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The Xanthines: Coffee, Cola, Cocoa, and Tea

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The following case history provides a vivid illustration of the effects of gross xanthine abuse:

> An ambitious 37-year-old Army lieutenant colonel was referred from a military medical clinic to a psychiatric outpatient facility because of a two-year history of "chronic anxiety." The symptoms, which occurred almost daily, included dizziness, tremulousness, apprehension about job performance, "butterflies in the stomach," restlessness, frequent episodes of "diarrhea" (two or three loose stools per day), and persistent difficulty in both falling and remaining asleep. Scores on the Hamilton Anxiety Scale were significantly elevated. He was unable to delineate any precipitating factors, but he did note that one year previously the symptoms were accentuated by the arrival of a new boss who expected a 12 to 14-hour work day from his subordinates.
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> Three complete medical workups had been negative. [Two different series of drugs over a fourteen-month period] had produced no relief. . . . In reply to questioning from the psychiatrist, he described consuming at least 8 to 14 cups of coffee a day ("My coffeepot is a permanent fixture on my desk"). He also frequently drank hot cocoa before bedtime to relax (an average cup of cocoa contains approximately 250 mg. of theobromine, another xanthine derivative). Furthermore, his soft drink preference was exclusively colas (3 to 4 a day). Total caffeine intake thus approximated 1,200 mg. a day [see Table 1].
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> He responded with incredulous cynicism when informed that caffeine toxicity might be causing his symptoms. Consequently, he was initially unwilling (or unable) to limit his intake of coffee, cocoa, and colas. When symptoms persisted, however, he voluntarily reduced his daily intake of caffeine, and four weeks after his initial visit he reported distinct improvement of his long-standing tremulousness, loose stools, and insomnia. His job apprehension continued unabated. . . . To reinforce a cause-and-effect relationship, he was "challenged" with large doses of caffeine for several days in succession. He experienced a

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prompt recurrence of symptoms until the pattern of consuming large doses of caffeine again ceased. Scores on the Hamilton Anxiety Scale obtained three months later were significantly lower.[1]

The spectrum of xanthine usage ranges from this kind of very serious abuse to abstention or the occasional consumption of chocolate and cocoa products, coffee, cola drinks, or tea. Between these extremes are found all combinations of xanthine consumers, with most people in the world using these drugs every day of their adult lives, and the majority possibly abusing them.[2] For example, the per capita consumption of coffee in America is three-and-one-half cups per day, an average intake of from 350 to 525 mg. of caffeine. Even 50 to 200 mg. of caffeine per day is considered medically a physiologic dose that may produce side effects. Two major pharmacology medical school texts[3] refer to doses of caffeine exceeding 250 mg. as significant. So, two cups of coffee or tea contain a clinically significant dose of this drug, and taking even a single cola drink can produce a minor stimulating effect and subsequent depression.

The purpose of this article is to identify what the xanthines are and where they are found, how they act on our bodies, why people use them, and what our knowledge of them says about the Word of Wisdom.

WHAT ARE THE XANTHINES AND WHERE ARE THEY FOUND?

Caffeine, theobromine, and theophylline are three alkaloids that occur in many plants throughout the world. Because they are so closely related both chemically and in their actions on the human body, they are collectively called the xanthines. From earliest times, man has made food solids and beverages from the extracts of plants that contain these substances.[4] Table 1 illustrates some common dietary sources of xanthines. A close examination of the table reveals that there are significant quantities of these drugs present in many popular commodities.

Coffee is derived from the seeds of *Coffea arabica* and its related species. According to legend, Arabian "shepherds reported that

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[1]J. F. Greden, "Anxiety or Caffeinism: A Diagnostic Dilemma," *American Journal of Psychiatry* 131 (1974): 1091.

[2]Ibid., p. 1092.

[3]J. C. Ritchie, "Central Nervous System Stimulants, the Xanthines," in *Pharmacological Basis of Therapeutics*, ed. L. S. Goodman and A. Gilman (New York: Macmillan Co., 1975), chap. 19, pp. 367–78; E. B. Truitt, "The Xanthines," in *Drill's Pharmacology in Medicine*, ed. J. R. Dipalma, 46th ed. (New York: McGraw-Hill, 1971), pp. 82–98, 547–49.

[4]G. E. Vail, J. A. Phillips, L. O. Rust, R. M. Groswold, and M. M. Justin, *Foods: An Introductory College Course* (Boston: Houghton Mifflin Co., 1973), pp. 82–84; *Encyclopaedia Britannica* (Chicago: William Benton Pub., 1974), 4:811, 818, and 18:16.

goats that had eaten the berries of the coffee plant gamboled and frisked about all through the night.''[5] An Arabian priest in a monastery obtained the plant and became the first known person to make and drink a beverage from it, allowing him to undergo long nights of prayer.[6] The coffee shrub produces a fruit called a ''cherry'' that contains two oval coffee beans. These are dried, hulled, roasted, and ground. Instant and freeze-dried coffee are produced by extracting ground coffee with water and freeze-drying the extract, by drying it on a drum in a vacuum, or by spraying it into a heated chamber. Decaffinated coffee is obtained by steaming green coffee and treating it with a chlorinated organic solvent which dissolves out nearly all the caffeine. Coffee contains the xanthine caffeine (see Table 1).

Cocoa, obtained from the seeds of *Theobroma cocoa*, was used in the New World long before Columbus. It grows as a bean in pods seven to twelve inches long, each containing from thirty to forty beans (seeds). The beans are removed, allowed to ferment for several days, dried, and hulled. The resulting ''nibs'' are ground into a semi-liquid paste called ''chocolate liquor.'' The liquor solidifies to a hard, brown block when cooled and is sold as baking chocolate or bitter chocolate. Milk chocolate for candy bars is made by adding milk, sugar, and flavorings; and sweet chocolate for cooking is made by adding only sugar and flavorings. Sometimes the liquor is squeezed in a hydraulic press to remove the cocoa butter. The defatted residue is the common ''cocoa'' used to make hot cocoa drink and also used in manufacturing confections as well as pharmaceutical and cosmetic preparations. Cocoa that has been treated with alkali to produce a less acid flavor is called ''Dutch'' chocolate. Cocoa and chocolate contain the xanthines theobromine and caffeine (see Table 1).

