Debating WATER FLUORIDATION Before Dr. Strangelove

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In the 1930s, scientists learned that small amounts of fluoride naturally occurring in water could protect teeth from decay, and the idea of artificially adding fluoride to public water supplies to achieve the same effect arose. In the 1940s and early 1950s, a number of studies were completed to determine whether fluoride could have harmful effects. The research suggested that the possibility of harm was small. In the early 1950s, Canadian and US medical, dental, and public health bodies all endorsed water fluoridation. I argue in this article that some early concerns about the toxicity of fluoride were put aside as evidence regarding the effectiveness and safety of water fluoridation mounted and as the opposition was taken over by people with little standing in the scientific, medical, and dental communities. The sense of optimism that infused postwar science and the desire of dentists to have a magic bullet that could wipe out tooth decay also affected the scientific debate. (*Am J Public Health*. 2015;105:1559–1569. doi:10.2105/AJPH.2015.302660.)

IN THE MOVIE DR. STRANGELOVE, General Ripper claimed that water fluoridation was destroying "our precious bodily fluids"—a reference to the claim that water fluoridation was a conspiracy designed to weaken US willpower and make the country susceptible to a Communist takeover. Although there were occasional references to a Communist conspiracy in the antifluoridation movement in the United States and Canada, this was not a common feature of the debate. More commonly, opponents believed that they should not have to take medicine against their will. Much of the opposition focused on the possible health risks.[1] As communities across the United States and Canada debated whether to add fluoride to their water supply in the 1950s and 1960s, fluoride proponents claimed that there was no legitimate scientific opposition to fluoride, but in fact, in the late 1940s and early 1950s there was a significant debate over the merits of fluoridation within the scientific, medical, and dental communities.[2] By the late 1950s, this opposition had all but disappeared, leaving behind a small number of doctors, dentists, and scientists who continued their campaign primarily in the public domain. Fluoride proponents dismissed them as cranks and quacks, although their views had a significant impact on antifluoridation referendums in communities across the United States and Canada.[3] In this article, I explore why opposition to water fluoridation was quickly relegated to the fringes, at least within the scientific, medical, and dental communities.[4] First, evidence regarding the safety and effectiveness of water fluoridation mounted quickly, although there were still some significant gaps in knowledge. Second, dentists were eager to have a magic bullet that would enhance their professional prestige, so they promoted it heavily. Finally, the enormous optimism and sense of possibility that informed postwar US science and public health made the scientists and doctors working on fluoridation quick to reject the

possibility of potential side effects. By the early 1950s, long before the early trials had been completed, most dentists, doctors, and biochemists agreed that water fluoridation would save children's teeth without harming anyone else. Most of those who had spoken out against fluoridation in the late 1940s and early 1950s either changed their minds in light of the growing evidence in favor of fluoridation or quietly turned their attention to other topics.

What makes this story so interesting is that the benefits of fluoridation do not seem to be as great as was initially touted by proponents. Today, controlled studies show that fluoridation reduces cavities by approximately 15% to 35%, far less than the two thirds reductions claimed by researchers and public health promoters in the 1950s and 1960s.[5] There are several reasons for this. First, cavity rates have plummeted in both fluoridated and unfluoridated communities. It is unclear exactly why children get fewer cavities than they did 60 years ago. Fluoridated toothpastes and better dental care undoubtedly play a role.[6] (Early fluoride researchers believed that the effects were systemic, whereas today most researchers believe that the effects are predominantly topical, making fluoridated toothpaste a more effective intervention than researchers thought it would be in the 1950s and 1960s.[7]) Some have argued that the extensive use of antibiotics in childhood has reduced tooth decay, that high-fructose corn syrup is less cariogenic than sucrose, or that better living conditions have improved dental health.[8] Even if communities are not fluoridated, fluoridation might play a role in the decrease in tooth decay as those of us living in countries with widespread fluoridation consume fluoridated products through packaged beverages regardless of whether we live in fluoridated communities. Moreover, some of the early fluoridation studies had methodological problems, which may have exaggerated their benefits. Determining whether a tooth is decayed is somewhat of a subjective exercise even when x-rays are used. Most of the early studies did not use x-rays or used them only partially. The early studies were also not blinded; everyone knew which community was fluoridated and which community was not.[9] There is also growing concern about dental fluorosis (tooth stains caused by excessive fluoride) despite the relatively low levels of fluoride used in community water fluoridation programs.[10]

EARLY HISTORY OF WATER FLUORIDATION

The history of water fluoridation began in the early 20th century when Fred McKay began practicing dentistry in Colorado Springs, Colorado. Many of his patients had ugly brown stains on their teeth. He eventually discovered that the stain also occurred in the Rocky Mountains as well as in Texas, Italy, and Portugal. In the early 1930s, two researchers, more or less simultaneously, discovered that the stain was caused by fluoride in the water supply. Margaret Smith, a biochemist at the University of Arizona, created mottled teeth (or dental fluorosis) in rats by feeding them fluoridated water.[11] H.V. Churchill, the chief chemist for the Aluminum Company of America, discovered that the water in Bauxite, Arkansas, which had experienced considerable trouble with mottled teeth since its water supply had been changed in 1909, had a high level of fluoride.[12] McKay arranged for other communities with a high degree of mottling to send water samples to Churchill for testing. All of the water tested high in fluoride.

