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Sinking Our Teeth into the Future

A Letter from Ian M. Cook, CEO, Colgate-Palmolive

A LOOK AT THE MOST INNOVATIVE and impactful developments in science, technology and medicine of the past 20 years reveals an important common thread: access. Greater access in areas like information, knowledge-sharing and e-health technologies—often customized and delivered on-demand—is a hallmark of the sweeping change we see around the world. In the medical and dental fields, much of this change is being driven by empowered patients in developed markets seeking flexible, digital healthcare. But the effects of these changes will be farther reaching and may very well revolutionize the practice of dentistry.

This special issue explores science, policy and new delivery models to better understand the current and future state of the multifaceted oral health field. Within this issue are updates on:

- Oral health of a growing elderly population; global health issues of caries and periodontal diseases and latest industry developments helping to improve access and cost-of-care in these areas
- The state of the science linking oral health and other areas in medicine and changes in the relationships between the dental and medical communities as they slowly de-silo and integrate to deliver better care and greater access for patients
- New tools being employed in diagnostics, biotechnology, and digital health that are advancing care, along with a special look at how dentistry and oral health will be managed in the future
- Philosophies and technologies that have fueled industry changes and ways in which global demographics are mandating more accommodating, on-demand approaches to dentistry that reduce cost and bring care to hard-to-reach populations

The burden of oral disease is felt most by the world's underserved populations (including those in poverty in the U.S.) who suffer from limited access to dental care, lack of clean water and limited education. Historically, the resources of industry, the profession and the public health sector have focused primarily on addressing oral disease through treatments and restorations, rather than targeting the elimination of the disease. And in many countries around the world where there is persistent scarcity of dental resources, public health education efforts must be supplemented with bold and innovative interventions.

As a world leader in oral care technology development, Colgate-Palmolive has long been committed to improving the oral health of people across the globe with products that meet a wide range of ever-changing consumer needs. This mission is driven by a relentless pursuit of scientific investigation. However, addressing the changing oral health care needs and emerging challenges facing billions of people worldwide today requires expertise and collaboration—from industry, educators, health care professionals and governments. Only by working collaboratively and globally can we find breakthrough solutions, and continue expanding access to reach the people who need it most.

Ian M. Cook
Chairman, President and CEO
Colgate-Palmolive Company

IAN M. COOK has been President and Chief Executive Officer of Colgate since July 2007 and Chairman of the Board since January 2009. Mr. Cook began his career at Colgate in 1976 and progressed through a series of senior marketing and management roles around the world. He was appointed Chief Operating Officer in 2004, with responsibility for operations in North America, Europe, Central Europe, Asia and Africa, and, in 2005, he was promoted to President and Chief Operating Officer, responsible for all Colgate operations worldwide.

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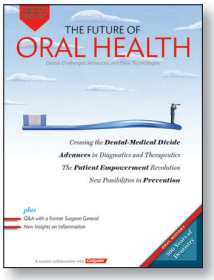

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by Michael Glenwood Gibbs

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THE FUTURE OF
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SCIENTIFIC AMERICAN CUSTOM MEDIA

Of Turning Tides & Tipping Points

Oral Health Goes Modern

by Jeremy A. Abbate and Sharon Guynup

In this, our modern, data-infused era of medicine, science has elucidated connections within our bodies that were not apparent only a few years ago. The Human Microbiome Project and similar initiatives have uncovered compelling evidence that the quality and diversity of bacteria residing inside of us can have a significant impact on both our health and susceptibility to disease. Innovations in cancer, leveraging tools of genomic sequencing, suggest that in many instances, a cancer's geography within the body may be less important than specific genetic mutations of the tumors.

These insights have given rise to new classes of drugs and therapeutic strategies. And in a recent discovery that upended decades of textbook teaching, researchers determined last year that the brain is directly linked to the immune system by vessels that were previously unknown. This insight might have profound implications for conditions ranging from Alzheimer's to autism and multiple sclerosis, and is uniting the fields of neurobiology and immunology like never before.

Indeed, the current ethos in the life sciences seems to be one of interdisciplinary connectedness, of silos coming down, of shared observational and computational tools—all giving rise to a more complete picture of human health.

It is thus no wonder that the historical divide between the dental profession and the evidence-based methods of general medicine is finally beginning to crumble. Over the past decade and a half, there has been considerably more awareness than ever before that oral health is indeed a part of our overall health.

This, however, has not been the case through the ages.

Dentistry is an old profession—practiced as early as 7,000 B.C. in the Indus Valley, refined by the Egyptians around 2,900 B.C. and written about by Hippocrates—the father of medicine—who believed that a complete knowledge of the body as a whole was necessary for effective medical treatment. Yet dentistry has traditionally remained a separate discipline from other areas of healthcare.