Tea is the national drink of most of the human race, being most popular in Asia, the Middle East, and the United Kingdom. The beverage use of tea probably started in China long before the birth of Christ. Tea is the dried leaves of *Thea sinesis*, an evergreen shrub. The young, unopened leaf bud is considered the highest quality. Black tea is made by rolling the leaves after they have withered and are soft. The rolling releases enzymes that cause chemical reactions within the leaf, and oxygen is taken up as a result. The leaves are spread out in order to absorb a maximum of oxygen. They are then heated and dried to be ready for use. For green tea, the leaves wither and are rolled, but are immediately heated and dried. Instant tea is

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[5]Ritchie, ''Central Nervous System Stimulants, the Xanthines,'' p. 367.
[6]Ibid.

TABLE 1

Some Common Sources of Xanthines[7-16]

Source	*Caffeine*	*Theobromine*	*Total Xanthines*
Beverages:			
Regular cocoa, 6 oz. cup	Amount not published	228–284 mg	At least 228 mg
Instant cocoa (hot chocolate), 6 oz. cup	18 mg	175 mg	193 mg
Coffee, brewed, 6 oz. cup	100–150 mg	0 mg	100–150 mg
Coffee, decaffeinated, 6 oz. cup*	2–4 mg	0 mg	2–4 mg
Cola, 12 oz. serving**	31–65 mg	0 mg	31–65 mg
Tea, 6 oz. cup***	38–81 mg caffeine and 1–5 mg theophylline	2 mg	41–88 mg
Carob, 6 oz. cup	0 mg	0 mg	0 mg
Other Cocoa Products:			
Baking chocolate, 1 oz.	35 mg	420 mg	455 mg
Milk chocolate candy bar, 1 3/8 oz. bar****	15 mg	81 mg	96 mg
Milk chocolate candy bar, 8 oz. bar****	87 mg	471 mg	558 mg
Confectionary covered with chocolate	3 mg	16 mg	19 mg
Powdered cocoa (baking), tablespoon	15 mg	85 mg	100 mg
Chocolate-flavored milk, cereal, etc.	Amounts not published		
Others:*****			
Prescription Medications: (dose per tablet)******			
APC's (aspirin, phenacetin, caffeine)	32 mg	0 mg	32 mg
Cafergot	100 mg	0 mg	100 mg
Darvon compound	32 mg	0 mg	32 mg
Fiorinal	40 mg	0 mg	40 mg
Migral	50 mg	0 mg	50 mg
Over-the-Counter Analgesics:******			
Anacin, aspirin compound, Bromo Seltzer	32 mg	0 mg	32 mg
Cope, Emperin compound, Midol, Vanquish	32 mg	0 mg	32 mg
Excedrin	60 mg	0 mg	60 mg
Many Over-the-Counter Cold Preparations:******	30 mg	0 mg	30 mg
Many Over-the-Counter Stimulants:******			
NoDoz	100 mg	0 mg	100 mg

*These figures are for those decaffeinated coffee brands which are 97 percent caffeine free. Some decaffeinated coffee brands do not state "97 percent caffeine free" and can contain between 28 to 35 mg. caffeine per cup.[7]

**Many "cola" drinks do not have "cola" in their name. That they are derived from kola nuts is indicated on their label as containing "caffeine" or "extract of kola nuts." The most current (1979) figures of caffeine content per 12 oz. can are: Coca Cola—65 mg.; Dr. Pepper—61 mg.; Mountain Dew—55 mg.; Diet Dr. Pepper—54 mg.; Tab—50 mg.; Pepsi Cola—43 mg.; RC Cola—34 mg.; Diet RC—33 mg.; Diet Rite—32 mg.; and others such as Barq's Olde Tyme Root Beer.[8]

***A new spectrophotometric micro-method for the determination of caffeine content in teas revealed that a 6 oz. cup of medium-strength tea contained: Red Rose Tea, black, hot bag—62 mg. caffeine; Lipton Tea, black, hot bag—53 mg. caffeine; Lipton Iced Tea with sugar and lemon—76 mg. caffeine; Nestea Iced Tea with sugar and lemon—67 mg. caffeine; and Lipton Tea from a Mr. Coffee automatic—71 mg. Add to each of the above caffeine figures 2 mg. theobromine and 1 mg. theophylline per cup for total xanthine intake.[9]

****Personal communications with an executive of the Chocolate Manufacturers' Association of the United States of America (1976) revealed the following values: cocoa—5 mg. caffeine plus 75 mg. theobromine per 6 oz. cup; milk chocolate candy bar—6 mg. caffeine plus 72 mg. theobromine per 1.2 oz. bar. The milk chocolate produced by one American chocolate manufacturer (personal communication, 1976) was reported to be 4 mg. caffeine plus 16 mg. theobromine per ounce of milk chocolate. In 1971 and 1975 the United States Government Food and Drug Administration "Fact Sheet on Caffeine" listed sweet chocolate as containing 20 mg. caffeine per ounce. American bittersweet chocolate candy bars and English milk chocolate and bittersweet chocolate candy bars are slightly higher in xanthine content than American milk chocolate candy bars.[10]

*****Xanthines are present *in* (1) Maté, "the national drink of many South American countries" (about 1.25 percent caffeine);[11] (2) "Kola nuts, the guru nuts chewed by the natives of the Sudan" (about 2 percent caffeine);[12] (3) Yerba plants;[13] (4) Guarana paste;[14] (5) Yonpon tea.[15] Decoctions of these are commercially prepared for sale worldwide, yet they do not bear the names "coffee," "tea," "cocoa," or "cola." (The pep pills sometimes provided to American high school and college athletes usually contain the sugar dextrose and/or sympathimimetic amines and do not contain xanthines.)

******Xanthines are present in many prescription medications and over-the-counter compounds. Those in the table are just a sample.[16]

[7]R. G. Martinek and W. Wolman, "Xanthines, Tannins and Sodium in Coffee, Tea and Cocoa," *Journal of the American Medical Association* 158 (1955): 1030–31.

[8]"Caffeine in Cola Drinks," *Church News: News of The Church of Jesus Christ of Latter-day Saints*, a section of the *Deseret News* (Salt Lake City, Utah), 20 January 1968, p. 5. Personal communication, 1976, with an executive of the National Soft Drink Association, Washington, D.C., revealed that American cola beverages contain from 3.2 to 3.9 mg. caffeine per oz., which is in line with the *Church News* figures; M. L. Bunker and M. McWilliams, "Caffeine Content of Common Beverages," *Journal of the American Dietetic Association* 74 (1979): 30.