At first, fluoride (or fluorine as it was referred to in many early studies) was seen as a problem.[13] In severe cases, the stain was disfiguring, and the teeth were brittle and difficult to repair. In the 1930s, a dentist with the US Public Health Service, H. Trendley Dean, began a widespread study of fluoride and tooth mottling to determine how high the level of fluoride in the water could be before it damaged teeth.[14] The Public Health Service hoped that communities with high levels of fluoride in the water could switch their water supply or reduce the fluoride within it. A number of researchers, including Smith and her husband H.V. Smith, began working on filters that could remove fluoride from water.[15] In the course of his study, Dean discovered that at lower levels fluoride seemed to have a protective effect. In 1938, he published an article showing that children in places with one part per million of fluoride in their water had less tooth decay than children in communities without it. He suggested that artificially adding fluorides to the water supply might reduce tooth decay and advised that more research be done.[16] Over the next few years, additional research showed that cities with naturally fluoridated water had lower rates of cavities than cities that lacked fluoride in their water supply. A large number of researchers also investigated the impact of dietary

fluoride on the teeth of rats. Most showed a substantial reduction in caries.[17]

RESEARCH ON THE EFFECTS OF FLUORIDE IN THE 1940S

By 1942, the US Public Health Service was considering a study that would artificially add fluorides to a city's water supply. But first they needed to make sure that fluorides would not cause any harm. There were several important issues. First, would fluoride have systemic effects on the body? Everyone recognized that high levels of naturally occurring fluorides led to tooth mottling—was there any possibility that it would affect the body in other ways? Fluoride accumulates in bones more than it does in teeth, so much of the research focused on bone health. Up to this point, Danish physician Kaj Roholm was the world's leading expert on fluoride. In the 1930s, Roholm began an extensive study of cryolite workers in Copenhagen. Cryolite is an unusual mineral used in glass and mineral production; it contains significant amounts of fluoride. He found that the vast majority of workers had some degree of osteosclerosis and a significant percentage (20.5%) had moderate or great reductions in the mobility of their spines. In the worst cases, workers could no longer bend down to pick up items from the floor. In addition, 81% of the workers complained of gastric symptoms and 51% of respiratory or circulatory problems.[18] As a result of Roholm's study, bone health became the primary concern of fluoride researchers, but some researchers were also concerned about the impact of fluoride on enzymes and on the thyroid.[19]

Two articles published in 1937 revealed cases of crippling fluorosis in Southern India.[20] Historian Christopher Sellers argued that the early fluoride researchers failed to take the Indian evidence seriously. In fact, they did examine the Indian evidence, but the most extensive article on fluorosis in India, published in 1940, argued that malnutrition was a significant complicating factor (there had been severe famines in the region), and the US researchers did not believe that the situations were comparable.[21] A US article published in 1941 showed that people living in communities with high levels of naturally occurring fluorides in their water showed no signs of sclerosis.[22] Within the US Public Health Service, Frank McClure, the chief of the Laboratory of Biochemistry, began investigating the ability of the body to excrete fluoride and the accumulation of fluoride in body tissues, particularly skeletal tissue. Other researchers, most notably Willard Machle and Harold Hodge, carried out similar investigations. They concluded that the body eliminated most of the fluoride and that there was no relationship between bone fractures and fluoride consumption. Fluoridated water also did not affect height or weight. Most of the research, however, was done on younger men, so there was little sense of what the impact of fluoride might be on older populations. Moreover, as McClure admitted,

> epidemiological studies of the non-dental effects of fluorine . . . are extremely few in number and very limited in scope.[23]

Most researchers dismissed the mild mottling caused by low levels of fluoride in the water, but not everyone concurred. In 1942, Margaret and H.V. Smith published a scathing critique of water fluoridation. They argued that although mottled teeth might be initially resistant to decay, they "are structurally weak, and that unfortunately when decay does set in, the result is often disastrous."[24] They studied a community in St. David, Arizona, where the water contained somewhere between 1.4 and four parts per million of fluoride. By their mid-20s, more than 50% of the population of St. David was wearing dentures. Margaret and Smith warned,

> The range between toxic and non-toxic levels of fluorine ingestion is very small. Any procedure for increasing fluorine consumption to the so-called upper limit of non-toxicity would be hazardous.[25]

