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Science, Voters, and the Fluoridation Controversy

Conflict among perceived experts leads voters to act negatively on the fluoridation innovation.

Harvey M. Sapolsky

In science and public policy discussions, voters' preferences are rarely mentioned. The omission is understandable, for neither voters nor their representatives participate directly in many of the decisions that determine either the scale and direction of the government's investment in research and development activities or the use of the discoveries and improvements that result from that investment. Fluoridation, however, is a science issue that has involved the direct participation of voters. By closely examining the fluoridation controversy, we should be able to see more clearly the role of the citizen in a scientifically complex society. From this perspective, an analysis of the fluoridation controversy becomes a study in the relation between science and democracy.

Fluoridation is the addition of fluoride compounds to the public water supply in order to reduce tooth decay in children. Fluorine, from which fluoride compounds are derived, is a dangerous element, and fluoride compounds themselves are sold as commercial poisons for rodent extermination. These facts have produced considerable confusion among laymen and have at times precluded rational discussion of fluoride's usefulness in the reduction of dental caries.

The history of the discovery of this beneficial property of fluorides is interesting (*1*). In 1901 research was begun to find the cause of a progressive discoloration and disfiguration of the teeth (now technically identified as dental fluorosis). By the early 1930's the causative agent was identified as fluorides in the water supply. During the course of the investigation, however, it had been noted that despite their mottled teeth, those with dental fluorosis were enjoying excellent dental health. Research then shifted to establishing the threshold levels for fluorosis and to documenting the effects of fluorides on the public's health. Through elaborate longitudinal experiments it was shown that, at dosage levels of one part fluoride per million parts water, there is approximately a 60 percent reduction in the rate of tooth decay in children up to the age of 16 without any general health danger to the entire exposed population (*2*). In 1950, the U.S. Public Health Service joined several state public-health departments in endorsing a national program for controlled water fluoridation (*1*, p. 74).

The benefits expected from fluoridation are considerable. Tooth decay, always annoying and often painful, affects an estimated 95 percent of the United States population. Dental care accounts for approximately one-twelfth of combined public and private health expenditures in the United States (or about $3 billion in 1964). It has been estimated that fluoridated water systems, if available throughout the country, could in time reduce the national dental bill by one half (*3*).

The addition of fluorides to the public water supply is not the only method of obtaining these benefits. Liquids containing fluoride compounds that can be directly applied to the teeth, and pills that can be used in the home to fluoridate the family water, are also effective in the reduction of dental caries. Fluoridation of the public water, however, is the least expensive method. Annual per capita costs, depending on the characteristics of the water system, range from $0.10 to $1.25 (*3*, *4*), in comparison with the annual costs of $3 to $5 per applicant for the liquid or pill method. Moreover, treatment of the

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public water supply has the added advantage of impersonal, automatic attention that guarantees treatment whereas the individual application of liquids or pills depends on the conscientiousness of parents.

Offering what appears to be a well-tested, relatively inexpensive, and effective avenue to improved dental health, fluoridation has received wide support. In addition to the Public Health Service the National Academy of Sciences, professional groups affiliated with the American Association for the Advancement of Science, the American Dental Association, the American Medical Association, the United Nations health units, and the English Health Service have all endorsed it. Presidents Eisenhower, Kennedy, and Johnson have issued public statements calling for the extension of fluoridation. And prestigious medical figures such as Paul Dudley White, Jonas Salk, and Benjamin Spock are listed among its supporters.

Voters and Diffusion of Fluoridation

Despite the endorsements, the years of research, and the support of the federal government, public acceptance of the innovation can hardly be described as enthusiastic. Sixteen years after the Public Health Service called for a national program of fluoridation, only 40.6 percent of the 153,680,000 persons served by public water supplies in the United States lived in areas with controlled fluoridation, and only an additional 6.4 percent lived in areas with natural fluoridation (*5*, Table 1, p. 1). It has been estimated that, since the benefits of fluoridation became known, between 75 and 90 percent of all communities over 10,000 in the United States have considered adoption (*6*), but only 773 of the 1899 communities in this category were actually using controlled fluoridation as of the end of 1966, the latest date for which such figures are available (*5*, Table 6, p. 6).

Figures on total adoption disguise the public's acceptance of fluoridation. Most communities that have adopted fluoridation have done so by administrative or legislative actions that were not subject to voter approval (Table 1). When voters have an opportunity to express their opinion on fluoridation, the likelihood of adoption is low. In the period from November 1950 through December 1966, 952 referendums were held on the issue, and fluoridation was rejected in 566 (*5*, Table 8, p. 11). There is no indication that the rejection rate has lessened significantly with time. It has been reported as having reached 90 percent in 1960 for cities 10,000 and over in population (*7*).