Of course, the field of oral care has been at the forefront of some of our most successful public health measures, including the introduction of fluoride treatment to prevent dental caries, or tooth decay, which is the most prevalent dental disease, but also a condition that affects most individuals worldwide. And many of us are far more likely to see a dentist than a general medical practitioner—which in an integrated healthcare environment could offer opportunities for general health screenings.

Meanwhile, we are amidst a global oral disease epidemic, and the statistics are startling: nearly 100 percent of adults have had cavities. About one-fifth of middle-aged adults have gum disease so severe that they could lose their teeth—and about a third of the world's elderly citizens no longer have any of their original teeth.

As research continues to reveal the many ways that the health of the mouth may impact the rest of the body, the implications of this schism between the dental and medical communities take on more serious dimensions. And it is clear that the exigencies of world health would mandate that these boundaries come down.

Jeremy Abbate *is VP and publisher of Scientific American and the publishing director of The Future of Oral Health.*
Sharon Guynup *writes for National Geographic, The New York Times, and Scientific American, and is currently a public policy fellow at the Woodrow Wilson International Center for Scholars.*

It was back in 2000 when then-U.S. Surgeon General David Satcher (interviewed in the following pages) prioritized the issue in his landmark report. He called the problems of global oral health "a silent epidemic promoting the onset of life-threatening diseases which are responsible for the deaths of millions of Americans each year."

Periodontitis—the swelling, bleeding, receding gums caused by some species of bacteria in our mouths—may raise the risk of a number of serious health conditions. That list includes stroke, respiratory illness, and cardiovascular disease. Infection and inflammation in the mouth may also worsen adult-onset (type 2) diabetes or cause premature birth.

Kenn Brown, Mondolithic Studios

Some of these conditions are exacerbated by the body's continually simmering inflammatory response, as the immune system fights the bacterial invaders in gum tissue. These microbes can also slip into the bloodstream, settling into the arteries around the heart, or may be inhaled into the lungs, causing pneumonia. Intensive research continues to explore the complex associations between periodontal disease, inflammation and various medical conditions.

But oral health is important not just because it is inextricably connected to our overall health, but also because of its social, economic and psychological significance. Consider the story of Laurie Abbott, which was reported in the *New York Times* a few years back. Abbott has diabetes, a condition that raises the risk of gum disease, and after her husband was laid off from his job, she couldn't afford dental work. She subsequently lost all of her teeth. "Since I didn't have a smile," she said, "I couldn't even work at a checkout counter."

On the other end of the generational spectrum, tooth decay can impact children's academic success: mouth pain from cavities is among the leading reasons that children are absent from school.

But finally, awareness is growing that the mouth is not separate from the rest of the body, and that oral health must be integrated within an overall healthcare plan. Radical changes are happening in education, with medical and dental schools beginning to merge curriculums. Some programs are now educating dentists on medical issues they should be aware of and are also teaching doctors about oral disease.

Healthcare professionals are starting to realize that for those who rarely see a doctor, basic screening for high blood pressure or elevated blood sugar during a visit to the dentist could save lives. In some countries, like Malaysia, dentistry has been integrated within the overall healthcare system.

In an attempt to address the global oral health crisis, governments are working to bring care to the most underserved populations: children, senior citizens, and those who live in remote areas. The focus is on prevention, education and innovative modes of treatment, which experts say will ultimately lower costs. Many countries are sending professionals out into schools, elder care facilities, and launching mobile dental clinics. Dental therapists are increasingly performing cleanings and taking x-rays, while leaving complex, difficult procedures to dentists.

But even within the traditional office paradigm, Millennial Generation dentists are reinventing the practice. They are incorporating exciting new technologies for diagnosis and treatment. Over the next decade, they will rely more and more on teledentistry, smartphone communications, and greater collaboration with colleagues in both dentistry and medicine. Like other areas of health, dentistry is becoming increasingly digitized, flexible and mobile.

Innovations continue to improve diagnostics. Soon, new biologically active fillings may be able to regenerate decayed teeth, and the most effective treatment options may be determined by analyzing personal genetics. If a crown is needed, it may be created on the spot with a 3-D printer.

The impact of oral disease on whole-body health and the changes to the practice of dentistry worldwide are the subjects of this publication from Scientific American Custom Media, *The Future of Oral Health*, produced in collaboration with Colgate. Here we present information on the latest trends and technologies, and look to the future through the eyes of top researchers and experts.

The future of dentistry looks very different from today, with greater emphasis on prevention that will translate into fewer cavities and less periodontal disease; easier access to care; and shorter treatment time. Much more can be done to improve the state of oral health around the world, but the prediction is that 21st century dentistry will increasingly provide healthy and brighter smiles.