[9]D. S. Grossier, "A Study of Caffeine in Tea. I. A New Spectrophotometric Micro-Method. II. Concentration of Caffeine in Various Strengths, Brands, Blends and Types of Teas," *American Journal of Clinical Nutrition* 31 (1978): 1728–29.

[10]E. M. Ghatt, "Cocoa Cultivation, Processing, Analysis," in *Economic Crops*, ed. A. I. Kertesz (New York: Interscience Publishers Inc., 1953), 3:211, 247.

[11]J. A. Widtsoe and L. D. Widtsoe, *Word of Wisdom, A Modern Interpretation* (Salt Lake City: Deseret Book Co., 1938), pp. 96–97.

[12]Ritchie, "Central Nervous System Stimulants, the Xanthines," pp. 367–76.

[13]Widtsoe and Widtsoe, *Word of Wisdom*, pp. 96–97.

[14]Ibid.

[15]Ibid.

[16]P. I. Stephenson, "Physiologic and Psychotropic Effects of Caffeine on Man," *Journal of the American Dietetic Association* 71 (1977): 241.

made in much the same way as instant coffee. Tea owes much of its flavor to the complex mixture of more than twenty substances that make up the tannins it contains. Tea contains the xanthines caffeine, theophylline, and theobromine (see Table 1).

Cola-flavored beverages contain an extract from kola nuts obtained from the *Cola acuminata* tree. Carbonated beverages were first made by early Europeans to imitate the popular and naturally effervescent waters from famous springs that were reputed to have therapeutic value. Today carbonation is achieved by cascading the chilled beverage mixture in thin layers over a series of plates in an enclosure containing carbon dioxide gas under pressure. Cola drinks contain the xanthine caffeine (see Table 1).

HOW DO THE XANTHINES ACT ON THE BODY?

Xanthines have both good and bad effects on the body, and these effects are generally determined by the size and frequency of dosage. Anyone who has experienced the distress of a headache and has had the pain alleviated by an aspirin compound that included caffeine (see Table 1) can attest to the advantages of the proper medical use of the xanthines. But anyone who has activated a stomach ulcer from daily doses of caffeine can attest to the bad effects of improper use of the xanthines.

The correct use of xanthine drugs continues to be a major contribution to the improvement of life. Caffeine and theophylline are widely prescribed today by physicians. For example, caffeine in combination with sodium benzoate is used as a stimulant, and theophylline in combination with EDTA dilates the lung bronchioles. Theobromine was fairly popular as a medication in the early 1900s, but its use has since declined.[17]

Although xanthines are best known to the layperson for their stimulating and pain-relieving effects, let me briefly summarize all their known pharmacological properties in man, both good and bad, including some of their less obvious medical contributions. The following information is taken from the pharmacology textbook currently used in most medical schools[18] and from the scientific literature. Table 2 summarizes their relative actions and lists the unit-prescription dose.

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[17]C. J. Dorfman and M. E. Jarvile, "Comparative Stimulant and Diuretic Actions of Caffeine and Theobromine in Man," *Clinical Pharmacology and Therapeutics* 11 (1970): 871.

[18]Ritchie, "Central Nervous System Stimulants, the Xanthines," pp. 367–78.

1. *Brain and spinal cord.*[19] Caffeine and theophylline are powerful central nervous system stimulants. They stimulate all portions of the cortex of the brain, resulting in greater sustained intellectual effort and a more perfect association of ideas. Reaction time is diminished, muscle activity is increased, and there is also a keener appreciation of sensory stimuli.

If a person has become depressed by barbiturates or other drugs, caffeine or theophylline may be administered to speed up breathing to an acceptable level, since they act on the respiratory center of the brain.

Overindulgence or abuse of the use of caffeine and theophylline products leads to "chronic xanthine poisoning" which may produce the following symptoms: diarrhea, dizziness, apprehension, restlessness, a high level of anxiety, and a ringing or hissing noise in the ears.

2. *Cardiovascular systems.*[20] All three xanthines have a powerful action on the heart and blood vessels. Xanthines cause the blood vessels that feed the brain to constrict, decreasing both the blood flow and the oxygen tension of the brain. This action is responsible for the striking relief from headaches obtained from xanthine consumption. Note in Table 1 that almost all prescription medications, over-the-counter analgesics, and cold preparations contain significant amounts of caffeine for that purpose.

All of the xanthines stimulate the heart directly to increase the force of contraction, the heart rate, and the output. Theophylline is a valuable drug in the emergency treatment of heart failure where the heart is filled with blood due to a venous obstruction. Because the xanthines dilate the blood vessels that nourish the heart, causing increased blood flow, they are used in the treatment of coronary artery disease and other coronary insufficiencies.

Large doses result in tachycardia (a rapid beating of the heart, over 100 beats per minute). Continued stimulation occasionally results in permanent heart irregularities. Such are sometimes "encountered in persons who use caffeine beverages to excess."[21]

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[19]W. Sprugel, P. Mitznegy, and F. Heirn, "The Influence of Caffeine and Theobromine on Locomotive Activity and the Brain GMP/cAMP Ratio in White Mice," *Biochemical Pharmacology* 26 (1977): 1723–24; A. M. Poisner, "Direct Stimulant Effect of Aminophylline on Catecholamine Release from the Adrenal Medulla," *Biochemical Pharmacology* 22 (1973): 469, 474–75.

[20]T. de Gubareff and W. Sleator, Jr., "Effects of Caffeine on Mammalian Atrial Muscle and Its Interaction with Calcium," *Journal of Pharmacological and Experimental Therapeutics* 148 (1965): 205–208; M. L. Marcus, C. L. Skelton, L. E. Grauer, and S. E. Epstein, "Effects of Theophylline on Myocardial Mechanics," *American Journal of Physiology* 222 (1972): 1361–65; D. M. Fowell, J. A. Winslow, V. P. Sydenstricker, and N. C. Wheeler, "Circulatory and Diuretic Effects of Theophylline Isopropanolamine," *Archives of Internal Medicine* 83 (1949): 150–57; and F. A. MacCornack, "The Effects of Coffee Drinking on the Cardiovascular System: Experimental and Epidemiological Research," *Preventive Medicine* 6 (1977): 104–19.

[21]Ritchie, "Central Nervous System Stimulants, the Xanthines," p. 369.