Adoption, measured by populations or number of communities, rose quite rapidly in the early 1950's, but began to taper off by the late 1950's, as opponents initiated referendum petitions against fluoridation. Spectacular changes in the national fluoridation census have occurred recently; New York City adopted fluoridation by an unchallengeable order from the Board of Estimate, and proponents won a referendum in Detroit [by a margin of 7500 in a total vote of 316,000 (*8*)]. In most of the nation, however, the momentum for acceptance that fluoridation had in the early 1950's appears to have been lost. An analysis of the geographic diffusion of the fluoridation innovation shows that since 1955 there has been a retardation in its adoption (*7*). Over 30 years after being discovered, the benefits of fluoridation have been gained by less than half of those potentially eligible to receive them.

Arguments against Fluoridation

To appreciate the dynamics of the controversy it is necessary to consider the three basic arguments raised against the introduction of fluoride compounds into the public water supply. My intention is not to exhaust the case for or against fluoridation, but rather to expose briefly some of the problems that confront the voter.

1) Antifluoridationists deny the effectiveness of fluoridation in preventing caries and stress the disfiguring effects. The justification for fluoridation rests on statistics gathered in public health experiments. Antifluoridationists challenge the validity of these data, emphasizing alleged defects in the statistical controls used to establish fluoridation's independent effect on dental health improvements, and selectivity in reporting of experimental results (*9*). The arguments on both sides can be technically quite complex, and understanding them demands some statistical sophistication. Moreover, while the proponents deny that there can be any disfiguring with controlled fluoridation,

Table 1. Authorization for fluoridation (*5*, Tables 6 and 7), 31 December 1966.

Population range of community	Number of communities	Using controlled fluoridation	All communities of same size (%)	Source of authority to fluoridate			
				Governing body alone	Referendum	Utilities commission	Other not specified
1,000,000 and over	5	3	60.0	3			
500,000 to 999,999	16	8	50.0	7	1		
250,000 to 499,999	30	13	43.3	12			1
100,000 to 249,999	81	35	43.2	29	4	1	1
50,000 to 99,999	201	82	40.8	67	8	4	3
25,000 to 49,999	432	167	38.7	129	13	4	21
10,000 to 24,999	1,134	465	41.0	363	43	16	43
5,000 to 9,999	1,394	505	36.2	378	40	21	66
2,500 to 4,999	2,152	507	23.6	389	42	16	60
1,000 to 2,499	4,471	620	13.9	490	39	27	64
Under 1,000 and not specified	10,677	740	6.9	568	26	42	104
Total	20,593	3,145	15.3	2,435	216	131	363

they do admit that with the standard dosage of one part per million, approximately 10 percent of the total exposed population will suffer from mild cases of fluorosis, a slight discoloration of the teeth.

2) Antifluoridationists stress health dangers involved in the use of mass fluoridation and claim that it contributes to many disabilities and illnesses (*10*). One computation of the health arguments raised by the opponents notes that several hundred ailments ranging from cancer to left-handedness have been attributed to fluoridation (*11*). The antifluoridationists stress that individual intakes of fluorides can vary considerably at the standard dosage of one part per million parts of water, not only because individual water consumption varies greatly but also because relatively high fluoride dosages are present in foods such as tea and fish. They continually cite the few recorded cases of deaths that might have been due to fluorosis (*12*). The proponents are quick to point out that areas high in natural fluoride appear to suffer from no unusual incidence of health problems, and that to get a lethal dose of fluoride, one would have to drink 50 bathtubs full of fluoridated water at one sitting. Nevertheless, it must be conceded that one hypothesis about the cause of a specific ailment is as good as another until disproven, and that medical science knows relatively little about the long-term effects of continuous fluoride intake.

3) The antifluoridationists argue that fluoridation is a mass medication that infringes upon constitutionally protected rights of individual liberty and religious freedom (*13*). Whether or not they label the instigators of the infringement as Communists, power-hungry bureaucrats, or well-meaning but misinformed humanists, the antifluoridationists all reject the attempts to draw an analogy between compulsory vaccinations, or the addition of chlorine to the public water supply, and fluoridation. Vaccination and chlorination are directed, it is argued, toward public protection from either contagious or fatal diseases, whereas fluoridation offers only protection from dental decay, a noncontagious, nonfatal, personal cosmetic problem. Although fluoridation has been challenged in the courts many times, it has been upheld in all final decisions. The U.S. Supreme Court, however, has never placed the issue on its docket.

