gen and two parts of hydrogen. It is an incredible mixture with remarkably variable powers. Nor are teeth and bones simply fixed fenceposts of the body. They are in a constant state of flux, now giving of their substance to tissues and organs and now taking away. Bones, especially, are storehouses of elements critical to life.

The Canadians found that distribution of fluoride through the body occurs generally in the same way occurred in the frozen-then-thawed milk. Fluoride is locked into the teeth and bones along with calcium phosphate and magnesium among other things. Is this a healthy prospect?

Magnesium is vital to many life processes, including the stability of the blood.

Calcium is particularly essential to pregnant women, and deprivation of it can damage the foetus.

Since the bones are the emergency storehouse, should any risk be taken of attaching padlocks to the storehouse doors?

If not, the Canadian report proposed that the following research would be in order before any arbitrarily fixed amounts of fluoride are added to water drunk by the sick as well as by the robust:

1. The ratio of fluoride distribution between teeth (A in the sketch on page 89) and fecal excretion (B in the sketch), or between teeth and absorption from the digestive tract (C in the sketch), should be thoroughly analyzed. The role of various ions that reduce absorption or subsequent deposition in bone while maintaining resistance against tooth decay should be explored. Particular emphasis should be placed on calcium and magnesium in hard waters, which may constitute a protective mechanism not available in extremely soft waters and which may also serve as supplements to diets otherwise low in magnesium.

2. The role of magnesium during various stages of fluoride accumulation in bone (E, F and G in the sketch) should receive greater attention relative to the biochemistry of the abnormal development of bone.

3. The effect of fluoride induced reduction in the solubility of bone mineral should be determined, particularly as it affects mineral resorptivity during periods of high metabolic demand (such as pregnancy). The possible effect of fluoride accumulation prior to the onset of stress is not known.

4. The effect of various dietary factors, particularly deficiencies in protein, calcium, magnesium, vitamin C, vitamin D on fluoride accumulation (E in the sketch) and subsequent effects (F, G in the sketch) should be studied "to ensure that long-term accumulation of fluoride in bone will not injure a segment of the population."

Does this amount to a stricture against the use of fluoride to protect against decay?

It does not.

One of the fundamental discoveries exposed by the Canadians was this: early theory of how fluoride gives its protective effect to teeth were wrong. Dr. McKay and the others who followed him believed that the fluoride traveled through the mouth and gut into the blood, then went back through the blood into the head and jaws to the

FLUORIDE'S CHECKERED PAST

THE practice of adding fluoride to drinking water (as opposed to the habitual drinking of naturally fluoridated water) is not yet twenty years old. In assessing its potential for harm, it is worth recalling that fluoride was not discovered in drinking water until twenty-eight years after the water was suspected of having effects now known to be due to fluoride.

Fluoride did not appear with a flourish as boon to man, or even to child. The early circumstances were not encouraging. The established facts are these:

In 1902, a J. M. Eager, U.S. Marine surgeon stationed in Naples, reported a human idiosyncrasy unlike anything in his previous experience or hearsay. The Italians called it "yellow writing on the teeth" in apt description of the disfiguring appearance it created in the face. Surgeon Eager's report drew so little attention that peculiar yellow and brown staining of teeth among townsfolk in the Rocky Mountains of the American West shocked a young New England dentist who went to Colorado Springs, Colo., to set up in practice just after being graduated from the University of Pennsylvania Dental School in 1900. Dr. Frederick Sumner McKay, native of Lawrence, Mass., never forgot the dilemma that confronted him when dentists older to the region sought his help in combating the stain, which in extreme cases was accompanied by pitted, grooved and chipped teeth. The disfigurements "numbered in the thousands," he would write later, and "individual deformities were of a very grave character." He took the problem to a meeting of the local dental society in May, 1908, led a discussion of it, and obtained the society's agreement (for a true copy, see page 87) "that a suitable patient exhibiting this condition be secured and that this society pay the expenses of such patient to the State Dental Society Association meeting at Boulder in June."