Addressing Oral Health as a Global Challenge

Crossing the Dental Divide

by Neil Savage

As a dentist, Thomas Nabors was attentive to his own mouth and he took good care of his teeth. But he was also acutely aware of the role that bacteria plays in oral health, and he had seen numerous studies linking gum disease to heart problems. So even though he didn't have other cardiovascular risk factors—he wasn't overweight and never smoked—he decided to undergo testing. It may have saved his life: he discovered that his carotid arteries were clogged, restricting blood flow, and the vessel walls were inflamed. It meant that he had a 50-50 chance of having a heart attack or stroke.

Oral bacteria were found amidst the plaque inside Nabors' heart vessels, making it a likely source of the inflammation. So Nabors investigated further, checking for an imbalance of bacteria in his mouth, using a saliva test he'd developed. He then asked his son, Thomas Nabors III (who is also a dentist), to give him a thorough exam, adding the extra step of getting a CT scan. Sure enough, those tests revealed extremely mild gum disease that had not yet produced symptoms, but even these "subclinical" infections can deliver bacteria into the bloodstream.

His son treated the periodontitis with a personalized antimicrobial therapy developed for cases like his. Within two months, follow-up tests showed the arterial inflammation had subsided and the plaque had stabilized, sending his risk plummeting. "Today my risk is very close to zero," says Nabors, 73, who has retired from dental practice but still teaches at the University of Tennessee Health Science Center in Nashville. Because he was proactive, Nabors was more fortunate than many.

In 2000, in his *Oral Health in America* report, then-U.S. Surgeon General David Satcher declared that poor dental health was "a silent epidemic promoting the onset of life-threatening diseases, which are responsible for the deaths of millions of Americans each year."

The report sparked awareness that the mouth is not separate from the rest of the body and oral health is vital to general health and welfare—and must be integrated within an overall healthcare plan. Towards that end, in 2005, New York University announced a radical plan to combine its dental and nursing schools.

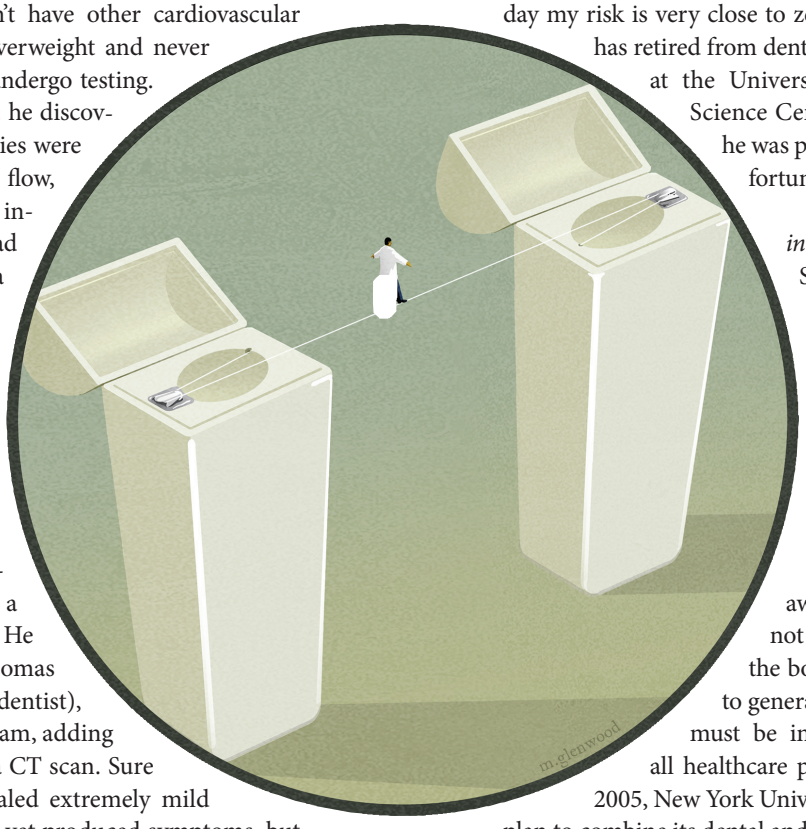


Illustration by Michael Glenwood Gibbs

The change was not readily embraced by all, with much of the push-back coming from the dental profession, says Michael Alfano, who was then dean of the College of Dentistry. "There was a perception that it was upsetting the paradigm…but the paradigm needed to change."

A decade later, the fields of dentistry and medicine are slowly merging, both in the U.S. and across the globe. A mounting body of evidence is connecting the inflammatory processes that cause gum disease with other medical conditions. Research is revealing how the health of teeth and gums, along with certain microbes commonly found in the mouth, impact overall, whole-body health. "Now you're seeing quite a bit of emerging evidence that a healthier mouth has beneficial effects on the body," says Marko Vujicic, chief economist at the American Dental Association's (ADA) Health Policy Institute.