Community Characteristics and Fluoridation

Most social scientists interested in analyzing the fluoridation innovation have focused exclusively on the referendum results, rather than on the factors that lead to referendums. A number of studies have sought to relate community characteristics with voting behavior in fluoridation referendums (*14–19*). The results have been disappointing. As Gamson and Irons conclude after a summary analysis of the work on this topic, the relation between community variables and outcomes of referendums on fluoridation is quite weak (*17*). The most powerful multiple correlation of two variables in any study appears to be percentage of population over 65 years old and percentage with incomes under $2000, but even this combination still accounts for less than 15 percent of the variance in referendum results (*17*).

As noted above, however, most cities adopting fluoridation do so by administrative action rather than by referendum. The analysis of fluoridation that focuses exclusively upon referendum results ignores a majority of the political decisions involved in the adoption of the innovation. Although examination of community characteristics tells us little about how a particular referendum will be decided, it does reveal a great deal about the likelihood that a referendum will be held at all; and experience has shown that when a referendum is held, there is a 60 percent chance that fluoridation will be defeated.

Crain and Rosenthal have reviewed a number of variables to determine what mode of decision-making a community would use in considering fluoridation (*20*). A central conclusion of their study of the decision on fluoridation in communities over 10,000 in population was that the structure of government had an important influence on the probability of adoption through its influence on the selection of a mode of decision-making. Governmental structures that permit relatively greater citizen participation in public policy formulation tend to have many referendums and therefore relatively few adoptions, whereas those that restrict citizen participation tend to have many administrative adoptions but few referendums. Communities that have a strong executive form of government rely on referendums less frequently and adopt fluoridation more by administrative means than do those that have a weak executive form of government.

By the use of standard classifications and correcting for regional variations, Crain and Rosenthal found that communities with a commission form of government which has a politically weak collective executive were the communities that were the least likely to deal effectively with fluoridation, having both few administrative adoptions and few referendums. Communities with a partisan mayor-council form of government, which is usually a strong executive form, adopted fluoridation most frequently by means of administrative action and had few referendums on the issue. In contrast, communities with the nonpartisan mayor-council form of government which normally leads to more direct citizen participation in policy-making had few administrative adoptions and many referendums. Finally, communities with a city-manager form of government, which combines a potentially strong executive with an orientation toward citizen participation, were high in both administrative adoptions and in frequency of referendums.

The analysis of governmental structures may help to explain the nearly perfect correlation between community population size and the rate of fluoridation adoptions (Table 1). The larger cities may use governmental structures that restrict referendum initiatives and direct citizen participation in public policy decisions (*21*). In this sense, big cities would be formally less democratic than smaller cities, and democratic procedures seem to produce inaction on fluoridation or referendums and possible defeat. Moreover, as Crain and Rosenthal point out, strong executive forms of government, particularly the partisan-mayor form, are more able to avoid recourse to the voters on policy issues, and the larger cities frequently have strong executive, particularly partisan-mayor, forms of government (*22*).

Partisanship alone tells a great deal about the probable outcome of a fluoridation debate (Table 2). Excluding Houston, Texas, which has natural fluoridation, and Washington, D.C., which lacks home rule, there were 19 cities in the United States in 1960 with populations over 500,000. Eight of the nine cities that have a partisan mayor-council form of government adopted fluoridation through administrative decisions without a referendum. Only two of the

other cities on the list adopted fluoridation administratively, and both of these cities (Chicago and Cleveland) are only nominally nonpartisan. The remaining nine cities with nonpartisan or city-manager forms of government either took no action or were forced into referendum on the issue. Fluoridation was defeated in seven of the 11 referendums that these cities held. With political power centralized in their hands, Mayor Daley and Mayor Wagner did not need to consult the voters and could act on the advice of the leading public health authorities (*23*).

Alienation as an Explanation

Research on citizen reaction to the fluoridation issue has been conducted largely by social psychologists and has centered on the alienation hypothesis. In the social sciences, the theory of alienation suggests that individuals who are not socially and politically integrated into society develop a sense of powerlessness and seek ways of attacking people whom they perceive as powerful (*24*). Fluoridation, it is hypothesized, provides an opportunity for the alienated to vent their frustrations, since they are being asked to approve a proposal clearly supported by the establishment—by big science, big government, and big business. A vote against fluoridation, then, is a vote against science expertise, modernization, and the mass society (*25*).