In short, by the mid-1940s, an increasing number of studies had demonstrated that fluoride was effectively excreted by the body and the apparent healthfulness of naturally fluoridated communities relieved many people's concerns. But scientific consensus had not yet been achieved. In 1944, the long-standing editor of the *Journal of the American Dental Association*, L. Pierce Anthony, opposed water fluoridation, saying that "sodium fluoride is a highly toxic substance"[26] and that we did not yet know enough about the impact it might have on bones or other tissues and that there was evidence that drinking water with as little as 1.2 to 3.0 parts per million of fluoride had caused osteosclerosis, spondylosis, osteoporosis, and goiter. He concluded that the potential benefits of reducing dental decay in children were smaller than the risk of "producing such serious systemic disturbances."[27] Two months later,

Anthony issued an addendum indicating that the original editorial had been misinterpreted. He maintained that dentists needed to keep in mind the "possibility of harm" but that there was "abundant evidence" that fluoride reduced cavities and asserted the fluoridation study being planned for the state of New York was fully justified.[28] Anthony then retied as editor of the journal. Was Anthony pushed out of the editorship because of his negative editorial? This is possible, but it seems more likely that at 68 years old he was ready to retire.[29] Regardless, the change in editors represented a significant shift in the conversation; dental researchers were increasingly optimistic about the possibilities of water fluoridation and were keen on promoting it. In 1945, the US Public Health Service, the state of New York, and the city of Brantford, Ontario (soon to be assisted by the Canadian Department of Health) began studies of controlled fluoridation. Although some people still expressed concern about the potential side effects, seven years of research had not resulted in any definite evidence of harm, at least in the US context. (The one exception, perhaps, was the research the Smiths conducted on the fragility of mottled teeth, but their findings had not been confirmed by other researchers, and the community in question had a much higher rate of fluoride in its water than was being contemplated through controlled fluoridation.)

PROMOTING WATER FLUORIDATION

The mid-20th century has often been regarded as the "golden age" of US medicine: infant mortality had plummeted, life expectancy had increased, the introduction of new vaccines had significantly reduced infectious disease, and new drugs promised to combat bacterial infections.[30] Infused with optimism about what postwar science and medicine could accomplish, some dentists and public health officials used the beginning of controlled trials to launch a concerted campaign in favor of fluoridation. Historian Donald McNeil has described the crusade led by John G. Frisch, a Madison, Wisconsin, dentist who was such an enthusiastic promoter of fluoride that he provided his children with fluoridated water that he mixed at home. He labeled the water that came out of the taps in his home as "poison." When his daughter developed a mild form of dental fluorosis, he eagerly displayed her damaged teeth across the state. Together with Frank Bull, dental health officer at the State Board of Health, he campaigned for fluoridation across the United States, but especially in Wisconsin, where more than 50 communities had fluoridated their water by 1950. Frisch was a dentist, not a researcher, and he had little patience for the detailed, careful studies being conducted by the US Public Health Service. When several biochemists at the University of Wisconsin objected to the fluoridation of Madison's water supply in 1947, asserting that fluoride tablets would be a better solution, Frisch claimed that they "didn't know a fluorosed tooth from a bed pan."[31] Indeed, as both Ruth Roy Harris and McNeil argued, scientists at the US Public Health Service were reluctant to endorse water fluoridation in 1950 but were ultimately overwhelmed by pressure from the state dental directors.[32]

Why were the state dental directors so eager to have fluoridation? First, the war had revealed the extent of dental disease in the United States. To join the armed services, men had to have six opposing teeth in their upper and lower jaws; in 1941, almost 10% of recruits were rejected for this reason alone. Dental defects were the leading cause of rejection. Eventually, the Selective Service began a dental program to upgrade the dental health of the men and render them eligible for service.[33] The US Office of Education, the US Public Health Service, and the American Dental Association joined forces to improve dental health among high school students so that they would be fit for service upon graduation.[34] Although today we might think of dental caries as a relatively minor problem, if untreated, as many people's cavities were during the mid-1900s, they can led to tooth loss, mastication problems, malnutrition, and infectious complications. In the early 1950s, two public health researchers stated that on average young men between the ages of 20 and 35 years had already lost an average of 4.2 teeth and that 90% of them were in need of bridges or full or partial dentures.[35]

Public health dentists were convinced that it would be impossible to meet the backlog of necessary dental care. Although they knew that significant improvements in dental health could be achieved by filling caries, this was too expensive to be undertaken on a wide scale.[36] There was also a significant shortage of dentists. In 1944, Henry Klein, the senior

dental officer in the US Public Health Service, suggested that the White population of the United States required at least double the number of dentists currently in practice to meet dental needs.[37] There was great hope that fluoride would provide the solution to both the growing problem of dental decay and the shortage of dental manpower.[38] Another advantage of fluoride is that it would reduce the amount of dental care required by children. Despite a growing number of dentists in the post-World War II era whose practice focused on children, there were still many dentists who dreaded the appearance of the screaming, uncooperative child.[39] Fluoridation could alleviate this problem by making significant improvements in children's dental health.