TABLE 2

Relative Effects of Xanthines on Body Systems of Laboratory Animals and Man

(Some figures extrapolated from reported data. Dosages listed as "mild," "moderate," or "strong" according to current [1980] medical usage.)

	Central Nervous System	*Voluntary Muscles*	*Heart*	*Usual Medicinal Unit-Dose Prescribed by Physician*[22] *(Compare with Table 1)*
Caffeine	Brain cellular activity increased 49% 30 minutes after exposure to 45 ug/g body weight (a moderate dose).[23]	Increased 5% with 300 mg (a strong dose).[24]	Heart contraction increased in direct proportion to amount consumed beginning at 0.25 mM (a mild dose) and was two times normal at 2.5 mM (a strong dose) in the blood.[25]	60 mg/oral capsule 500 mg/intramuscular injection
Theobromine	Nonquantified clinical observations reported a noticeable stimulation, which was less than that observed with caffeine or theophylline.[26]	180 ug/g body weight (a mild dose) produced no change from normal.[27]	Clinical data demonstrated a greater increase than observed with caffeine.[28]	500 mg/oral tablet
Theophylline	2.43 mM (a strong dose) in the blood, doubled the concentration of nerve stimulant.[29]	Increased muscle tension up to 23% at 2.40×10^{-4} M (a moderate dose) in the blood.[30]	An immediate marked increase persisted for 15 to 30 minutes. Increase was proportional to amount of drug from a weak to a strong dosage.[31]	100 mg/oral capsule 250 mg/intravenous injection 125 mg/rectal suppository

3. *Smooth muscle*.[32] The xanthines, particularly theophylline, relax the smooth muscles that surround the bronchioles (the air tubes that go to the lungs). They are used to relieve respiratory distress, especially in the treatment of certain cases of bronchial asthma.

4. *Skeletal muscle*.[33] Caffeine and theobromine strengthen the contraction of the voluntary muscles of the body (e.g., arm and leg muscles), resulting in an increased capacity for muscular work. Abuse may result in shaking or trembling.

5. *Kidneys*.[34] Theobromine and theophylline increase the production of urine and are sometimes used as diuretics. Overuse causes more frequent urination.

6. *Gastric secretion*.[35] Moderate doses of caffeine increase the amount of acid secreted into the stomach. Repeated daily doses of caffeine have been shown to contribute to ulcers. For this reason, excessive use of coffee and cola beverages is a concern to many physicians. Abuse of these stimulants may also cause nervous or "butterfly" stomach.

7. *Body metabolism*.[36] The xanthines cause an increase in the basal metabolic rate (they increase the amount of energy produced by the cells). Ingestion of 500 mg. of caffeine (about four cups of coffee—see Table 1) increases the basal metabolic rate ten percent to twenty-five percent. However, the effects are not seen until a few hours after the drug is taken. As would be expected, this stimulation

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[22]Ibid., p. 374.

[23]Sprugel, Mitznegy, and Heirn, "The Influence of Caffeine and Theobromine," pp. 1723–24.

[24]A. Goldstein, G. Kaiser, and R. Warren, "Psychotropic Effects of Caffeine in Man," *Journal of Pharmacological and Experimental Therapeutics* 150 (1965): 14.

[25]de Gubareff and Sleator, "Effects of Caffeine on Mammalian Atrial Muscle," p. 205.

[26]Ritchie, "Central Nervous System Stimulants, the Xanthines," p. 368.

[27]Sprugel, Mitznegy, and Heirn, "The Influence of Caffeine and Theobromine," pp. 1723–24.

[28]Ritchie, "Central Nervous System Stimulants, the Xanthines," p. 368.

[29]Poisner, "Direct Stimulant Effect of Aminophylline," pp. 474–75.

[30]Marcus, Skelton, Grauer, and Epstein, "Effects of Theophylline on Myocardial Mechanics," pp. 1362–63.

[31]Fowell, Winslow, Sydenstricker, and Wheeler, "Circulatory and Diuretic Effects of Theophylline Isopropanolamine," p. 153; Ritchie, "Central Nervous System Stimulants, the Xanthines," p. 369.

[32]A. R. Dowell, "Effect of Aminophylline on Respiratory Center Sensitivity in Chayne–Stokes Respiration and in Pulmonary Emphysema," *New England Journal of Medicine* 273 (1965): 1450.

[33]Marcus, Skelton, Grauer, and Epstein, "Effects of Theophylline on Myocardial Mechanics," pp. 1362–63; Goldstein, Kaiser, and Warren, "Psychotropic Effects of Caffeine in Man," p. 14; Sprugel, Mitznegy, and Heirn, "The Influence of Caffeine and Theobromine," pp. 1723–24.

[34]Ritchie, "Central Nervous System Stimulants, the Xanthines," p. 371.

[35]J. A. Roth, A. C. Ivy, and A. J. Atkinson, "Caffeine and 'Peptic' Ulcer," *Journal of the American Medical Association* 126 (1944): 814–20; H. L. Bockus, ed., *Gastroenterology* (Philadelphia: W. B. Saunders Co., 1974), 1:513; M. H. Sleisenger and J. S. Fordtran, "Peptic Ulcer Pathogenesis," *Gastrointestinal Disease: Pathophysiology, Diagnosis and Management* (Philadelphia: W. B. Saunders Co., 1978), p. 814.

[36]Ritchie, "Central Nervous System Stimulants, the Xanthines," pp. 367–78.

is usually followed by a period of sluggishness or mild body depression.

Just as the correct use of the xanthines can be greatly beneficial, their abuse can damage the body. Overindulgence leads to a condition described as "chronic poisoning." The case history presented at the beginning of this article is an example. In chronic xanthine poisoning it may be that only some of the symptoms the man in that case experienced will be evident simultaneously but, in some instances, there may be several additional symptoms. A few or several of these symptoms may be manifested even in persons who ingest only small quantities of xanthines.