Support for this hypothesis is offered in content analyses of antifluoridation literature, in studies of antifluoridation leaders, and in attitudinal surveys of the general population. Davis, for example, finds in an examination of extremist publications that antifluoridation is merely one manifestation of "a latent tendency toward naturalism" (*26*). Green, on the basis of interviews with antifluoridation leaders in six Massachusetts communities, argues that the active opponents of fluoridation are less concerned with the specific health issues raised by the proposal than with the general threat to the individual presented by the impersonal instruments (the U.S. Public Health Service and the American Medical Association) of an industrialized society (*27*). The Mausners' survey of the attitudes of citizens in Northampton, Massachusetts, just before a refrendum, led them to conclude that antifluoridationists have a pervasive suspicion of science and scientists (*28*). Surveys conducted in Cambridge, Massachusetts, by Gamson (*29*), and in two small New York State communities by Simmel (*30*), note feelings of political alienation and deprivation among the opponents of fluoridation. Finally, while finding no evidence to equate opposition to fluoridation with an antiscientific attitude, Kirscht and Knutson, in a survey of citizens of Berkeley, California, report that antifluoridation attitudes correlate with fears about the indirect effects of progress in science (*31*).

Nevertheless, there are reasons to be skeptical about the alienation explanation. First, although it is at times explicitly denied, there is a tendency in the alienation argument to attribute the strange and wonderful attitudes of the antifluoridation leaders to all persons who vote against fluoridation. To be sure, the analysis of the antifluoridation literature and interviews with antifluoridation leaders reveal a profound distrust both of change and of the proponents of change, but does this necessarily mean that the voter who casts his ballot against the adoption of fluoridation holds the same views?

Second, there are problems with the application of the concept of alienation to the fluoridation controversy. Some of the measures of "alienation," in this case, could indicate something other than a lack of social and political integration. For example, a respondent ranks higher on a standard alienation index if he agrees with the following statement: "Sometimes politics and government seem so complicated that a person like me can't really understand what's going on" (*29*). The well-integrated, responsible citizen who sought his own answers on the safety and efficacy of fluoridation would have good reason to agree with the statement. Moreover, when a majority of the persons who are described as alienated in fluoridation surveys report that they believe the fluoridation problem should most appropriately be settled by experts, and when they cannot be distinguished from the proponents in the answers to a question on the role of government in health matters (*19*, *29*, *32*), one wonders whether or not the term "alienation" is descriptive of those that oppose the adoption of fluoridation.

Third, the available attitude surveys do not adequately support the alienation hypothesis. The samples in these surveys are small and highly biased. Gamson, for example, reached his conclusion on the relation between a perceived lack of political efficacy and an antifluoridation position through the analysis of a single, mixed, lower-lower middle-class precinct in Cambridge (*29*). He admits that it is impossible to generalize from such samples (*32*). Middle-class communities also reject fluoridation; according to Pinard they are more likely both to hold a fluoridation referendum and to reject fluoridation in the referendum than are other types of communities (*18*). Moreover, in terms of current sociological and social-psychological research, it is not surprising to discover that persons who are lower-class, or who live in a small town or a community dominated by a prestigious institution of higher education, express feelings of political alienation and deprivation. Until we have more stratified attitudinal surveys and more information on the extent of middle-class alienation, we cannot rely too heavily on the alienation hypothesis.

Table 2. Structure of government and the use of controlled fluoridation in cities over 500,000* (*20*). Numbers in parentheses indicate the number of referendums held.

Administrative adoption	Action on fluoridation †		
	Referendum		No action
	Won	Lost	
	Partisan mayor-council		
Baltimore Buffalo Philadelphia Pittsburgh New York St. Louis			New Orleans
	Nonpartisan mayor-council		
Chicago Cleveland	Detroit Milwaukee San Francisco	Seattle (2)	Boston Los Angeles
	City manager (nonpartisan electoral systems)		
	Dallas	Cincinnati San Antonio (3) San Diego	

* 1960 census, Houston and Washington, D.C., excluded. † Results through June 1967.

Fourth, there is no support for the claim that a substantial proportion of the population rejects science. Actually the evidence supports an opposite observation. In general surveys, the public gives science a strong endorsement, with a consistently favorable if not particularly well-informed opinion of science and scientists (*33*). In the fluoridation surveys themselves, the opponents are hardly consistent in their "rejection" of science and professional advice. The fluoridation opponents in one survey, for example, had a preventative dental care record (periodic checkups) equal to that of the proponents (*34*). The public is even predisposed to favor fluoridation. Opinion surveys taken independently of and prior to referendum campaigns show up to four-to-one profluoridation majorities (*35–37*). It seems that only when fluoridation is put to a vote is science "rejected."