Researchers have known for about half a century that periodontitis—swelling, bleeding and receding gums—is caused by an imbalance of oral bacteria. The condition destroys gum tissue as well as the ligaments and bone that anchor teeth within the mouth. But ongoing studies are revealing more serious implications: gum disease may also raise the risk of serious or life-threatening health conditions, from stroke and pneumonia to heart disease. It may worsen diabetes (which, in turn, exacerbates gum disease) or may bring on early labor, giving premature babies a tough start in life. The enzymes, chemicals and bacterial toxins that are part of the inflammatory process in the mouth may also cause cell mutations, changes that could eventually progress to oral cancers.

Poor oral health and recent dental procedures have also been targeted as one cause of endocarditis, a potentially fatal heart valve infection that was first described in 1885—which highlights one of many reasons that preventative care is imperative.

Oral Report

The prevalence of caries, or cavities, in adult permanent teeth makes tooth decay the most widespread health condition across the planet, according to a 2013 study led by researchers at Queen Mary University of London. Untreated tooth decay affects one-third of the world's adult population, more than 2.4 billion people. An additional 11 percent—743 million people—suffer from severe periodontal disease. At least 158 million individuals have lost all of their teeth.

But dental disease is not limited to adults. Worldwide, untreated cavities in baby teeth is the most prevalent chronic health condition in children. For example, at least 70 percent of Indian children suffer from decaying teeth, according to the World Dental Federation's *Oral Health Atlas*.

Svante Twetman, a professor who studies tooth decay at the University of Copenhagen, finds these numbers embarrassing. The cause, he says, is "too much sugar, too little fluoride, and too little cleaning."

Lifestyle factors such as diet and hygiene are sometimes worsened by the inability to get care, either because of availability or cost. Those who live in areas where there is little or no access to dental care—or sometimes even to toothbrushes and toothpaste—fare the worst, and these

Q&A

Thomas Van Dyke on Fighting Inflammation

Thomas Van Dyke is chair of the Department of Applied Oral Sciences, vice president of clinical and translational research at the Cambridge, Massachusetts-based Forsyth Institute and a lecturer at the Harvard School of Dental Medicine. He studies the role of inflammation in gum disease and its impact on systemic health.

Scientific American Custom Media: What's the relationship between gum disease and inflammation?

Thomas Van Dyke: The American Academy of Periodontology [now] categorizes periodontitis [gum disease] as an inflammatory disease induced by bacteria, rather than an infectious disease. It's not like you catch periodontal disease. All the damage that's caused is really not the bacteria destroying tissue—it's the host's response: inflammation. That creates an environment in which bacteria in the mouth overgrows: there's a feedback [mechanism] that then develops more disease.

SACM: How does oral inflammation influence other medical conditions?

TVD: All of the diseases associated with periodontitis are inflammatory diseases. Some we didn't used to think of as inflammatory, like cardiovascular disease. It's been demonstrated epidemiologically that you have excess risk for cardiovascular disease if you have inflammatory disease. In animal models, there's a pretty direct demonstration that having periodontal disease makes the [progression] of cardiovascular disease more rapid, and even possibly makes you susceptible to cardiovascular events—heart attacks—because gum inflammation elevates the systemic inflammatory response.

The same thing is true in type 2 diabetes. Basically, the pathogenesis is this: you get fat, you become inflamed, that causes insulin resistance so you have to make more insulin—to maintain

continued on next page

Q&A

with Thomas Van Dyke

continued from previous page

your blood sugar, and eventually your pancreas stops producing insulin and you become diabetic. Diabetics are much more susceptible to developing periodontal disease because their inflammatory response has been heightened.

SACM: Is it correct that you believe aspirin can help with these conditions by fighting inflammation?

TVD: It's not aspirin itself, it's molecules called lipoxins and resolvins, compounds that regulate inflammation. Taking aspirin produces these molecules that then have a longer lifetime in the blood. Some of these compounds come from your own fatty acids, and others come from dietary omega 3 fatty acids [found in nuts and fish oil]. So if you actually take omega 3 fatty acids and baby aspirin at the same time, you get increased resolvins in the blood and this dampens the inflammatory response—which then dampens the cardiovascular disease process. There's a lot of data that shows if you reduce inflammation, you reduce second heart attacks. Statins do that too, by the way.

SACM: Is this a proven treatment?

TVD: A lot of this stuff is still under investigation, but there has been significant progress in that direction. The role of inflammation in these diseases…has basically been strengthened over the past 10 years. The effects [of resolvins and lipoxins] in animal models are quite profound and are unlike anything we've been able to demonstrate with any other type of compound. But it still remains to be proven in humans.