A "certain degree of tolerance and of psychic dependence (i.e., habituation) develops . . . even in those individuals who do not partake to excess," but only moderately ingest xanthines.[37] It is not surprising, therefore, that the withdrawal from xanthines by individuals habituated to them usually results in a "withdrawal headache."[38] The headache is at first localized but then becomes a generalized, throbbing pain. It is sometimes accompanied by nausea, nasal/sinus congestion, depression, drowsiness, and a disinclination to work.[39]

There is little doubt that the popularity of the xanthine beverages results from their stimulant action.[40] Figures 1 and 2 illustrate the United States per capita consumption of the xanthines. A person who ingests colas, coffee, tea, or chocolate in order to experience a temporary increase in intellectual effort and/or muscle activity should understand the consequences of his action. Not only will he experience a longer time period of decreased efficiency later, he will also run the risk of habituation. More importantly, he will be exposing most of the vital organs of his body to the drug. Because he does not feel the increased heart rate, dilation of heart vessels, the decreased blood flow and oxygen tension of the brain, the increased gastric secretion nor the increased body metabolism, but only observes the stimulation and the diuretic effect, the price only appears small. He would never think of needlessly taking even one dose of a drug that adversely affected so many body organs, much less taking the drug several times each day. Besides, the consumption of

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[37]Ibid., p. 376.

[38]A. Goldstein and S. Kaizer, "Psychotropic Effects of Caffeine in Man, III. A Questionnaire Survey of Coffee Drinking and Its Effects in a Group of Housewives," *Clinical Pharmacology and Therapeutics* 10 (1969): 487; A. Goldstein, S. Kaizer, and O. Whitby, "Psychotropic Effects of Caffeine in Man, IV. Quantitative and Qualitative Differences Associated with Habituation of Coffee," *Clinical Pharmacology and Therapeutics* 10 (1969): 496.

[39]Greden, "Anxiety or Caffeinism," p. 1090.

[40]Ibid., pp. 1089–92.

both caffeine and theobromine in a chocolate bar to increase mental and voluntary muscle activity (e.g., for typing) is self-defeating; theobromine neutralizes much of the caffeine effect.[41]

A well-nourished body has no unnatural cravings and provides optimum intellectual effort and muscle activity without the ingestion of drugs. Often xanthines eventually become toxic to people who have come to rely on their use in order to be efficient. However, after withdrawal symptoms and a week or so of feeling fatigued, they report that they feel more alert and efficient without the drug than they were while under its influence.[42]

Because theobromine, unlike caffeine and theophylline, only slightly stimulates the central nervous system, some people incorrectly assume that its other effects are minimal. This has resulted in the ingestion of cocoa and chocolate by people who refrain from caffeine and theophylline in tea, coffee, and cola drinks. As early as 1939, in an article appearing in the *Journal of the American Medical Association*,[43] a question concerning the use of cocoa and chocolate was answered: "In considering cocoa as a beverage for children, it should be regarded as a stimulant similar to coffee." Today, as a result of many years of research and clinical experience with the xanthines, it is known that theobromine is more potent than an equal amount of caffeine in causing heart stimulation, dilation of heart vessels, smooth muscle relaxation, and diuresis[44] (see Table 2).

Many people are aware that cola drinks contain a harmful drug, but because they do not know the quantity of that drug, they rationalize that it must be in such small quantity that they can ingest significant amounts without effect. Yet, many cola drinkers readily admit to the mental and physical "pick-up" obtained from a cola drink when they are tired or even slightly fatigued.

Many of the soft drinks on the grocers' shelves contain caffeine (see Table 1 note). Per capita consumption of soft drinks since 1900 has increased quite dramatically, as seen in Figure 1. Per capita consumption of soft drinks in 1942 was approximately one-and-a-half 12 oz. bottles (or 18 ounces) per week. In 1978 (the most recent complete figures), it was more than five times that figure (eight 12 oz. bottles or 96 ounces) per week per person. This would have been 627 soft drinks a year per person, and 539 (or six out of every seven drinks)

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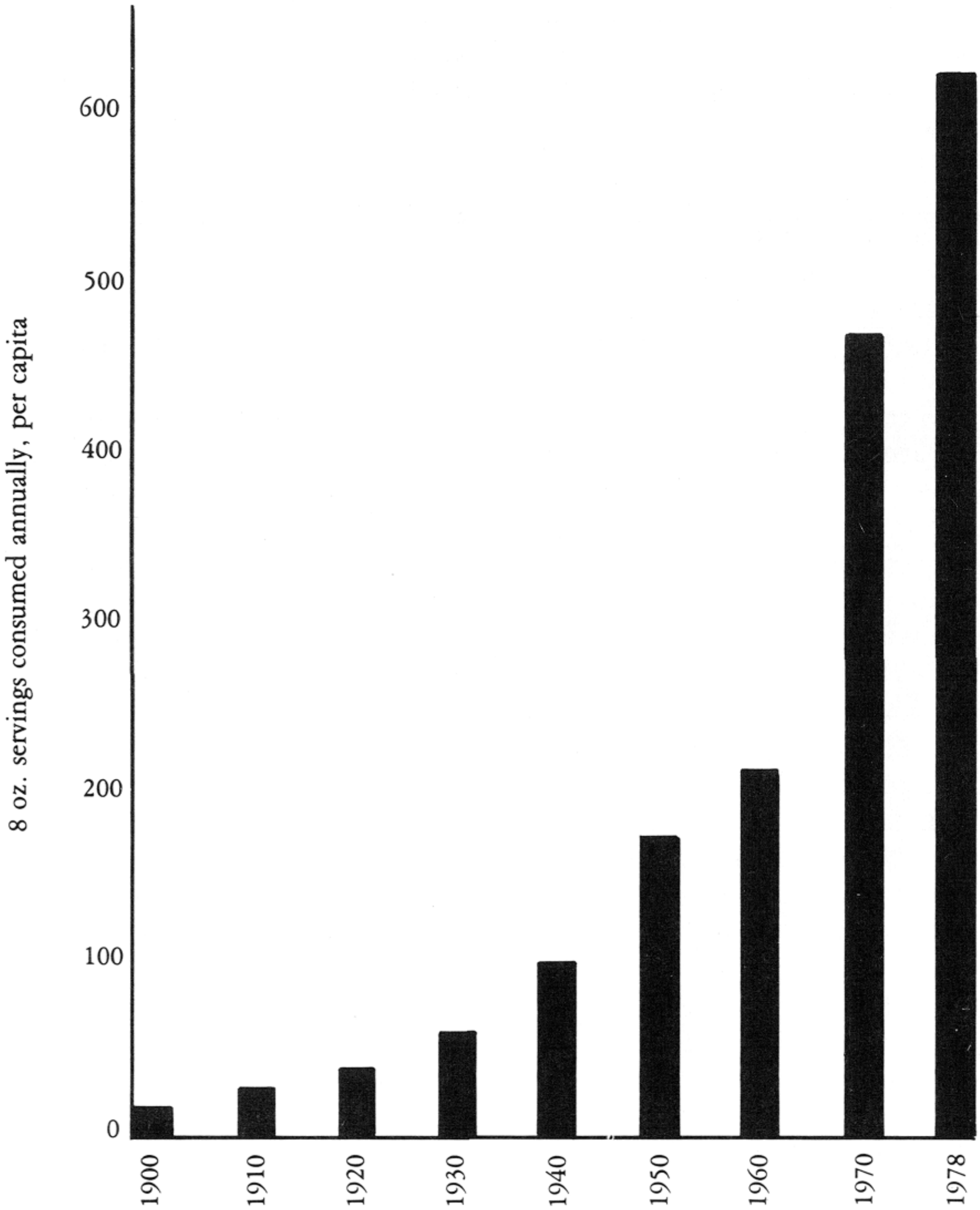
[41]Sprugel, Mitznegy, and Heirn, "The Influence of Caffeine and Theobromine," pp. 1723–24; Ritchie, "Central Nervous System Stimulants, the Xanthines," p. 368.