An Alternative Explanation

Important clues to the fluoridation puzzle must lie in the referendum campaigns, for it is during this period that a basically favorable public opinion is converted into a basically negative one. An analysis of studies of fluoridation campaigns (*27, 37, 39*) suggests that the shift in opinion is due to confusion that develops in the minds of the voters. The voters, although predisposed to favor fluoridation, are initially quite ill informed about it. Studies reveal that even among the proponents there is much misinformation. Gamson, for example, reports that half of the proponents in his sample thought fluoridation directly increased the dental health of adults while nearly a third did not know that fluorides are poisonous in certain quantities (*40*). A national survey on the public knowledge of dental health demonstrated that despite a preponderance of favorable attitudes toward fluoridation, 56 percent of the respondents were partially or completely misinformed about fluoridation's purpose (*35*). The percentage favorable to fluoridation was slightly higher among those who held incorrect opinions about its purpose (in all but a few cases mistaking it for a water purification process) than among those who could correctly identify it as a method of reducing tooth decay (*41*).

During a referendum campaign, voters are exposed to the public information programs of both opponents and proponents. Each side purports to be presenting an objective survey of available research material (*39*). Studies of public information programs, however, have shown that increased dissemination of information can, at times, have the effect of reversing favorable dispositions (*42*). The diminution of support for fluoridation over the period immediately prior to a referendum can, perhaps, be seen in this light. The particular nature of the information programs on fluoridation would, more specifically, seem quite likely to create voter anxiety due to exposure to the real and dangerous properties of fluorides.

The health officials believe that fluoridation's safety and efficacy are technical public health problems, for which they can present the only legitimate scientific position (*43*). They do not perceive the antifluoridationists to be experts in public health problems and on this basis easily dismiss their arguments. The opponents, however, number among themselves persons with scientific or professional credentials. In most communities there is at least one doctor, dentist, university science professor, or research scientist who will speak out against fluoridation. Several of these persons have gained national reputations through their fight against fluoridation, and are active in referendum campaigns throughout the country (*44*). While the public health officials may consider these professional antifluoridationists to be marginal at best in their scientific professions, and to be speaking outside their particular fields of competence, the voters might well consider them to be qualified to discuss the technical issues and to be granted the status of fluoridation experts.

In their effort to defeat fluoridation, the opponents have formed or have obtained support from many organizations having particularly impressive names. The American Academy of Nutrition, the Association of American Physicians and Surgeons, the Medical-Dental Ad Hoc Committee, and the National Health Foundation have all attacked controlled fluoridation and have participated in the campaigns against its adoption. To the informed citizen as well as to the public health official, the National Academy of Sciences, the American Association for the Advancement of Science, and the American Dental Association are distinctive, respected, and prestigious organizations whose opinions and endorsements in science and health matters carry great, if not decisive, weight. To the average voter, however, they are probably not particularly familiar groups and their purposes and endorsements are likely to be confused with those of less solid organizations.

The proponents do not enhance their chances when they act as though there is no legitimate opposition to fluoridation. Voters are socialized to expect two sides in every election issue. In fluoridation referendums the other side is vigorously argued. To be told that a certain doctor or scientist has no right (meaning competence) to speak on what is obviously a health or science issue would only increase the voters' suspicions and fears.

For a fluoridation referendum to be defeated the voters do not have to accept completely the antifluoridation arguments; they need only to begin to wonder about the risks of adoption (*37*). The voters do not have to reject completely the expertise of public health officials for fluoridation to be defeated; they need only to perceive the controversy as a dispute among conflicting experts and to be concerned about the costs of making a wrong choice. The fluoridation referendums always provide the voters with a convenient and safe alternative. They can postpone adoption, with the knowledge that experimentation will continue elsewhere.

We argue, then, that the voters reject fluoridation not because they are alienated, but because they are confused. The public, believing the fluoridation controversy to be a conflict among scientific experts, seeks the safest course. Unable to decide between what appear to be two contending scientific positions, the voters opt to avoid the greatest potential health risks by defeating the fluoridation proposals.

As in the case of the alienation hypothesis, this hypothesis remains unproved. We do not know enough about the voters' perception of fluoridation opponents or their behavior in risky situations to prove the argument presented here. We can, however, point to some possible supporting evidence. Eighty-three percent of the opponents in Gamson's survey said they would vote for fluoridation if ". . . fluoridation was shown to be perfectly safe and able to help peoples' teeth" (*29, 45*). The sample size, of course, is small, but it does seem to indicate that there is more to be learned about the voters' problem in dealing with specific data in the fluoridation referendums.