As Alyssa Picard has also argued, fluoridation was connected to the issue of professional prestige.[40] At the turn of the century, Painless Parker was still traveling across the United States with placards that promised tooth extraction along with circus tricks. In the 1910s and 1920s, the theory of focal sepsis—the idea that infections in one part of the body led to infections in another—began to shift the image of dentists from mechanics to practitioners of scientific medicine. It also resulted in an explosion of unnecessary tooth extractions.[41] In the interwar years, most dental schools revised their curriculum and extended the amount of time required to complete a degree. Even still, research in dentistry was limited. In the 1920s, there were only a dozen dental schools in the United States that conducted research. The National Institute of Dental Research had only been created in 1948. By 1961, total spending on dental research by the federal government, universities, philanthropy, and industry only amounted to slightly over six million dollars.[42] Few dental researchers had a PhD.[43] Dentists continued to worry about the prestige of their profession. In 1955, for example, Leroy Johnson, the former dean of the Harvard School of Dental Medicine, wrote that although American dentists were the best in the world in creating bridges and plates and restoring teeth, this work was too expensive, and there were not enough dentists to meet the demand. He complained that reveling in "repair" compromised the status of dentistry as a profession. To gain respect, dentists needed to improve their training in the basic sciences, cooperate with medical schools and do more research, and serve more people.[44] Fluoridation was based on solid research and stressed prevention over cure; many believed it to be a panacea for dentistry's image problem.

Fluoridation also seemed like a boon to frustrated dentists who believed that the public could not be trusted to brush their teeth or eat less sugar. Francis Arnold, an important fluoridation proponent within the National Institute of Dental Research, dismissed dietary interventions as unlikely to have much success.[45] David Ast, the director of the New York State Bureau of Dental Health and leader of the Newburgh fluoridation experiment, said that there were two sure-fire methods of preventing tooth decay—reducing sugar consumption and brushing teeth after every meal. But, he added, these methods were "unrealistic" because "few people will adopt them conscientiously."[46] Francis Bull, the state dental director in Wisconsin, argued that cavities could be decreased by practicing good oral hygiene, restricting sugar consumption, and improving diet, but he did not think that the public was likely to do these things. Fluoride, in his view, offered the first real preventive for dental caries.[47]

CONTROLLED STUDIES AND ONGOING OPPOSITION

By the early 1950s, the controlled studies were producing impressive results. After five years, cavities in Newburgh were down by 30%, with more pronounced improvements among the six-year-olds who had drunk fluoridated water for most of their lives.[48] Still, not everyone was convinced. In 1950, James Delaney, a Democratic congressman, established a committee to investigate the use of chemicals in foods and cosmetics. Many people concerned about food additives and pesticide use also opposed water fluoridation, and the Delaney committee also examined water fluoridation.[49] In the years to come, the antifluoridation movement would make extensive use of these committee hearings. The committee invited scientists from the US Public Health Service and the National Institute of Dental Research, including Bruce Forsyth (Assistant Surgeon General and Chief Dental Officer, Public Health Service), Trendley Dean (National Institutes of Health), and John

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Knutson (Public Health Service). Forsyth explained that fluoridation had been more thoroughly studied than any other public health measure and that it reduced cavities by two thirds. Knutson and Dean described the studies that had been carried out by the National Institute of Dental Research. They also provided the commission with a bibliography pertaining to the safety and effectiveness of fluoridation and copies of the research articles produced by the Public Health Service.[50]

The committee also invited several opponents. The first was Robert S. Harris, a nutritionist at the Massachusetts Institute of Technology. During World War II, he worked on developing nutrient-enriched food products that could be used among undernourished populations. In 1950, in collaboration with a dentist from Tufts University, he began researching diets and dental caries. These studies convinced him that phosphate and other minerals played an important role in dental health.[51] At the hearings, he introduced a metaphor that would subsequently be used by many antifluoride activists. If you have a headache and take aspirin and the headache goes away, that does not mean that the headache was caused by an aspirin deficiency. The fact that fluoride reduced cavities did not mean that humans required fluorides. Instead, we should be investigating the cause of dental decay.[52] He was concerned about the long-term effects of fluoride consumption, testifying as follows:

> The literature indicates that fluorine at 1 part per million in water supplies can effectively reduce the incidence of caries in children in certain areas. The literature does not indicate, however, that the continued ingestion of fluorine at this level is harmless.[53]

He believed, as did most dental researchers, that dental decay was multicausal and that the emphasis on a single solution was misguided. Harris went on to have a successful career in dental caries research and always emphasized the multiple causes of dental decay.[54]