[42]Greden, "Anxiety or Caffeinism," p. 1091.

[43]Cited in L. D. Widtsoe, *How to Be Well* (Salt Lake City: Deseret Book, 1943), p. 94.

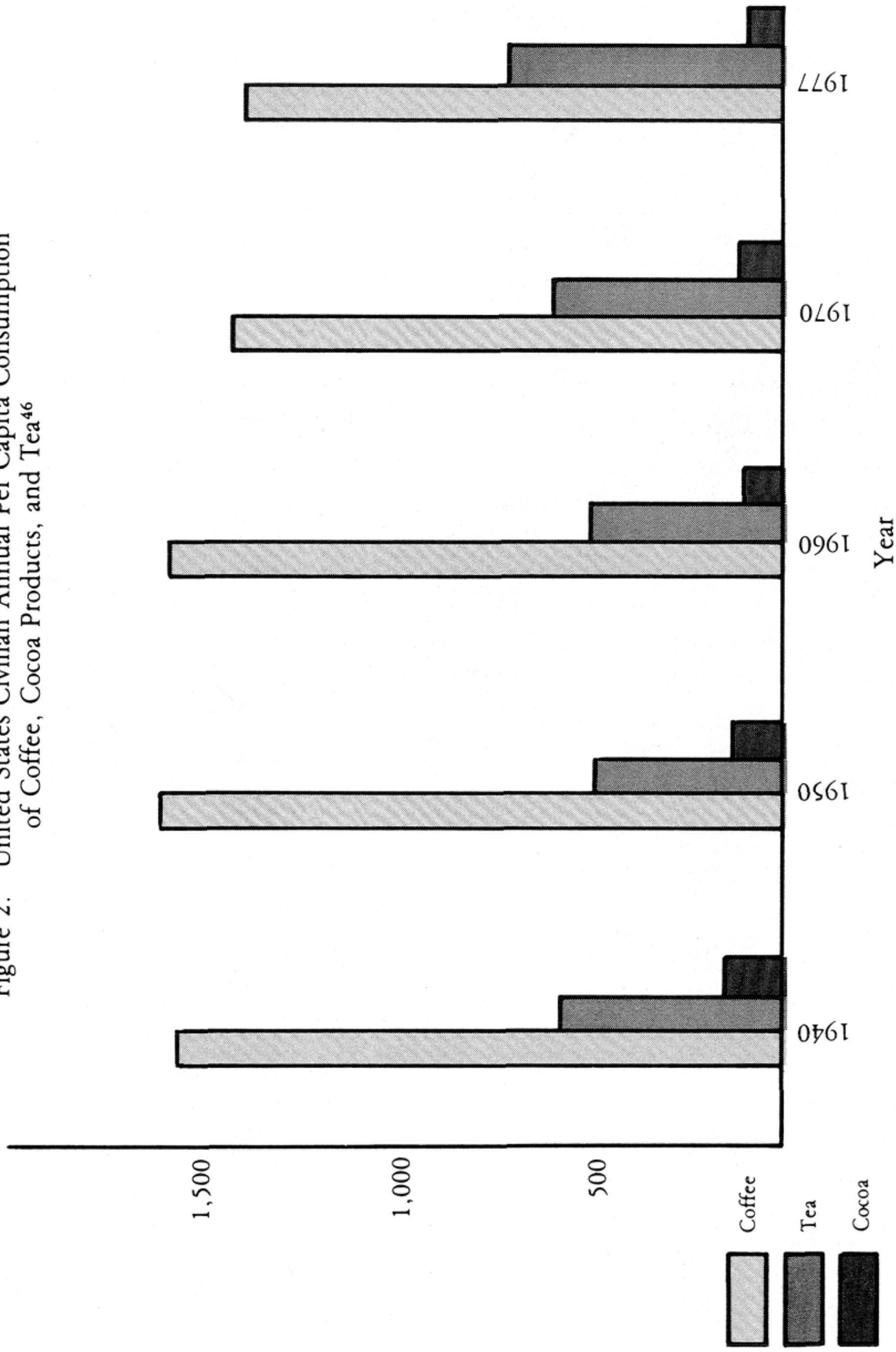
[44]Ritchie, "Central Nervous System Stimulants, the Xanthines," p. 368.

Figure 1. United States Per Capita Consumption of Soft Drinks[45]



[45]M. R. Jacobson, "Nutrition Scoreboard, Your Guide to Better Eating," Center for Science in the Public Interest (New York: Avon Books, 1975), p. 137; "FDA Ponders Caffeine Ban," 21 April 1979, and tables on per capita consumption and top ten drinks, 18 May 1979, *Beverage Industry*, ed. John C. Maxwell, Jr. (New York: The Maxwell Division, Wheat First Securities, Inc.).

Figure 2. United States Civilian Annual Per Capita Consumption of Coffee, Cocoa Products, and Tea[46]



[46] "United States Bureau of the Census, Statistical Abstract of the United States," (Washington, D.C.: Government Printing Office, 1975 and 1979), pp. 92, 127.

contained caffeine—a total of 17,800 mg.[47] (The lethal oral dose of caffeine to man is 3,000 to 10,000 mg., depending on an individual's size, weight, etc.; but this would need to be a single dose.) Of course there are many Americans who do not consume cola drinks, meaning that the average caffeine consumption among cola drinkers was significantly more than 17,800 mg. that year. And, this frequently was in addition to coffee, tea, and cocoa product consumption.