The above formulation might help to explain the unexpected curvilinear relationship between education and vot-

ing for fluoridation (*17*, *32*). Educational levels alone do not provide enough information to accurately predict voters' sophistication about matters of science. Studies of the distribution of knowledge about science in the general public, however, have shown that college-trained persons are the most knowledgeable about scientific principles and keep the most abreast about scientific developments (*38*, *39*). Those with the lowest levels of education are the most misinformed about science and fail to keep up with science as well as with current events. It would seem, then, that the least educated favor fluoridation because they mistake it for chlorination and are unaware of its controversial aspects, whereas the most educated favor fluoridation because they are able to deal with scientific arguments or can recognize leading scientific authorities and defer to their judgments. The middle ranges of education, that account for the majority of voters, include those who are aware of conflicting opinions, but who are neither knowledgeable enough to recognize authoritative scientific judgments, nor confident enough to weigh the evidence themselves.

Conclusions

Fluoridation, as a problematic innovation of public health, is not an issue completely without precedent. A former surgeon general of the United States has included it as one of the four ". . . great mass preventative health measures of all time. . .; the pasteurization of milk, the purification of water, immunization against disease, and controlled fluoridation of water" (*46*). The enrichment of flour and bread program started in the early 1940's is also similar (*47*). Each of these innovations experienced a period of controversy centered around a set of difficult scientific and political questions.

The distinguishing feature of fluoridation, is that its fate has largely been decided by the public. The benefits of pasteurization, chlorination, vaccination, and bread enrichment were obtained not by referendums, but by administrative and legislative means. Introduced as they were during periods when democratic rights were either being developed or were suspended because of war, these particular health innovations were not subject to voter tests.

Although the voters' position on fluoridation is generally negative, the public health officials seem uncertain as to what course of action to follow. On one hand, they recognize that widespread adoption is most likely to occur when fluoridation becomes an issue that is decided only by administrative agencies or legislatures. On the other hand, they would like to have their good work understood and accepted by the public. Thus, they appear torn between advocating the removal of the public's opportunity to vote on fluoridation and committing themselves to the sponsorship of more intensive educational programs to promote its merits (*48*).

The public health officials' dilemma concerning fluoridation may not be particularly compelling, but it does point to an important problem—what is the citizen's role in a society that seeks to be both scientifically advanced and democratic? Science does not advance by a show of hands and democracy cannot exist without citizen participation.

The problem was theoretically solved several decades ago by Schumpeter when he noted two conceptions of democracy (*49*). One view is that the citizen must directly decide public policy in order for a society to be called democratic, whereas in another view, it is enough for the citizen to influence public policy decisions by choosing among competing political leaders. The latter conception, Schumpeter argued, is the only realistic one in a complex industrial society.

The experience with fluoridation seems to confirm the inappropriateness of direct citizen involvement in policy-making. The technical intricacies of the problem are too great for the average voter to resolve. Administrative agencies and legislatures, with their more deliberate procedures and their greater capacity to distinguish among experts, are more able to rationally consider questions of safety and efficacy (*50*). Nor would the value aspects of fluoridation be ignored if the decision were to be restricted to administrative agencies or legislatures. On the contrary, they would be clarified by a careful treatment of the technical questions.

The gap between theory and practice, however, may be quite large. Structural reforms limiting citizen participation are not easily obtained. Affluence and increasing average levels of educational attainment bring demands for more, not less, participation in policy decisions. Moreover, shifts in federal research programs toward a greater concern for health and welfare problems are likely to produce more innovations which, like fluoridation, require local government approval for adoption and which, in turn, provide more opportunities for frustration by referendum. Finally, it must be noted that for the citizen to perform adequately even a restricted role in a scientifically advanced society, he must have at least a slight understanding of science in order to judge wisely the abilities of competing leaders to deal with complex issues.

The need, then, may be for new educational programs. These programs would not train the citizen to be knowledgeable in the various fields of science, but rather would equip him to deal with scientific arguments and scientific experts, through understanding the limits and uses of science. This is a long-run goal. In the meantime, we may have to continue to forego the benefits of fluoridation and other similar innovations.