Another opponent who appeared before the Delaney Commission was Alfred Taylor, a biochemist at the University of Texas who specialized in cancer research. Taylor discovered that rats that were fed fluoridated water died earlier than those that were fed unfluoridated water. Although this work had not yet been published when he testified, it was published in 1954.[55] The US Public Health Service had heard about his results in advance of the hearings, and in 1951, they sent Dean and Howard Andervont, chief of the biology section of the National Cancer Institute, to investigate. They discovered that the rats were consuming very high amounts of fluoride in their food, which they felt invalidated the results of his experiment. In addition, the sample sizes were small, and the observed differences fell within the normal range of variability.[56]

The Smiths also testified against water fluoridation. Margaret Smith began by stating that it was clear that fluoride played an important role in diminishing tooth decay. She expressed her respect for the research carried out by the US Public Health Service and believed in their results, but she argued that tooth mottling could occur at low levels of fluoride and that the psychological effects of having damaged teeth could be severe. She pointed out that people drink variable amounts of water, especially children, making it difficult to control the dose. She argued that the topical application of fluoride held greater promise and took the view that better nutrition and teeth-cleaning habits might be better ways to reduce tooth decay. By this point, she had resigned from her position at the University of Arizona to care for her children, but her husband continued their work. At the hearings, H.V. Smith argued that even at one part per million a significant number of children would have mottled teeth. The Smiths' views were informed by the fact that they lived in Arizona, where several communities had high levels of naturally occurring fluoride in their water supply and where water consumption was higher than average because of the heat, thus producing a greater degree of mottling even at recommended levels of fluoride. Indeed, scientists at the Public Health Service agreed that the amount of fluoride in the water needed to be adjusted for climactic conditions. Smith also worried about the effects of fluoride on people with inadequate renal function and the fact that the amount of fluoride in food varied widely, making it very difficult to control the dose.[57] In 1952, in short, there were still highly respected scientists expressing concerns about fluoridation.

CHANGING NATURE OF OPPOSITION TO WATER FLUORIDATION

By 1954, when another set of hearings were held in Washington, DC, scientists who had expressed concerns about water

fluoridation just a few years previously were either not asked to appear or chose not to appear. In 1954, H.V. Smith publicly retracted his opposition after visiting Newburgh, New York. He stated that the mottling in Arizona had to do with climatic differences.[58] Alfred Taylor did not appear before the hearings in 1954, although in subsequent work he continued to argue that fluoride might increase tumor growth. There were doctors and dentists who testified against fluoridation at these hearings, but for the most part they did not have the same prestige as the people who appeared before the Delaney committee two years earlier. Leading the crusade in 1954 was Seattle radiologist Frederick Exner. Exner had been president of both the local Anti-Tuberculosis League and the State Radiological Society, but he had no record as a researcher. He complained that the leading fluoridation scientists were all just quoting and citing one another. He pointed to errors in McClure's study of fluoride excretion, argued that children consume widely varying amounts of water, suggested that mottling was more severe than Dean's studies indicated, and asserted that dentists varied widely in the number of cavities they found. He condemned fluoridation as "totalitarian medicine" and described the fluoridation trials at Newburgh and Grand Rapids as a "flagrant violation of the most sacred laws of God and man."[59] Although a number of Exner's concerns were similar to those expressed by those at the 1952 hearings, his passionate opposition to fluoridation, his attacks on the honesty and professionalism of fluoride scientists, and his scattered use of evidence diminished the quality of his testimony. It was clear he had an axe to grind, and it was easy for people sympathetic to fluoridation to dismiss his views.

The other leading opponent was George Waldbott, an allergist from Detroit, Michigan. Waldbott did not attend the hearings, but he did send a statement. Waldbott, like Exner, was a respected physician—he was vice president of the American College of Allergists and had published more than 100 articles, although most were case studies.[60] He feared that one part per million might not be safe for everyone in the community, especially people with allergies or those with impaired kidney function. He worried that mottled teeth would not remain healthy over the long term and pointed out that it would be extremely difficult to trace the symptoms of fluoride poisoning because many of the symptoms (joint pain, malaise) were vague and could result from any number of conditions. He asserted that the best dental journals refused to publish anything with an antifluoride stance and complained that the American Medical Association's endorsement of fluoridation had been rushed through the House of Delegates. Again, his allegation that there was some nefariousness on the part the profluoridation forces (which has been a consistent aspect of the antifluoridation discourse ever since) weakened his argument in the view of many dentists and research scientists who believed that researchers like Dean, McClure, and Hodge were fair, evenhanded scientists. Moreover, some of the concerns about the potential long-term effects of fluoride on the body had been alleviated by a long-term study of Bartlett, Texas, which had approximately eight parts per million of fluoride in its water, and Cameron, Texas, which had approximately 0.4 parts per million of fluoride in its water. Long-term residents of both communities had medical histories, physical and dental examinations, and blood and urine analyses taken in 1943 and 1953. The study showed that there were no significant differences in the health of the two populations other than a high rate of dental fluorosis in Bartlett.[61]