At first Dr. McKay assumed that teeth suffering such major structural defects must be uncommon prey to decay. But examination revealed they had no greater tendency to decay than could be ascribed to normal teeth. On further study, he discovered that the crippled teeth actually were marked with less decay than normal teeth.

Dr. McKay tried for many years to determine the source of the "browning." Local folklore said the drinking water was responsible, and he intuitively accepted that judgment. For a time he sought alternate water sources in hope of stopping the discoloration, which came to be accepted as a visible symptom of more serious weaknesses hidden in the bones of the body.

So subtle was the influence at work that fluoride's identification as the causative agent did not come until 1930. The discoverer was an Aluminum Company of America chemist, Dr. H. V. Churchill, who had been assigned by the company to try to help Alcoa employees at Bauxite, Arkansas, find some relief from whatever it was that disfigured their mouths.

Fluoride then was known only as a poison. It had not been considered as a possible constituent of drinking water. The immediate reaction was one of alarm, for fluoride had a powerful effect on body tissues and nerves as well as on bones. Where fluoride content of the water was high, thought was given to means of lowering it. In Colorado Springs, the municipal water supply came under taboo as a source of drinking water for the town's babies. Pure water bottled in Denver was brought in and delivered each day along with

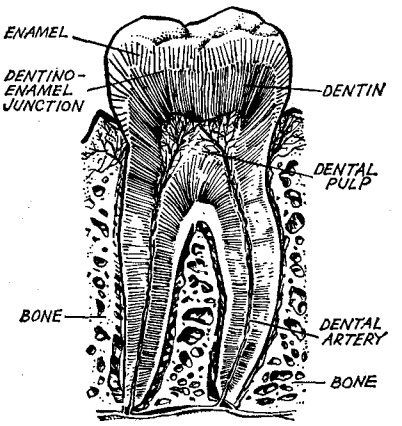
pulp of the teeth (see sketch, at right) and finally worked its way through the dentin to the enamel. There it fought off corrosion by acids produced by salivary bacteria in the course of decomposing fragments of food left in the mouth after meals.

Mr. Marier and Drs. Rose and Boulet turned up what seems to be conclusive proof that fluoride really accomplishes its influence on tooth enamel from the outside. The fluoride ion apparently attaches itself to the tooth surface upon contact and later moves inward through the lattice of the crystals in the enamel.

The evidence for this new concept comes from research performed by Dr. Finn Brudevold at Rochester. Inventing his own tools for the purpose, Dr. Brudevold took teeth that had been pulled and analyzed them microscopically, one fine layer at a time. They found the highest concentration of fluoride in the outermost layer of the enamel. The proportion of fluoride dropped progressively until the dividing line between the enamel and the dentin within it was reached. A fluoride concentration roughly equal to the concentration in the outer enamel was found at the center of the pulp. This concentration also decreased progressively as analysis of the tooth proceeded outward from the pulp to the outer edge of the dentin. The weakest fluoride concentration of all occurred where the dentin meets the enamel (again, see sketch, at right). In short, the effect of the fluoride from the bloodstream falls to the vanishing point before it gets to the enamel.

According to this scheme of things (which is confirmed by two sets of other experiments—one showing that fluoride injected into the blood had no effect against tooth decay, the second showing that mothers who have enjoyed the benefit of fluoridated water do not pass the benefit on to their children through the blood of the feotus) it should be possible to obtain the decay-resistant effect of fluoridated water through use of a mouth rinse.

It should also be possible to put fluoride into milk, where it could bathe the mouth and then, having performed its one useful task in the body, be excreted quickly through combination with the milk's calcium. Calcium fluoride has as much effect on tooth enamel as sodium fluoride (the form of fluoride usually added to water) but has less deleterious effect on bone.



—Doug Anderson

CROSS SECTION OF A TOOTH, above shows how blood enters pulp inside dentin and enamel. Note location of junction and enamel mentioned in text.

