I. INTRODUCTION

From the earliest times, individuals and populations have appreciated that food has a profound influence upon health. As the nature of these influences has been more clearly defined and quantified, the need for dietary standards has become apparent. After recognizing that vitamins and minerals are indispensable for sustaining optimal health, individual countries and authorities began to quantify nutrient requirements which are adequate and toxicologically safe for the daily consumption. In the United States, Recommended Dietary Allowances (RDAs) were first established in 1941, to "provide standards to serve as a goal for good nutrition" [1]. Since then, these allowances have been revised, with increasing and more detailed recommendations. In the 1989 edition of Recommended Dietary Allowances, it is stated that: "RDAs are the level of intake of essential nutrients that, on the basis of scientific knowledge, are judged by the Food and Nutrition Board to be adequate to meet the known nutrient needs of practically all healthy persons" [2].

The daily requirement for a nutrient is still a matter of considerable dispute throughout the world, primarily because of an inadequacy of the database. In theory, data for RDAs can be derived by a number of approaches [3]:
- the derivation of estimates of functional and normative storage requirements;
- the epidemiological approach;
- the balance and factorial approach;
- the pragmatic approach.

In practice, RDAs are based on the available scientific evidence, and the exercise of reasonable judgement. There are considerable differences in judgement. The lack of consensus is understandable, both because there is incomplete information on the functions of specific nutrients, and because the concept of normal health is arbitrary and subjective, at least to some extent. According to the International Union of Nutrition Sciences Committee Report [4], most differences from country to country can be explained by:
- different subdivisions of people into age groups and physiological groups;
- different criteria for nutritional adequacy;
- different foods available and preferred in each country.

The great differences existing between RDAs in different countries indicate that it is not scientific evidence alone that determines RDA levels, but that political and socio-economic considerations are also involved.

The currently available scientific data on requirements for Vitamin C (ascorbic acid) in man will be discussed.

II. RDAs FOR VITAMIN C

Vitamin C is involved in multifunctional biological mechanisms. It is essential for man that these function at full capacity. Well-established functions include the synthesis of collagen, carnitine, hormones and neurotransmitters, the hydroxylation of xenobiotics, the metabolism of cholesterol, and the inhibition of nitrosamine formation. A further function, the inhibition of oxygen-derived free radicals, seems to be potentially important in
the prevention of cancer, cardiovascular diseases, cataracts etc. Vitamin C also plays an important role in immunomodulation [5].

Recommendations for dietary allowances issued by different authorities and countries vary widely; the values range from 30 to 100 mg/d. Requirements have been set for specially defined risk groups, such as pregnant women, nursing mothers, smokers, etc. The original RDA for vitamin C was based on the daily requirement necessary to prevent scurvy (approximately 10 mg/d). Since scurvy is an extreme form of vitamin C deficiency, this cannot be used to define the optimal supply. For vitamin C, this would mean that in addition to its antiscorbutic function, new roles on maintaining optimum health are included. This view is further supported by results from numerous animal and clinical investigations which indicate that vitamin C has functions which are in fact quite distinct from its basic antiscorbutic role. The requirement for vitamin C to guarantee optimal functioning of these other properties proved to be much higher than the amount necessary to prevent the appearance of scurvy only.

There is no consensus regarding the criteria for vitamin C adequacy. Nevertheless, many investigators consider tissue saturation to be a desirable condition. Depletion studies and steady-state kinetic studies clearly demonstrate that on average the body pool is about 1500 mg or higher in adults. Saturation of the plasma levels can be assumed with intakes of about 100 to 150 mg/d [6]. Kallner et al. [7] found that body stores tended to become saturated at intakes above 80-100 mg/d. A recent study by Jacob et al. [8] indicated that 138 mg vitamin C per day maximized the body pool in healthy young men. Turnover studies under steady-state conditions also showed that an amount of about 100 mg vitamin C is necessary to match the daily dietary requirement [7]. Cigarette smokers have an increased turnover of vitamin C. New data indicate that smokers need more than 200 mg vitamin C daily in order to lower their risk of deficiency to the same level as that of non-smokers consuming 60 mg/d [10].

In the blood, vitamin C combats oxidation reactions which can damage blood fats, genes and proteins. Frei [9] showed that 150 mg vitamin C daily is necessary to protect these components from oxidative damage.

Approximately 100 mg vitamin C is needed daily by a healthy person to ensure and maintain normal biochemical functions. This amount can normally be obtained daily from a balanced diet made up of common foods.

However, in recent years, studies with amounts of vitamin C varying from 200 to 2000 mg demonstrated prophylactic health benefits. In the following, those areas are identified in which the data for a beneficial effect are most convincing.