SACM: How does taking care of oral health help fight other diseases?

TVD: "Every little bit helps" is a good way to look at it. If somebody has cardiovascular disease, it's because they have a lot of risk factors. So you lower blood pressure, you lose weight, you exercise more, etc., etc. Each one of those that you do increases the chances for a better outcome, and periodontal disease is just one of the things on the list. If you take care of it, it increases your odds.

are often the people who are most uninformed about oral hygiene. This seems to be true across the world, from developing countries in Africa, Asia, or Latin America to impoverished regions of wealthier countries.

In Spain, a nationwide dental study found that young adults from lower socioeconomic groups had twice as much untreated tooth decay as their wealthier compatriots. This also holds true in the United States, for example in Appalachia and parts of the South. A recent report by the Pew Charitable Trusts found substantial, economically driven racial disparities in dental health among U.S. children. National Health Statistics data from the Centers for Disease Control and Prevention (CDC) showed that untreated dental decay among 2- to 8-year-olds was 10 percent among white kids, 19 percent among Hispanic children and 21 percent among African American children; overall, 43 percent of preschool children had untreated decay.

Sugar is a huge factor. While eating some sugar won't necessarily rot teeth, sipping soda, juice, or sports drinks or sucking on sugar-sweetened mints frequently during the day can damage teeth. The World Health Organization (WHO) recommends that no more than 10 percent of a day's calories come from added sugar. Surprisingly, residents of some of the poorest African and Asian countries have less tooth decay than those living in Europe and North America simply because they eat less sugar, according to WHO. That's changing, however, as people in even the most remote corners of the globe gain ever-greater access to processed and sweetened foods. "If we could just get people to change their behavior in terms of nutrition, it would be huge," says Carol Summerhays, president of the ADA. She notes that limiting sugar intake not only preserves teeth, but also helps in the fight against type 2 diabetes.

This oral health crisis has sparked a global push to integrate dental care and medical care, and to improve access to dentistry. It's pressuring governments to provide better dental care for children and the elderly and to expand education on proper oral hygiene, particularly among the poor. WHO is now encouraging school curriculums to include oral hygiene in school health programs.

Head Start, a U.S. Department of Health and Human Services program that helps low-income Pre-K children prepare for school, includes an oral health component. The program ensures that infants and young children have access to dental care, fluoride treatments, and any necessary medications. It also educates kids and their caregivers about the importance of oral hygiene and visiting the dentist, using a guide developed by Colgate that includes information on brushing, flossing, nutrition—and limiting sugary foods. This guide is part of the company's "Bright Smiles, Bright Futures" program that sends a fleet of mobile dental vans to about 1,000 communities each year, offering free dental screenings to some 10 million children.

Another US campaign, the 2MIN2X initiative, encourages parents to teach their kids to brush for two minutes, twice a day, to fight cavities. A dedicated website offers two-minute videos for children to watch while they brush, and a "Toothsavers" phone app challenges them to

Illustration by George Retseck

In a "Toothsavers" phone app, kids can save the inhabitants of a fairytale kingdom from ***a tooth-rotting spell cast by an evil sorceress****—by brushing their teeth.*

save the residents of a fairytale kingdom from a tooth-rotting spell cast by an evil sorceress—by brushing their teeth.

The World Health Organization promotes water fluoridation as a broader public health solution, which Summerhays says is extremely helpful in fighting tooth decay. Community water fluoridation launched in Grand Rapids, Michigan, in 1945; within 50 years, tooth decay had dropped by 25 percent and the CDC listed fluoridation as one of the 10 great public health achievements of the 20th century. By 2012, the initiative had reached three-quarters of U.S. citizens. Although some 25 countries have established similar community programs, in 11 of these, fewer than one-fifth of the population drinks fluoridated water.