The two most popular soft drinks in the United States from 1973 through 1978 contained approximately 65 mg. and 43 mg. caffeine per 12 oz. serving respectively[48] (see Table 1 note). These two soft drinks continue to sell more than twice as many units as do all the rest in the top ten put together.[49] In 1978, the sales of these two drinks contained 2,781,000,000,000 mg. of caffeine.[50] The total amount of caffeine consumed in America annually in all cola-containing soft drinks has not been determined, but it has been significantly greater than this two-and-a-half trillion mg. per year since seven of the ten top-selling soft drinks in the United States contain caffeine.[51]

Recently released figures demonstrate that Americans between the ages of twenty-five and forty-four are the major purchasers of cola-containing beverages. In 1977 that age group spent $1.3 billion on cola drinks as opposed to $210 million in the "under twenty-five" age group.[52]

HOW DOES CAFFEINE AFFECT CHILD HYPERACTIVITY, BIRTH DEFECTS, AND CANCER?

Recently, the Federation of American Societies for Experimental Biology recommended that the Food and Drug Administration remove caffeine from the Generally Recognized as Safe List for food additives. The Food and Drug Administration would then specify limited conditions under which caffeine could be used.[53]

Many of my pediatrician colleagues counsel their young patients to minimize consumption of or to abstain from xanthine products, since drug potency is related to body weight. To an adult weighing 150 lbs. "a cup of instant coffee or a can of cola beverage could give

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[47]"Consumption of Soft Drinks by Company," 2 April 1976; "FDA Ponders Caffeine Ban," 21 April 1979; tables on per capita consumption and top ten drinks, 18 May 1979; and "Soft Drink Sales Remain at Record Levels Despite Softening Economy," 4 April 1975, *Beverage Industry*, ed. John C. Maxwell, Jr. (New York: The Maxwell Division, Wheat First Securities, Inc.).

[48]Bunker and McWilliams, "Caffeine Content of Common Beverages," p. 30.

[49]*Beverage Industry*, 4 April 1975, p. 1, and 21 April 1979.

[50]Calculated from fns. 47 and 48.

[51]*Beverage Industry*, 21 April 1979.

[52]Ibid., 18 May 1979, p. 28.

[53]Ibid.

about 1 mg. caffeine per kilogram of body weight. In a very young child, the cup of chocolate or candy bar would give the same proportion of caffeine to body weight. When this child drinks a can of cola, . . . caffeine intake is comparable to an adult drinking 4 cups instant coffee. A nursing mother should be aware that caffeine passes into her milk and that this could have a stimulating effect on her infant. . . . Restlessness, irritability, sleeplessness, and nervousness are some of the symptoms'' of xanthine-induced child hyperactivity.[54]

Xanthines might also affect the fetus. In the United States each year about one in seven pregnancies ends in stillbirth, miscarriage, a malformed infant, or a similar reproductive problem, due to various causes including xanthine abuse. Last year the Center for Science in the Public Interest, located in Washington, D.C., wrote to ''12,500 obstetricians and gynecologists and 1,500 midwives urging them to advise pregnant women not to consume caffeine.''[55] The concern is based on several human and laboratory animal studies which demonstrated that caffeine may be responsible for a variety of birth defects: delayed fetal development,[56] missing fingers and toes,[57] disruption of the normal fetoplacental unit,[58] and an effect on some cellular processes of the fetus.[59]

One study on caffeine and pregnancy will be of particular interest to the readers of *BYU Studies*. A retrospective study was conducted in which 75 percent of the population studied were members of The Church of Jesus Christ of Latter-day Saints. Of the pregnant women who had consumed at least 600 mg. caffeine per day, 94 percent lost their babies to spontaneous abortion, stillbirth, or prematurity with death within forty-eight hours. Only 22 percent of the women who had zero daily caffeine consumption lost their children. Although there were probably other factors affecting the data, such as lack of smoking and alcohol consumption, the researchers concluded ''the results of the survey do suggest that a daily

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[54]Bunker and McWilliams, ''Caffeine Content of Common Beverages,'' p. 31.

[55]Associated Press, ''Consumer Group Urges Warning on Use of Caffeine in Pregnancy,'' *New York Times*, 18 November 1979, p. 32.

[56]P. E. Palm, E. P. Arnold, P. C. Rachwall, J. C. Leyczek, K. W. Teague, and C. J. Kensler, ''Evaluation of the Teratogenic Potential of Fresh-Brewed Coffee and Caffeine in the Rat,'' *Toxicology and Applied Pharmacology* 44 (1978): 1–16; I. Borlée, M. F. Lechat, A. Bouckert, and C. Misson, ''Le Café: Facteur de Risque Pendant la Grossesse?'' *Louvain Medicine* 97 (1978): 279–84.

[57]Groupe d'Etude des Risques Tératogénes, ''Tératogénese Experimentale: Etude de la Caféine Chez la Souris,'' *Therapir* 24 (1969): 575–80.

[58]E. F. Gilbert and W. R. Pistey, ''Effect on the Offspring of Repeated Caffeine Administration to Pregnant Rats,'' *Journal of Reproduction and Fertility* 34 (1973): 495–99.

[59]P. S. Weathersbee and J. R. Lodge, ''Alcohol, Caffeine and Nicotine as Factors in Pregnancy,'' *Postgraduate Medicine* 66 (1979): 165–71.

caffeine intake of 600 mg. or greater may predispose a woman to reproductive difficulty.''[60]

With so many common compounds proving to be carcinogenic, it is not surprising that caffeine would be tested to see whether it too is carcinogenic. The tests show there is no direct evidence that caffeine causes cancer in humans.[61] However, fibrocystic breast disease, a benign condition, recently has been linked to caffeine consumption. When twenty afflicted women abstained from caffeine, thirteen experienced a remission of all symptoms.[62]

A report published last year (1979) stated that from 20 to 30 percent of all Americans ingest 500–600 mg. of caffeine a day, and 10 percent may consume more than 1,000 mg. a day.[63] The Food and Drug Administration will soon release the results of a lengthy study it has undertaken on the effects of caffeine. The preliminary reports indicate that the findings will strongly confirm the suspected hazards.[64]

WHY DO PEOPLE CONSUME LARGE QUANTITIES OF XANTHINE-CONTAINING FOODS IF THEY ARE NOT HEALTHFUL?