III. HEALTH BENEFITS OF VITAMIN C

Colds

The presently available evidence suggests that vitamin C is important for many aspects of immune function. Based on the immunostimulatory properties of vitamin C, and in the light of the decrease in vitamin C concentration in leukocytes within the first 24 h following the onset of common cold symptoms, vitamin C in increased doses has been postulated to be effective in the prevention and/or amelioration of the common cold.

The most recent well-controlled, double-blind placebo trial by Mink et al. [11] showed that the group receiving vitamin C (500 mg 4 times a day) showed a lower incidence of contracting the virus, and those that did become infected experienced half the degree of symptom severity seen in the placebo group. The vitamin C serum levels were significantly higher in the vitamin-supplemented group, whereas substantial declines were seen in the placebo subjects.

Cardiovascular Health

The extensive literature on the relationships between vitamin C and cardiovascular health was recently reviewed [12]. Cardiovascular disease is largely
associated with atherosclerosis, hypertension and smoking. Oxidative free radicals and lipid peroxidation are commonly believed to play a major role in atherogenesis. Vitamin C may ameliorate atherosclerosis by acting as an anti-oxidant. A high level of plasma cholesterol is a major risk factor for heart disease; the risk is correlated with the amount of cholesterol carried on the low-density lipoproteins (LDL), but is inversely related to the amount carried on the high-density lipoproteins (HDL). High intakes and/or plasma levels of vitamin C have been associated with higher plasma HDL cholesterol.

Hypertension is another risk factor for cardiovascular disease. It appears that there is a significant correlation between higher blood levels of vitamin C and lower blood pressure.

**Vitamin C and Cancer**

There have been many reports in the literature suggesting that vitamin C may act as an anti-tumour agent. Anti-cancer activity has been demonstrated in vitro in tissue cultures, in vivo in animals and in epidemiological studies in human populations. Several epidemiological studies showed that lower vitamin C intakes may be associated with higher risks of certain cancers, particularly oral, oesophageal, gastric and colorectal cancer. A comprehensive review on the epidemiological evidence was recently published by Block [13].

Vitamin C is involved in many biochemical reactions; it acts as an anti-oxidant, blocks the formation of nitrosamines and faecal mutagens, affects immune function and accelerates the detoxification of liver enzymes. Vitamin C may protect intracellular structures, including DNA, against damage that may initiate cancer development. Nitrosamines, which are formed in the body from nitrites and amines or amides, are carcinogenic compounds. Vitamin C blocks the formation of nitrosamines in the stomach and in food stored under normal conditions.

**Cataracts**

The lens of the eye is at high risk from photo-oxidative damage, which results in cataracts. Besides an enzymatic defence system, the human lens contains vitamin C in high concentrations. Extensive in vitro and in vivo studies in different animal species have demonstrated highly significant protective effects of vitamin C against light-induced cataracts. Epidemiological and supplementation studies showed that persons with higher intakes and higher blood levels of vitamin C had a significantly reduced risk of cataract development [14,15].

**Other effects**

In recent years, the use of vitamin C in further situations with exceptional demands has been proposed and investigated, e.g. wound healing, bone metabolism, periodontal disease and iron absorption. There is substantial evidence that the regular intake of vitamin C in amounts higher than RDA levels, up to 1 g/d, contributes to human health. To attain this goal, there is a need for the intake of supplements or functional foods.

**SUMMARY**

Increasing evidence is accumulating that a synergistic role of the so-called antioxidant vitamins (C, E, β-carotene) may have a dominant role in the prevention of cancer, cardiovascular diseases and cataract formation.

Controversy still exists regarding the optimum intake of vitamin C. This is partly due to lack of accurate and easily accessible health-relevant endpoints, and lack of knowledge of the role of vitamin C in biochemical functions. Today, it is clearly recognized and broadly accepted that optimal health is a consequence of dietary optimization. Attainment of optimal health rather than prevention of deficiency symptoms is the goal. There can be little doubt that in this respect the requirements for vitamin C are greater than the amount required for the mere prevention of overt or classical scurvy.

The recommendation of varying levels of requirement could overcome the controversy. The following is therefore proposed:
The lowest level is that value which prevents deficiency symptoms.

The second level is valid for healthy populations (<200 mg/d). This level would take into account needs which differ according to age, sex, physical activity, physiological status (e.g. pregnancy or lactation) and environmental factors such as smoking, pollution and alcohol intake.

Finally, a third level should be determined for the prevention of the above-mentioned non-communicable diseases. These diseases are an important cause of disability, resulting in costs of billions of dollars annually in medical costs. Many of the above-mentioned diseases can be prevented by supplementation with vitamin C. Medical costs could thereby also be dramatically reduced.

REFERENCES

[1] National Research Council (1941), Recommended Dietary Allowances report, Committee on Food and Nutrition, National Research Council, Washington, D.C.