In absence of any uncontested evidence that fluoride aids the human body except by preventing dental

the morning's milk. The Borden Milk Company still continues this practice today.

SINCE medical men had been dealing with poisons for centuries, using them in dilute form as remedies for ailments of the body and mind, it was inevitable that someone should attempt to turn fluoride's effect on tooth decay to good purpose. Dr. H. T. Dean, a U.S. Public Health Service officer, did this, in three main stages:

First, with Dr. Churchill's help, it was determined that when the fluoride content of water was one part or less per million parts of water, the decay resistant effect operated without marked mottling of the teeth.

Second, epidemiological studies of many towns with naturally fluoridated drinking water turned up no obviously serious damage to the inhabitants when the fluoride content was under four parts per million.

Third, addition of fluoride to the drinking water of three cities—Newburgh, New York; Grand Rapids, Michigan, and Brantford, Ontario—while nearby cities of comparable size went without fluoridation, showed that half the children under 16 years of age had less tooth decay in the towns with the fluoridated water.

Viewed as strictly controlled scientific experiments, the comparative studies at Newburgh, Grand Rapids and Brantford were failures, for other forms of oral hygiene were intensified at the same time that fluoride was added to the drinking water. Fluoride versus no-fluoride never got a clear-cut test.

Nevertheless, a tendency to resist tooth decay was evident among large numbers of fluoridated water drinkers. And this was enough for parents who had lost disciplinary control of their children and for dentists who despaired of coping with the rise in tooth decay that followed popularization of soft white bread, demineralized foods, the ubiquitous candy bar.

Because of fluoride's long, horrible record in chemistry as an inhibitor of enzymes vital to life, and because fluoride in drinking water had escaped detection for so very long, many conservative scientists withheld endorsement of fluoridation until more could be learned about the long term effects. Some were sufficiently aroused to oppose fluoridation wherever it was proposed. For some reason, these "regulars" became known as cranks and crackpots while the "regulars" who sprang up among fluoridation's proponents were known as dedicated crusaders.

Although the American Dental Association, the American Society of Dentistry for Children, the American Public Health Association, the American Medical Association, the American Association for the Advancement of Science and The National Research Council of the National Academy of Sciences all lined up in advocacy of fluoridation, the people remained in opposition. In local referendum after referendum, fluoridation of municipal water supplies was defeated. Proponents of fluoridation reacted by adopting self-defeating tactics. In Camp Hill, Pennsylvania, mimeographed broadsides were distributed urging fluoridation's backers to ridicule the opposition rather than to reason with it. In Columbus, Ohio, Dr. Jonathan Forman lost his job as editor of the Ohio State Medical Journal for opposing fluoridation.

It seems to have been forgotten that ideas cannot be stamped out but only encouraged to expose their own fallacies. —J. L.

caries, there would seem to be no logical reason to add fluoride deliberately to the diet.

We take medical remedies only as long as we are sick. When the sickness subsides, we stop the medicine. Why do otherwise with fluoride, which does no demonstrable good outside the mouth and is known to be capable of much harm elsewhere in the body?

The science editor has come to the end of his explanation to his readers. Again, he regrets having confused them by failing to give the documentation for his view last month. If he had done so, perhaps the reaction to his report on fluoridation might have been different.

As he understands the phrase, public health measures are measures intended to protect the health of the whole public. Fluoridation of water protects only half of certain age groups for uncertain periods of time, while holding possible danger to others.

Introduction of chlorine into public drinking water is not a valid precedent for the introduction of fluoride. Chlorine is a gas, which acts at once following its introduction, then decomposes. Its purpose is to kill bacteria that carry transmissible disease. It is not designed to reach the water drinker or to affect the metabolic processes of his body. Fluoride kills nothing in the water conveying it. Fluoride is directed inside the body to do its work there.