There are three basic reasons people use foods containing large amounts of the xanthines. Primarily, people are uninformed. Much of our knowledge about the xanthines has come about only within the last decade, and it takes time to spread scientific information. This knowledge must counter the fact that people enjoy consuming xanthine products. In practically every culture in the world, xanthine beverages play important cultural–social roles. The British ''cup of tea'' and the American ''coffee break'' are well-established cultural mores.

Second, the stimulant effect and the undesirability of the withdrawal symptoms felt when intake is interrupted also promote sustained consumption.

Third, and of very significant importance in the developed countries, is the sustained, massive advertisement by companies that market these products. Figure 2 illustrates the per capita consumption of coffee, cocoa products, and tea in America. Note that the yearly per capita consumption (since 1940) of coffee, cocoa products,

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[60]P. S. Weathersbee, L. K. Olsen, and J. R. Lodge, ''Topics in Primary Care, Caffeine and Pregnancy: A Retrospective Survey,'' *Postgraduate Medicine* 62 (1977): 64–69.

[61]J. Timson, ''How Harmful Is Your Daily Caffeine?'' *New Scientist* 78 (1978): 736–37.

[62]J. P. Minton, M. K. Foecking, J. T. Webster, and R. H. Matthews, ''Caffeine, Cyclic Nucleotides, and Breast Disease,'' *Surgery* 86 (1979): 105–109.

[63]J. F. Greden, ''Coffee, Tea and You,'' *The Sciences* 19 (1979): 6.

[64]R. Reinhold, ''Caffeine Quandary Illustrates FDA's Plight,'' *New York Times*, 8 January 1980, pp. C1, C2.

and tea has not changed dramatically—a slight decrease for coffee and cocoa products and a slight increase for tea. Figure 2 demonstrates the dramatic increase in the United States per capita consumption of soft drinks from 1900 to 1978. Much of this change is the result of increased and more effective advertisement. Through massive media exposure the American public has been led to believe these products are desirable. For example, in 1978 (the latest available figures), $410 million were spent on the television advertisement of confectionary and soft drinks, including chocolate confectionary and cola drinks. This compares with $313 million for all beer and wine commercials and $103 million for all insurance advertisements using the same media. The $410 million figure in 1978 was almost twice the amount ($220 million) spent in 1975, just three years earlier.[65] In 1979, more soft drinks were consumed than milk and juices combined.[66]

WHAT IS THE RELATIONSHIP BETWEEN XANTHINES AND THE WORD OF WISDOM?

As Latter-day Saints, we need to understand how modern prophets have interpreted the Lord's counsel that "hot drinks are not for the body or belly."[67] Joel H. Johnson, an early member of the Church who was with the Prophet Joseph when the Word of Wisdom was received in 1833, recorded in his journal an interesting sermon that the Prophet gave five months later:

> "I understand that some of the people are excusing themselves in using tea and coffee, because the Lord only said 'hot drinks' in the revelation of the Word of Wisdom.
>
> "The Lord was showing us what was good for man to eat and drink. Now, what do we drink when we take our meals?
>
> "Tea and coffee. Is it not?
>
> "Yes; tea and coffee.
>
> "Then, they are what the Lord meant when He said 'hot drinks.'"[68]

Patriarch Hyrum Smith, speaking to a congregation in Nauvoo almost nine years later, reiterated that interpretation: "'There are many who wonder what this [reference to "hot drinks"] can mean;

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[65]Calculated from "U.S. Bureau of the Census, Statistical Abstract of the United States," 1979, p. 596.
[66]*Beverage Industry*, 18 May 1979.
[67]Doctrine and Covenants (Salt Lake City: The Church of Jesus Christ of Latter-day Saints, 1921), 89:9.
[68]J. H. Johnson, *Voice from the Mountains* (Salt Lake City: Juvenile Instructor Office, 1881), p. 12.

whether it refers to tea, or coffee, or not. I say it does refer to tea, and coffee.' ''[69]

Dr. John A. Widtsoe, an LDS apostle and a chemist of international reputation, was an early authority on the Word of Wisdom. He thought the Lord purposefully used the term ''hot drinks'' rather than ''tea and coffee'' because by so doing the ''host of other injurious habit-forming beverages'' and products that would be used in the future would automatically ''become subject to the Word of Wisdom. Indeed, the use of the words, 'hot drinks' implies a knowledge beyond that possessed by man when the Word of Wisdom was received.''[70]

The medical research referred to in this article stands as a witness of the validity of the ''hot drinks'' instruction in the Word of Wisdom. When this revelation was given in 1833, caffeine had been discovered as a substance, but its physiological effects were not known and the announcement of its discovery was buried in scientific publications. ''It is very unlikely that the Prophet Joseph had heard of it.''[71] But even if he had, no one at that time knew of its harmful effects.

In 1976, the results of two major studies comparing the longevity and healthfulness of Latter-day Saints to nonmembers were published.[72] In summary, the male death rate in Utah County (85 percent LDS) was 35 percent below the national average. Female death rate was 28 percent less. Male and female Latter-day Saints were contracting cancer 29 percent less frequently than nonmembers, and the death rate of Latter-day Saints in Utah and Los Angeles counties due to heart attack and cardiovascular disease was 33 to 50 percent less than among non-LDS. Mormons had a 51 percent less incidence of bladder and kidney disease than non-Mormons. Such dramatic results leave little doubt about the validity of the teachings of the Word of Wisdom.

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[69]*Times and Seasons* 3 (1 June 1842): 800; see also Bruce R. McConkie, *Mormon Doctrine*, 2nd ed. (Salt Lake City: Bookcraft, 1966), pp. 368–70.

[70]Widtsoe and Widtsoe, *Word of Wisdom*, p. 99.

[71]Ibid.

[72]J. L. Lyon et. al., ''Cancer Incidence in Mormons and Non-Mormons in Utah, 1966–1970,'' *New England Journal of Medicine* 294 (1976): 130–31; J. E. Enstrom, ''Cancer Mortality among Mormons,'' *Cancer* 36 (1975): 826–29, 831; J. E. Enstrom, ''American Heart Association Conference Report,'' Tampa, Florida, March 1975; also cited in Bill Davidson, ''What Can We Learn about Health from Mormons?'' *Family Circle*, January 1976, pp. 78–82.