In the years to come, Exner and Waldbott would become the leading scientific voices in the antifluoridation movement. Exner and Waldbott's antifluoride work was widely accessible. In 1957, they published *The American Fluoridation Experiment* with a mainstream press. Written in clear, passionate prose, Exner and Waldbott argued that the fluoride experiment marked an unprecedented expansion of the powers of public health officials into the lives of the public, that it would provide entire communities with a medication that would only benefit a few, and that more research needed to be done because it was likely that fluorides would accumulate in the body and cause damage to bones, teeth, and joints, as well as gastric distress. They argued that the best way to reduce cavities was to cut sugar consumption and asserted that the Sugar Research Foundation was a leading force behind fluoride promotion. In a chapter entitled "Big Brother Knows Best: Budding Authoritarianism in Our Public Health Service," Exner argued that bureaucrats were interested in increasing their sphere of authority while the aluminum and fertilizer companies who produced fluoride were eager to

increase their profits.[62] In 1955, Waldbott and his wife started the *National Fluoridation News*, a tabloid-style newspaper that favored conspiratorial headlines, shocking revelations of profluoridation tactics, scathing denouncements of fluoride's dangers, and funny cartoons.

In this increasingly fractious atmosphere, it became more difficult to engage in the debate on the opposition side without losing respect in the scientific community. One of the few who successfully walked the line was Clive McCay, a nutritional researcher at Cornell University.[63] McCay was best known for his research on how underfeeding rats led to significantly longer lifespans. He and his wife Jeanette created Cornell bread—a whole wheat flour bread enriched with high-protein soy flour, wheat germ, and milk solids that was distributed by food cooperatives. He also tried to convince the government of New York to tax carbonated beverages. (In short, he had much in common with the natural food activists who became some of the leading opponents of water fluoridation.) He had done some research on fluorides ever since he started at Cornell in 1927, although it was never the major focus of his research. He was uneasy about the potentially toxic effects of fluorides and worried that researchers had not followed people or animals for a long enough period of time to determine the long-term effects of fluoride in the body.[64] He expressed respect for the leading fluoridation researchers but believed that water fluoridation was moving ahead too quickly.[65] In 1953, his opposition was reinforced when he spent a sabbatical year in Switzerland, where a scientific committee had rejected fluoridation. Indeed, water fluoridation never became widespread in Europe. He believed that the Swiss investigations showed that there was more than one way of understanding the fluoride science. In 1954, when fluoridation was under consideration in Ithaca, New York, where Cornell is located, he gave a radio talk against the procedure. He argued that fluoride did improve teeth and that the leading researchers in the field were "honest, critical, and reliable men" but that he was still not convinced that long-term consumption of fluoride would not damage the thyroid or kidneys. He also expressed concern about the impact fluoride might have on aquatic life. He felt that fluoridated sugar would be a better option because sugar was the leading cause of dental decay.[66] In 1956, one of his graduate students completed a PhD on the long-term effects of fluoride consumption on white rats. The thesis concluded that fluoride accumulated in bones, even at one part per million, and that this accumulation had a serious impact on their teeth and likely on their kidneys as well. As a result, McCay became more willing to share his views, although he never became an antifluoridation crusader. In a 1956 letter, he claimed that he was opposed to water fluoridation but that "I have decided to keep out of the controversy" because "I did not think it has been handled in a scientific manner." He complained that "it is being considered as a panacea by one party and a poison by another."[67] In 1957, he became one of the scientists to sign the Statement on Fluoridation by the Medical–Dental Ad Hoc Committee on Evaluation of Fluoridation. Indeed, McCay's reasoned opposition to fluoride was unusual in a debate that was so fiercely divisive. By the late 1950s, there was little room for doubts or uncertainties on either side.

CONCLUSIONS

As communities across the United States and Canada debated the possibility of adding fluorides to the water supply in the 1950s and 60s, proponents regularly stated that dentists, doctors, and scientists were unanimous in their approval.[68] This was not true. There were dentists, doctors, and scientists who opposed fluoridation, but as the debate grew more heated, and the scientific evidence mounted in favor of fluoridation, the experts who had initially expressed hesitation either changed their mind or removed themselves from the debate, leaving the opposition largely in the hands of a few crusaders. The extreme views expressed on both sides of the debate created a hostile atmosphere for researchers who were opposed to water fluoridation. Eventually, fluoride opponents would establish their own journal, *Fluoride*, which exclusively published articles critical of fluoridation.[69] Most scientists doing research in the field were very clearly identified as profluoridation or antifluoridation, with confusing ramifications for the public debate. Who should members of the public believe? The reassuring pamphlets that told the public that fluoridation was safe, effective, thoroughly tested, and endorsed by experts? Or the far more lengthy and detailed books, leaflets, and pamphlets distributed by the antiforces that asserted that fluoride might lead to joint problems, heart and kidney disease,

and cancer? The fact that the scientists and doctors appeared to be so divided may have contributed to the perception that the experts were hiding evidence of possible harm. As the most thorough review of fluoridation debates showed, the public felt they were being asked to decide on the safety of fluoridation during referendums and thus often chose caution.[70]