The issue here is not anti-science or anti-intellectualism. It is anti-coercion. American democracy depends on an educated citizenry. If the scientists concerned with control of tooth decay cannot educate the people to accept fluoridation of public drinking water and vote to put to use in their local communities, the fault may be with the scientific evidence—not with the popular intelligence.

New York's Mayor Wagner has said that "if you need a referendum, you don't have a government." The fact is that referenda are and always have been part of the process of democratic government. So deep rooted is this tradition that one of the shrewdest foreign critics of American behavior recently proposed, as a memorial to the late President John F. Kennedy, adoption of an amendment to the U. S. Constitution to give the President a means of appealing to the nation as a whole against the factional interests represented in the Congress.

A possible danger in the continuing effort of the U. S. Public Health Service to fluoridate public drinking water is that it runs counter to the personal responsibility of the citizen.

—JOHN LEAR,
Science Editor.

THE PURPOSE OF EXPERIMENTS

Discoveries are prepared accidents

By PAUL WEISS

EXPERIMENTS ought to be done for a purpose—a purpose other than just to do another experiment. Experimentation used to be deliberate, not improvised; planned to reduce confusion not just to add profusion; it was meant to be relevant and incisive, not just trifling and redundant. Or, to put it succinctly, in the tradition of past centuries, designing an experiment was like training a gun at a target, rather than like spattering buckshot all around at random in the hope that somewhere something might be hit. The targets, in turn, were products of experience, including those extrapolations from experience by logic and imagination which generate hypotheses and theories. Throughout, deliberate orientation of experiments toward visible or envisioned goals was the practice and tacitly accepted work rule.

Work rules have a way of changing imperceptibly as time goes on and as conditions change. Much as in evolution, such trends of change may be for the better or the worse, ending, respectively, in progress or disaster. But unlike evolution, intelligence ought to be able to recognize turns into disastrous courses in advance and thus prevent potentially monstrous products. For instance, let us take a complex system —an organism or a community or any social enterprise—whose proper functioning requires that all its vital parts maintain harmonious proportions; let one set of parts defy this harmony and go off on its own, with no regard to the others and the total pattern, and the result will be monstrosities. The dinosaurs, extravaganzas in size and mass beyond the power of a nervous system to manage and coordinate, were such monstrosities. Now, consider that the body of knowledge likewise is a cohesive, consistent, integrated system, not just a hodge-podge of miscellaneous information, which therefore likewise requires for its healthy growth a sound balance among its tributaries—experience, experiment, and logic. So, if biological research were to allow the share of experience to dwindle and let experimentation gain in volume, while losing in purpose and direction, biology might yet meet the fate of the dinosaurs. This is a fate which we can forestall if we heed signs, or even mere forebodings, that such a trend is in the offing.

I submit that such warning signals have indeed appeared; that biological experimentation, at the height of success, is beginning to drift from the rigorous work maxim of its preceptors into habits that threaten to place bulk ahead of brains, and routine exercises ahead of thought. I shall elaborate my reasons for this critical assertion.

I said experiments should be purposeful and meaningful. To be concrete, let me illustrate briefly some of those purposes and meanings. Organic nature confronts us with a host of puzzling questions, which we then try to answer by experiments. But the major class of experiments is that which boldly tosses questions back at nature and tricks nature into answering them by confronting her with combinations and constellations of conditions unprecedented in her standard repertory. To mention some examples at random: the taking of living cells out of the body and growing them in an extraneous medium—the ingenious experiment of Harrison that started tissue culture; or the surgical removal by Lashley or arbitrary fractions of the visual brain cortex in rats that had been trained to discriminate visual patterns, with the result that the learned patterns persisted in the defective brains as proof that visual memory is not a fractionable mosaic; or the first injection of foreign molecules into a rabbit, which then formed antibodies matching the alien agent, thus proving that immune responses are truly adaptive; or the transfer of the perfusion fluid of an excited frog heart into another heart, which thereby got excited, proving the humoral character of the transmission from nerve to muscle; and so forth.

What really distinguishes such ex-