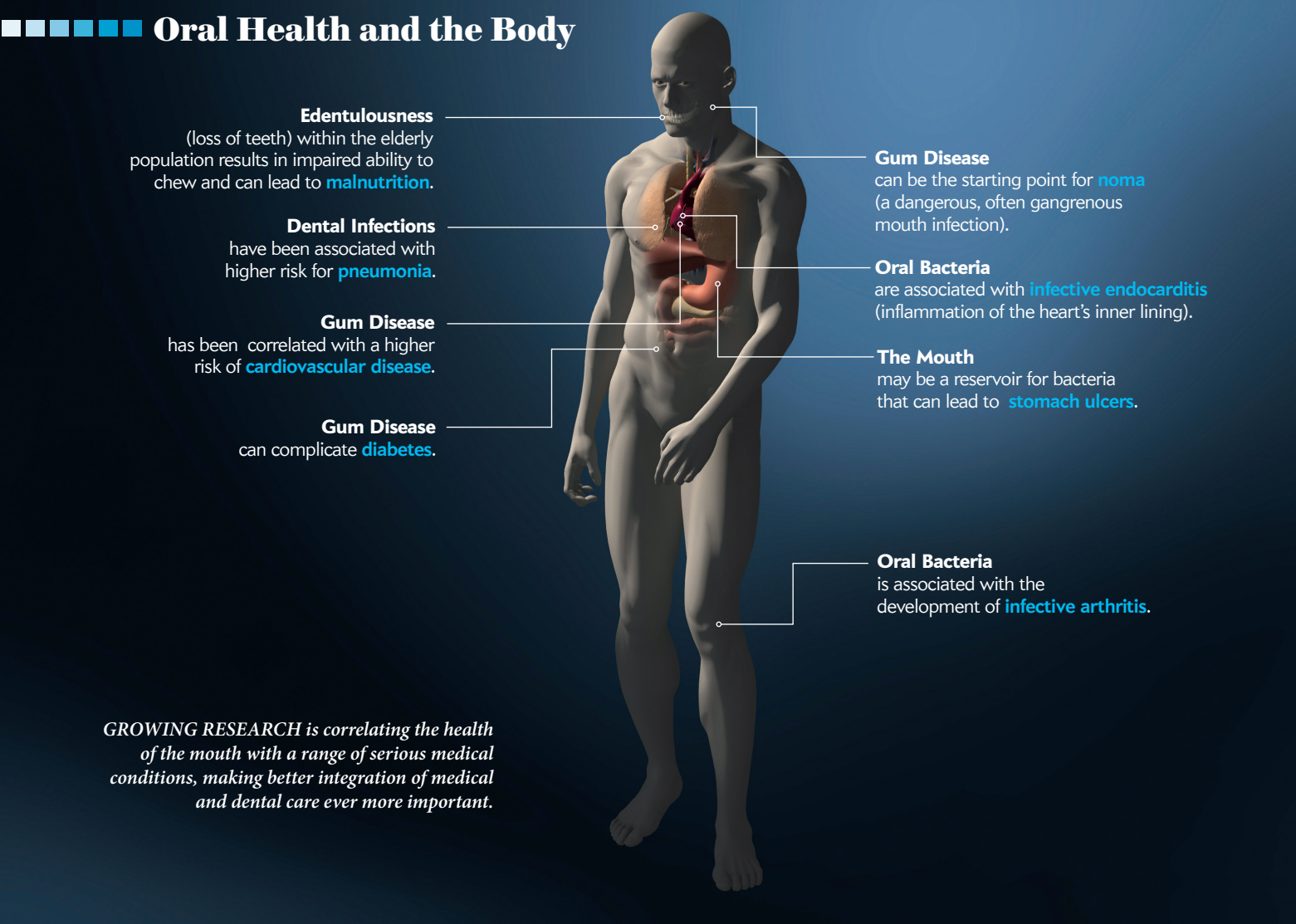
Longer in the Tooth

One of the most pressing global challenges to dental health is an aging world population. While the good news is that we're living longer and tooth loss no longer has to be a natural part of growing older, "we [are seeing] a dramatic increase in root caries," says Twetman.

With age, people grow "long in the tooth." Gums recede, exposing roots that had been protected from decay. The process may be exacerbated by certain medications that are commonly prescribed to the elderly, drugs with side effects such as dry mouth. A lack of saliva not only promotes cavities, but along with swallowing difficulties, it increases bacteria in the mouth, which can cause gum disease or even pneumonia if it's inhaled into the lungs. Across the globe, pneumonia remains the deadliest infectious disease.

But many senior citizens never see a dentist. Despite the complex needs of the elderly, oral health care for older, infirm people who are homebound or confined to nursing homes is sometimes overlooked altogether.

Oral Health and the Body



GROWING RESEARCH is correlating the health of the mouth with a range of serious medical conditions, making better integration of medical and dental care ever more important.

Treating the Whole Body

Meanwhile, the logistics of dental care are changing. Many dental schools are now training their students to practice in a collaborative, team-based manner, says Richard Valachovic, president of the American Dental Education Association. It's part of a larger trend to integrate the healthcare landscape and make care more accessible. He uses the local drug store as an example. "Pharmacists didn't think of themselves as healthcare providers 10 years ago," he says, adding that today, they administer vaccines that once required a visit to the doctor's office.

Dental offices can provide patients with an entrée into the healthcare system by screening for common health problems: at least 20 million Americans who go to the dentist each year do not see a doctor. Among them, "there are millions of hypertensives; there are a couple of million undiagnosed diabetics," says NYU's Alfano.