At the same time, the fact that dental leaders and public health officials believed that fluoridation had been proven safe (and dismissed the few opposing researchers as cranks) meant that little money or resources were devoted to fluoridation research after the 1950s. Although research on the safety and effectiveness of fluoridation continued, the quality was often poor. In 2000, when the University of York published the most extensive systematic review of fluoridation ever completed, the authors expressed dismay at the quality of much of the fluoride research that had been done in the preceding decades. Most of the studies they reviewed were published after 1966. They divided the studies into evidence levels A, B, and C, with A representing the highest-quality studies. On the question of whether water fluoridation prevented cavities, they found 26 studies. There were no randomized controlled trials, and none of the 26 studies was characterized as being in the A category of evidence. On the question of whether fluoride had negative effects, the studies were of equally dismal quality. All studies of the impact of fluoride on bone health were ranked as evidence level C. All but one of the studies on dental fluorosis were ranked as evidence level C.[71] After more than 70 years of investigation, there are still questions about how effective water fluoridation is at preventing dental decay and whether the possible risks are worth the benefits. Although water fluoridation undoubtedly did improve the dental health of many children in the 1960s and 1970s, fluoride proponents were perhaps too hasty in declaring that community water fluoridation was the best (or only) solution for dental decay. A less fractious debate might have encouraged a more open discussion in which the possible harms could have been more fully discussed and other options, such as providing fluoridated toothpaste, more fully considered. ■

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Endnotes

1. This article focused on the United States and Canada, where much of the early science and debate over water fluoridation took place. European countries (with the exception of the United Kingdom, Ireland, Spain, and Serbia) do not fluoridate their water. Fluoridation is also widespread in Australia, New Zealand, and some South American countries, including Brazil and Chile.

2. For a review of the political debates over water fluoridation, see G. Reilly, "'This Poisoning of Our Drinking Water': The American Fluoridation Controversy in Historical Context, 1950–1990." PhD diss., George Washington University, 2001; C. Carstairs and R. Elder, "Expertise, Health and Popular Opinion: Debating Water Fluoridation," *Canadian Historical Review* 89, no. 3 (2008): 345–371.

3. Review of fluoridation referendums can be found in D.R. McNeil, *The Fight for Fluoridation* (New York, NY: Oxford University Press, 1957); R.L. Crain, E. Katz, and D.B. Rosenthal, *The Politics of Community Conflict: The Fluoridation Decision* (Indianapolis: Bobbs-Merrill, 1969); and C. Sellers, "The Artificial Nature of Fluoridated Water: Between Nations, Knowledge and Material Flows," *Osiris* 19 (2004): 182–200.

4. One of the few works to examine the scientific debate over water fluoridation is B. Martin, *Scientific Knowledge in Controversy: The Social Dynamics of the Fluoridation Debate* (Albany, NY: State University of New York Press, 1991). However, this sociological study examines the contemporary scientific debates rather than the history of the debate.

5. M. McDonagh, P. Whiting, M. Bradley, J. Cooper, A. Sutton, I. Chestnutt, K. Misso, P. Wilson, E. Treasure, and J. Kleijnen, "A Systemic Review of Public Water Fluoridation NHS Centre for Reviews and Dissemination," http://www.york.ac.uk/inst/crd/CRD_Reports/crdreport18.pdf (accessed March 26, 2015); D. Locker, *Benefits and Risks of Water Fluoridation: An Update of the 1996 Federal Provincial Subcomittee Report* (Toronto, ON: Community Dental Health Services Research Unit, 1999); Australian Government, National Health and Medical Research Council, *Fluoridation: A Systematic Review of the Efficacy and Safety of Water Fluoridation* (Canberra, Australia: National Health and Medical Research Council, 2007).

6. H.G. Petersson and D. Brathall, "The Caries Decline: A Review of Reviews," *European Journal of Oral Sciences* 104 (1996): 436–443; D.H. Leverett, "Fluorides and the Changing Prevalence of Dental Caries," *Science* 217 (1982): 26–30; M. Diesendorf, "The Mystery of Declining Tooth Decay," *Nature* 322 (1986): 125–129.

7. V.C.C. Mariho, J.P.T. Higgins, S. Logan, and A. Sheiham, "Fluoride Toothpastes for Preventing Dental Caries in Children and Adolescents," *The Cochrane Collaboration* 1 (2009): CD002278.