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9. For example, J. Polya, *Are We Safe?* (Cheshire, Melbourne, 1964), chap. 10; and *Fluoridation of Water*, hearings before the Committee on Interstate and Foreign Commerce, U.S. House of Representatives, 83rd Congress, 2nd Session (U.S. Government Printing Office, Washington, D.C., 1954).
10. F. Exner and G. Waldbott, in *The American Fluoridation Experiment*, J. Rorty, Ed. (Devin-Adair, New York, 1961).
11. K. Elwell and K. Easlick, *Classification and Appraisal of Objections to Fluoridation* (Univ. of Michigan Press, Ann Arbor, 1960).
12. New York *Times*, 8 February 1966, p. 18.
13. Among the opponents are Christian Scientists who believe fluoridation violates their religious rights. The legal issues involved are reviewed in A. Miller, *Saturday Rev.* **48**, 49 (1965); and *George Washington Law Rev.* **23**, 343 (1955).
14. J. Coleman, *Community Conflict* (Free Press, Glencoe, Ill., 1957).
15. P. Rossi, *Admin. Sci. Quart.* **1**, 415 (1957).
16. A. Green and J. Briggs, "Fluoridation in Massachusetts: A statistical comparison of communities" (Harvard School of Public Health, Boston, mimeographed, 1957); T. Plaut, *Public Opin. Quart.* **23**, 213 (1959).
17. W. Gamson and P. Irons, *J. Social Issues* **17**, 66 (1961).
18. M. Pinard, *Amer. J. Sociol.* **68**, 513 (1963).
19. W. Gamson and C. Lindberg, *Health Educ. J.* (1961).
20. R. Crain and D. Rosenthal, *The Fluoridation Decision*, Report 2, *The Community Confronts an Innovation* (National Analysts, Inc., Philadelphia, 1963).

21. See the discussion in E. Banfield and J. Wilson, *City Politics* (Harvard–M.I.T., Cambridge, 1963), pp. 77–86.
22. O. Nolting and D. Arnold, Eds., *Municipal Year Book 1966* (International City Manager Association, Chicago, 1966), p. 90. Table 2 shows the distribution of form of government by city size.
23. L. Gulick, *Public Admin. Rev.* **17**, 106 (1957).
24. For a discussion of alienation as a political concept, see W. Thompson and J. Horton, *Social Forces* **38**, 190 (1959–1960); J. Horton and W. Thompson, *Amer. J. Sociol.* **67**, 485 (1962); C. Stone, *Public Opin. Quart.* **29**, 213 (1965).
25. This is the thrust of the discussion by W. Kornhauser, in *Perspectives on the American Community*, R. Warren, Ed. (Rand-McNally, Chicago, 1966), pp. 489–498.
26. M. Davis, *Public Opin. Quart.* **23**, 479 (1959).
27. A. Green, *J. Social Issues* **17**, 13 (1961).
28. B. Mausner and J. Mausner, *Sci. Amer.* **192**, 35 (1955).
29. W. Gamson, *Public Opin. Quart.* **25**, 526 (1961).
30. A. Simmel, *J. Social Issues* **17**, 26 (1961).
31. J. Kirscht and A. Knutson, *ibid.*, p. 37.
32. W. Gamson, *Health Educ. J.* **18**, 159 (1961).
33. For survey reports and summaries, see National Association of Science Writers, *Science, the News, and the Public* (New York Univ. Press, New York, 1958); and W. Schramm, *Science and the Public Mind* (AAAS, Washington, D.C., 1962).
34. H. Freeman and C. Lambert, Jr., *J. Health Hum. Behav.* **6**, 143 (1965).
35. L. Harris, cited in U.S. Public Health Service, *Emphasis: Fluoridation* (U.S. Government Printing Office, Washington, D.C., 1966), p. 5.
36. A. S. Metz, *Social Forces* **44**, 477 (1966).
37. J. Mueller, *West. Polit. Quart.* **19**, 59 (1966).
38. There have been a number of fluoridation campaign studies. Particularly useful is I. Sanders, *J. Social Issues* **17**, 55 (1961); W. Gamson, *Trans-Action* **2**, 9 (1964).
39. H. Raulet, *J. Social Issues* **17**, 41 (1961).
40. W. Gamson, *Health Educ. J.* **19**, 51 (1961), Table 3.
41. The figures are 74 percent favorable with incorrect information and 70 percent favorable with correct information (*36*).
42. For example, R. Bauer, I. de S. Pool, L. Dexter, *American Business and Public Policy* (Atherton Press, New York, 1963).
43. J. Steiner and F. Stare, in U.S. Public Health Service, *Emphasis: Fluoridation* (U.S. Government Printing Office, Washington, D.C., 1966).
44. Among the leading antifluoridationists are G. L. Waldbott, B. Exner, C. Brusch, J. Forman, C. Fredericks, L. Gross, V. O. Kurme, R. Lee, L. Spera; see reports on each of these individuals in Bureau of Public Information, *J. Amer. Dent. Ass.* **71**, 1155 (1965).
45. As Mueller (*37*) notes, these data do not support Gamson's (*29*) suggestion that these persons oppose fluoridation because the measure somehow symbolizes the buffeting about one takes in a society where not even the water one drinks is sacrosanct.
46. L. Terry, in U.S. Public Health Service, *Emphasis: Fluoridation* (U.S. Government Printing Office, Washington, D.C., 1966), p. 4.
47. For a history of this program see R. Walder and R. Williams, *Enrichment of Flour* (National Research Council, Washington, D.C., 1944).
48. Recommendations of the First National Conference on Fluoridation, in *Emphasis: Fluoridation*, (U.S. Government Printing Office, Washington, D.C., 1966), p. 17.
49. J. Schumpeter, *Capitalism, Socialism, and Democracy* (Harper, New York, 1950), chaps. 21 and 22.
50. Even legislatures may be unable to deal with difficult scientific issues. See S. Reiser, in *Knowledge and Power*, S. Lakoff, Ed. (Free Press, New York, 1966), pp. 293–311.