According to the New York State Health Foundation, about a quarter of people with diabetes and up to 90 percent of pre-diabetics don't know they have high blood sugar—while roughly 13 million U.S. adults don't realize they have high blood pressure, according to the CDC. Major health problems could be avoided by many if a standard dental exam added a blood pressure cuff and a finger-prick blood test to monitor for hypertension, high cholesterol and elevated blood sugar.

"This is really an unrealized healthcare opportunity," says Ira Lamster, a professor of health policy and management at Columbia University's Mailman School of Public Health. "You don't have to send the patient to a lab or send them back to a physician [for tests] because they're already in the office," he says. Some practices, like Delta Dental of New Jersey, are beginning to incorporate screenings for hypertension, diabetes and obstructive sleep apnea as part of standard care.

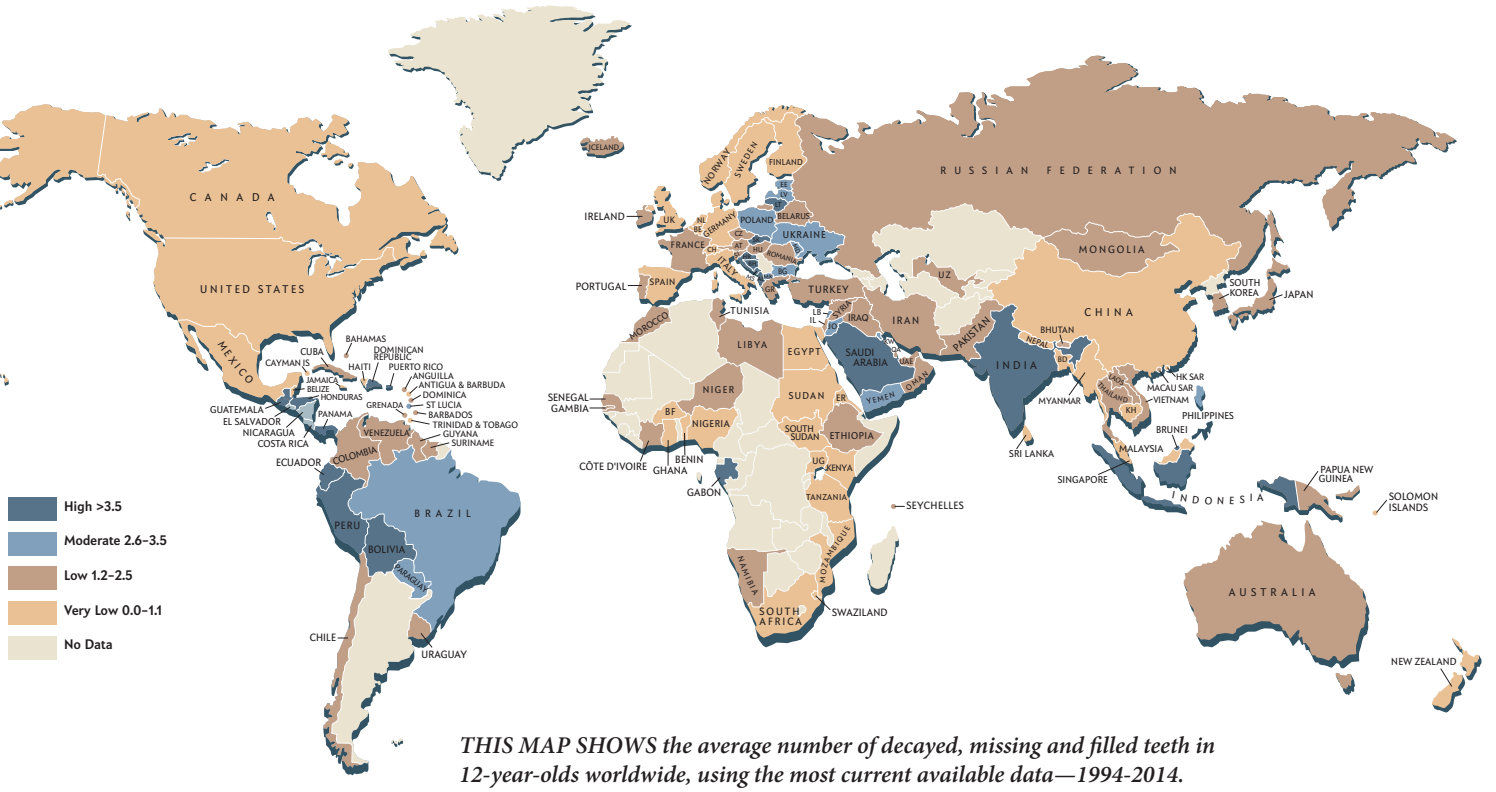
Some health centers in the U.S. have begun integrating dentistry into their practices, with dentists seeing patients in the same clinics as general practitioners, gynecologists, pediatricians and others. The Erie Family Health Centers in Chicago, for instance, have added full dental services to four of their 13 locations.

