND	0.9	ND	40	ND	ND	ND	ND	ND	60	ND	ND	5
Children																	
1-3 y	ND	3	2.5	ND	1,000	1.3	200	40	65	2	300	0.2	3	90	ND	ND	7
4-8 y	ND	6	2.5	ND	3,000	2.2	300	40	110	3	600	0.3	3	150	ND	ND	12
Males, Females																	
9-13 y	ND	11	2.5	ND	5,000	10	600	40	350	6	1,100	0.6	4	280	ND	ND	23
14-18 y	ND	17	2.5	ND	8,000	10	900	45	350	9	1,700	1.0	4	400	ND	ND	34
19-70 y	ND	20	2.5	ND	10,000	10	1,100	45	350	11	2,000	1.0	4	400	ND	1.8	40
>70 y	ND	20	2.5	ND	10,000	10	1,100	45	350	11	2,000	1.0	3	400	ND	1.8	40
Pregnancy																	
≤18 y	ND	17	2.5	ND	8,000	10	900	45	350	9	1,700	1.0	3.5	400	ND	ND	34
19-50 y	ND	20	2.5	ND	10,000	10	1,100	45	350	11	2,000	1.0	3.5	400	ND	ND	40
Lactation																	
≤18 y	ND	17	2.5	ND	8,000	10	900	45	350	9	1,700	1.0	4	400	ND	ND	34
19-50 y	ND	20	2.5	ND	10,000	10	1,100	45	350	11	2,000	1.0	4	400	ND	ND	40

[a]UL=The maximum level of daily nutrient intake that is likely to pose no risk of adverse effects. Unless otherwise specified, the UL represents total intake from food, water, and supplements. Due to lack of suitable data, ULs could not be established for arsenic, chromium, and silicon. In the absence of ULs, extra caution may be warranted in consuming levels above recommended intakes.
[b]Although the UL was not determined for arsenic, there is no justification for adding arsenic to food or supplements.
[c]The ULs for magnesium represent intake from a pharmacological agent only and do not include intake from food and water.
[d]Although silicon has not been shown to cause adverse effects in humans, there is no justification for adding silicon to supplements.
[e]Although vanadium in food has not been shown to cause adverse effects in humans, there is no justification for adding vanadium to food and vanadium supplements should be used with caution. The UL is based on adverse effects in laboratory animals and this data could be used to set a UL for adults but not children and adolescents.
[f]ND=Not determinable due to lack of data of adverse effects in this age group and concern with regard to lack of ability to handle excess amounts. Source of intake should be from food only to prevent high levels of intake.
SOURCES: Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride (1997); Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B_6, Folate, Vitamin B_{12}, Pantothenic Acid, Biotin, and Choline (1998); Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids (2000); and Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc (2001). These reports may be accessed via www.nap.edu.
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signifies a need for data, and in its absence, food sources only are recommended.

Bioavailability

One major change is due to new information that indicates that conversion of dietary provitamin A carotenoids from food to retinol or active vitamin A has been significantly overestimated in the past. Therefore, a new equivalency is proposed: *Retinol Activity Equivalent* (RAE)(Table 6). A change that means twice as much provitamin A carotenoids contained in green leafy vegetables and fruits are required to provide a given amount of vitamin A. Given possible future changes in equivalency, a recommendation is made that the actual weight of carotenoids found in specific foods be listed in food tables to allow for future adjustments when more data are available. Iron bioavailability for those -consuming a typical mixed diet in the United States and Canada was estimated to be 18% for those with minimal iron stores, while for vegetarians it was estimated to be 10%.

USES OF THE DRIs

The four primary uses of DRIs are for assessing intakes of individuals and of population groups and in planning diets for individuals and for groups (Table 7). Another DRI report released in 2000 provides suggested approaches for using specific DRIs in dietary assessment (8). It focuses on the use of the EAR in estimating the prevalence of inadequacy and the extent to which an AI can be used given the absence of an EAR, and it provides the statistical basis for these applications. A future report will focus on using DRIs to plan diets for individuals and groups.

WHAT'S ON THE HORIZON

As indicated earlier, four reports have been released on DRIs, thus completing the initial review of vitamins and almost all elements (a review of electrolytes—sodium, potassium chloride, etc—and water is still to be initiated). Currently, a panel of experts is reviewing protein, amino acids, fats and fatty acids, carbohydrates and fiber, and energy expenditure using the DRI framework, with the report expected by the end of this year. In addition to electrolytes and water, two additional panels will evaluate other food components, such as phytoestrogens and other phytochemicals found in foods like tea or garlic, assuming adequate data relating these compounds to risk of chronic disease and health are available, and the role of alcohol in health and disease. Perhaps even before these panels start, it will be time to review the data on some of the vitamins or elements already evaluated because of new science indicating a need for substantive reevaluation.

Table 5
Adverse Effects

Nutrient	Adverse Effect
Vitamin A[1]	teratological effects, liver toxicity
Boron	reproductive and developmental effects*
Copper	liver damage
Iodine	elevated TSH concentration
Iron	gastrointestinal distress
Manganese	elevated blood concentration
Molybdenum	reproductive effects*
Nickel	decreased body weight gain*
Vanadium	renal lesions*
Zinc	reduced copper status

[1]From preformed Vitamin A only.
*As observed in animal studies.
NOTE: ULs were not determined for vitamin K, arsenic, or silicon.