8. R.A. Freeze and J.H. Lehr, *The Fluoride Wars: How a Modest Public Health Measure Became America's Longest-Running Political Melodrama* (Hoboken, NJ: John Wiley and Sons, 2009): 191–212; P. Nadanovsky and A. Sheinam, "Relative Contribution of Dental Services to the Changes in Caries Levels of 12 Year Old Children in 18 Industrial Countries

"As the most thorough review of fluoridation debates showed, the public felt they were being asked to decide on the safety of fluoridation during referendums and thus often chose caution."

in the 1970s and Early 1980s," *Community Dentistry and Oral Epidemiology* 23 (1995): 331–339.

9. Of the first three studies in Grand Rapids, MI, Newburgh, NY, and Brantford, ON, none initially used x-rays. Newburgh started using x-rays in 1949, whereas Grand Rapids did some examinations by x-ray beginning in 1946. See F. McClure, *Water Fluoridation: The Search and the Victory* (Bethesda, MD: US Department of Health, Education, and Welfare, 1970), 119, 124. In a 1941 study of eight examiners using a mirror and explorer found substantial differences in the number of cavities found—on average there was a 5.8 carious surface difference. Thus, for example, in the case of one patient, the first examiner found 21 carious surfaces, whereas the third examiner found only 8. See D. Radusch, "Variability of Diagnoses of Incidence of Dental Caries," *Journal of the American Dental Association* 28 (1941): 1959–1961. In a review chapter, Burt and Eklund described the early fluoride studies as "pioneering" but added as follows: "Sampling methods and dental examiners tended to vary from one year to another, thereby risking bias and unnecessary random error. Methods of statistical analysis, by today's standards were crude." See B.A. Burt and S.A. Eklund, *Dentistry, Dental Practice, and the Community, 4th Edition* (Philadelphia, PA: W.B. Saunders, 1992), 158.

10. D. Locker, *Benefits and Risks of Water Fluoridation*; S. Erdal and S.N. Buchanan, "A Quantitative Look at Fluorosis, Fluoride Exposure, and Intake in Children Using a Health Risk Assessment Approach," *Environmental Health Perspectives* 113 (2005), no. 1: 111–117.

11. M.C. Smith, E.M. Lantz, and H.V. Smith, "The Cause of Mottled Enamel," *Science* 74 (1931), no. 1914: 244.

12. H.V. Churchill, "Occurrence of Fluorides in Some Waters of the United States," *Industrial and Engineering Chemistry* 23 (1931), no. 9: 966–968. An excellent account of the McKay's efforts can be found in McNeil, *The Fight for Fluoridation*, 4–18.

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17. H. Hodge and R.R. Sagnnaes, "Experimental Caries and a Discussion of the Mechanism of Caries Inhibition by Fluorine," in F.R. Moulton, ed., *Dental Caries and Fluorine* (Washington, DC: American Association for the Advancement of Science, 1946): 53–73.

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19. D.A. Greenwood, "Fluoride Intoxication," *Physiological Reviews* 20 (1940), no. 4: 582–616; F.J. McClure, "Nondental Physiological Effects," in *Dental Caries and Fluorine*, 88–89; W. Machle, E.W. Scott, and E.J. Largent, "The Absorption and Excretion of Fluorides," *Journal of Industrial Hygiene and Toxicology* 24 (1942), no. 7: 199–204; W. Machle and E.J. Largent, "The Absorption and Excretion of Fluoride," *Journal of Industrial Hygiene and Toxicology* 25 (1943), no. 3: 112–123; F.A. Smith, D.E. Gardner, and H.C. Hodge, "Investigations on the Metabolism of Fluoride," *Journal of Dental Research* 29 (1950), no. 5: 596–600; G.J. Cox and H. Hodge, "The Toxicity of Fluorides in Relation to Their Use in Dentistry," *Journal of the American Dental Association* 40 (1950): 440–451.

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64. C. McCay to unknown recipient, December 13, 1951, Box 14, File: "Fluorides 1948–1952," Cornell University Archives.

65. In 1951, although he expressed concerns about the toxicity of fluoride, he told a letter-writer that "if the question of using fluorides in our local water supply arises I will not oppose it because I feel the value probably outweighs the danger." Letter from C. McCay to M. Ambrose, March 21, 1951, Box 14, File: "Beverages 1948–1952," Cornell University Archives.

66. C. McCay, "Should We Put Fluoride into the Water Supply of Ithaca, NY," to be recorded for a radio presentation, December 14, 1954, Box 14, File: "Fluoride," Clive McCay Papers, 1920–1967, Division of Rare and Manuscript Collections, Cornell University Library (hereafter Clive McCay Papers).

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69. *Fluoride* is published by the International Society for Fluoride Research, a coalition of antifluoridationists. See http://www.fluorideresearch.org (accessed March 26, 2015).

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