NEWS AND COMMENT

1968 Nobel Laureate in Medicine or Physiology

The Nobel Prize in Medicine or Physiology for 1968 has been awarded, jointly, to Robert W. Holley of the Salk Institute, Har Gobind Khorana of the University of Wisconsin, and Marshall W. Nirenberg of the National Institutes of Health.

The announcement of the awards emphasized that each man was recognized for work carried out independently of the other two. But the work of the three is interrelated, and the significance of each achievement is enhanced by the achievement of the others. These three men together constitute a triplet of great sense.

It is difficult to decide where to start the story of the genetic code—no point in time is really a beginning. The acceleration of research in this area does, however, seem to coincide with the initial experiments reported by Nirenberg and his co-worker Heinrich Matthaei (now of the Max-Planck Institute, Göttingen). Nirenberg was interested in the chemical mechanism underlying the well-documented theory that what is specified by the genes is the structure of proteins. How, within a cell, does the linear sequence of the four nucleotides in the DNA structure specify the linear sequence of a protein? A protein contains a linear arrangement of amino acids held together by covalent bonds. The structural uniqueness of a protein, and consequently the uniqueness of its function, is defined by the number and linear order of the 20 possible amino acids. Nirenberg and Matthaei made a crude, cell-free preparation from the bacterium *Escherichia coli* and looked for protein synthesis that was dependent on the addition of nucleic acid. Given the complexity and crudity of the system, the concept seemed then, and even now, too simple. But it worked. The addition of nucleic acid did indeed stimulate the incorporation of amino acids into protein.

The active nucleic acid was not DNA, but the chemically related nucleic acid, RNA. [That RNA served to relay the genetic information was consistent with the theory proposed by Jacob and Monod in 1961. These men, Nobel laureates themselves (1965), proposed that an RNA, messenger RNA, containing a replica of the sequence of the DNA, actually functions in defining amino acid sequences.] Most surprisingly, however, natural RNA containing the four common ribonucleotides [adenylic (A), uridylic (U), cytidylic (C), and guanylic (G) acids] was not necessary in Nirenberg's cell-free system. An RNA-like polyribonucleotide containing only one of the ribonucleotides, uridylic acid, was extremely active. Furthermore, polyuridylic acid stimulated the incorporation of only one of the 20 possible amino acids, namely phenylalanine. The "protein" being made was composed exclusively of phenylalanine units. Nirenberg and Matthaei concluded that one or more uridylic acid residues represented the code for phenylalanine.

When, in the spring of 1961, these results became known to some of Nirenberg's colleagues at the NIH, the excitement ran high. And the formal announcement of the results at the International Biochemistry Congress in Moscow that summer was electrifying. The possibility of determining the entire code was clear.

The extension of the experiment to other amino acids required a variety of polyribonucleotides containing the other common ribonucleotides, either singly or in combinations. Such polymers, while not widely available, could be prepared with polynucleotide phosphorylase. This enzyme had been discovered in 1955 by Grunberg-Manago and Ochoa, and it was for this finding, in part, that Ochoa shared a Nobel Prize in 1959. The enzyme catalyzes the synthesis of polyribonucleotides of any de-