References

1. Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Molybdenum, Nickel, Silicon, Vanadium and Zinc.* Food and Nutrition Board. Washington, DC: National Academy Press; 2001.
2. Institute of Medicine. *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride.* Food and Nutrition Board. Washington, DC: National Academy Press; 1997.
3. Institute of Medicine. *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline.* Food and Nutrition Board. Washington, DC: National Academy Press; 1998.
4. Institute of Medicine. *Dietary Reference Intakes for Vtiamin C, Vitamin E, Selenium, and Carotenoids.* Food and Nutrition Board. Washington, DC: National Academy Press; 2000.
5. Yates, AA, Schlicker, SA, Suitor, CW. Dietary reference intakes: The new basis for recommendations for calcium and related nutrients, B vitamins, and choline. *J Am Diet Assoc.* 1998;98:699-706.
6. Monsen, ER. Dietary reference intakes for antioxidant nutrients: Vitamin C, vitamin E, selenium, and carotenoids. *J Am Diet Assoc.* 2000;100:637-640.
7. National Research Council, Subcommittee on the 10th Edition of the RDAs, Food and Nutrition Board, Commission on Life Sciences. *Recommended Dietary Allowances.* 10th ed. Washington, DC: National Academy Press; 1989.
8. Institute of Medicine. *Dietary Reference Intakes: Use in Dietary Assessment.* Food and Nutrition Board. Washington, DC: National Academy Press; 2000.

The Panel on Micronutrients was chaired by Robert Russell (USDA Jean Mayer Human Nutrition Research Center on Aging, Tufts University); other members were John L. Beard (Pennsylvania State University), Robert J. Cousins (University of Florida, Gainesville), John T. Dunn (University of Virginia), Guylaine Ferland (University of Montreal), K. Michael Hambidge (University of Colorado Health Sciences Center), Sean Lynch (retired from the Veteran's Administration Medical Center, Hampton), James G. Penland (USDA Human Nutrition Research Center, Grand Forks), A. Catharine Ross (Pennsylvania State University), Barbara J. Stoecker (Oklahoma State University); John W. Suttie (University of Wisconsin, Madison), Judith R. Turnlund (USDA Western Human Nutrition Research Center and the University of California, Davis);Keith P. West (Johns Hopkins School of Hygiene and Public Health), and Stanley H. Zlotkin (The Hospital for Sick Children and the University of Toronto). The Subcommittee on Upper Reference Levels is chaired by Ian Munro (CanTox, Inc.) and includes George C. Becking (Phoenix OHC), Renate K. Kimbrough (Institute for Evaluating Health Risks), Rita B. Messing (Minnesota Department of Public Health), Sanford A. Miller (University of Texas Health Science Center at San Antonio), Harris Pastides (University of South Carolina), Joseph V. Rodricks (The Life Sciences Consultancy), Irwin H. Rosenberg (USDA Jean Mayer Human Nutrition Research Center on Aging,Tufts University), Steve L. Taylor (University of Nebraska), John A. Thomas (Retired from the University of Texas Health Science Center at San Antonio), and Gary M. Williams (New York Medical College). The Subcommittee on Interpretation and Uses of Dietary Reference Intakes was chaired by Suzanne Murphy (University of Hawaii); other members include Lenore Arab (University of North Carolina, Chapel Hill), Susan I. Barr (University of British Columbia), Susan T. Borra (International Food Information Council), Alicia Carriquiry (Iowa State University), Barbara L. Devaney

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Table 6
Comparison of the 1989 National Research Council and new 2001 Institute of Medicine Interconversion of Vitamin A and Carotenoid Units

1989, NRC	IOM, 2001
1 retinol equivalent (RE)	1 retinol activity equivalent (RAE)
=1 μg of all-trans-retinol	=1 μg of all-trans-retinol
=2 μg all-trans-β-carotene in oil	=2 μg all-trans-β-carotene in oil
=6 μg dietary all-trans-β-carotene	=12 μg of dietary all-trans-β-carotene
=12 μg of other dietary provitamin A carotenoids	=24 μg of other dietary provitamin A carotenoids
=3.33 IU vitamin A activity from retinol	=3.33 IU vitamin A activity from retinol

Table 7
Uses of Dietary Reference Intakes for Healthy Individuals and Groups

Type of Use	For the Individual	For a Group
Assessment	EAR: use to examine the probability that usual intake is inadequate. RDA: usual intake at or above this level has a low probability of inadequacy. AI[c]: usual intake at or above this level has a low probability of inadequacy. UL: usual intake above this level has a potential risk of adverse effects.	EAR: use to estimate the prevalence of inadequate intakes within a group. RDA: do not use to assess intakes of groups. AI[c]: mean usual intake at or above this level implies a low prevalence of inadequate intakes. UL: use to estimate the percentage of the population potentially at risk of adverse effects from excessive nutrient intake.
Planning	RDA: aim for this intake. AI[c]: aim for this intake. UL: use as a guide to limit intake; chronic intake of higher amounts increases potential risk of adverse effects.	EAR: use to plan an intake distribution with a low prevalence of inadequate intakes. AI[c]: use a plan mean intakes. UL: use to plan intake distributions with a low prevalence of intakes that have a potential risk of adverse effects.

RDA=Recommended Dietary Allowance; EAR=Estimated Average Requirement.
AI=Adequate Intake; UL=Tolerable Upper Level.
[a]Evaluation of true status requires clinical, biochemical, and anthropometric data.
[b]Requires statistically valid approximation of distribution of usual intakes.
[c]For the nutrients in this report, AIs are set for infants for all nutrients, and for other age groups for vitamin K, chromium, and manganese. The AI may be used as a guide for infants as it reflects the average intake from human milk. Infants consuming formulas with the same nutrient composition as human milk are consuming an adequate amount after adjustments are made for differences in bioavailability. When the AI for a nutrient is not based on mean intakes of healthy populations, this assessment is made with less confidence.