Because of his close shave with heart disease, Nabors urges his students to always get complete medical histories from their patients. His son, Thomas, has seen the value of this first-hand in his own practice. One of the most dramatic examples came during a routine screening when a middle-aged woman told him she had shortness of breath and pain in her arm. Her primary care physician had attributed the symptoms to asthma, but Thomas was concerned. He referred her to a cardiologist—who discovered that four of her coronary arteries were severely blocked, requiring immediate, life-saving bypass surgery.

A study published in 2014 by researchers from the State University of New York at Buffalo quantified the benefits of a more integrated dental-medical model. As part of patients' regular dental appointments, they tested the blood sugar levels of 1,022 people age 45 and older. About 41 percent had elevated numbers and were referred to doctors. Almost a quarter of those proved to be pre-diabetic, while another 12.3 percent were diagnosed with full-blown type 2, or adult-onset, diabetes.

Since diabetes also impacts the mouth, screening during

A Global Snapshot of Tooth Decay



THIS MAP SHOWS the average number of decayed, missing and filled teeth in 12-year-olds worldwide, using the most current available data—1994-2014.

a dental exam has clear benefits. People with diabetes develop gum disease at about three times the rate as those with normal blood sugar levels, and as their gums recede, they often develop cavities in the exposed roots of their teeth. They are more vulnerable to *Candida*, a type of yeast that can infect the mouth, and may suffer from burning sensations in their mouths or painful, swollen salivary glands. Other evidence shows that people with diabetes and moderate to severe periodontal disease are twice as likely to have kidney problems. There are feedback loops in the other direction, too: tooth loss from severe periodontal disease makes it harder to eat well, making it more difficult for those with diabetes to manage blood sugar.

Regular dental care that addresses broader issues not only makes us healthier, but it saves money, too. A 2016 study published in the journal *Health Economics* examined insurance claims from 2006 to 2011. Researchers found that when newly-diagnosed type 2 diabetes patients were treated for gum disease, within three to four years their healthcare costs were about $2,000 less than those who were untreated. Even though medical and dental insurance in the U.S. are separate entities, some health insurance companies are now realizing that it's better for their bottom line to offer dental coverage to diabetic patients.

'Part and Parcel'

Despite the potential for improved wellbeing and lower costs, much of the world has not yet integrated dental and medical care. One exception is Malaysia, where the Ministry of Health has made dentistry part of its overall health system. The government provides dental care for some 80 percent of the country's population, says Rahimah Abdul Kadir, pro-chancellor of Lincoln University College in Petaling Jaya and former dean of the college's dental school. In Malaysia, dentists make annual visits to schools and children's oral care is fully covered until they turn 18. Because pregnancy often causes inflammation and bleeding of the gums, prenatal clinics offer free dental checkups. Basic services such as fillings, extractions, and dentures are available for adults at low cost.

Outreach teams travel into the countryside to provide services to those who don't live near clinics. Kadir notes that as part of a commitment to meld oral and medical care, "we've developed health centers where dental care is part and parcel of the whole clinic. We don't actually have special dental clinics standing all by themselves. That was the old days."

As former president of both the Asian Academy of Preventive Dentistry and the South East Asia Association for Dental Education, Kadir has a broad perspective on the general state of oral health across the region. Dental care in other former British territories, including Hong Kong and Singapore, is also superior to many other parts of Asia, she says. China is one country in need of better care: the latest survey found that 94 percent of the population suffers from some kind of dental problem, but there are only about 100 dentists for every million people, compared to 1,736 per million in Singapore.

Imperfect Coverage

While the mouth is not separate from the rest of the body, most insurance companies treat it that way, and both checkup and treatment costs can be prohibitive. The Affordable Care Act, which took effect in 2014, gave low-income children in the U.S. greater access to dental care through the Medicaid program. However, it didn't bestow dental care on everyone. Medicaid is administered by individual states, and while most pay for emergency dental services for poor adults—such as dealing with a broken or abscessed tooth—fewer than half provide comprehensive or preventative care such as cleaning and scaling. Five states—California, Colorado, Illinois, South Carolina, and Washington—added dental coverage as part of the Affordable Care Act, but have struggled to pay for it.

It all comes down to money. State legislatures find it hard to come up with the tax dollars to pay for Medicaid dental coverage, Summerhays says, adding that many dentists are reluctant to see Medicaid patients because it places a financial strain on their practice. In California, reimbursement to dentists is just 30 cents on the dollar; in Illinois, it's less than the cost of dental supplies. The "Santa Fe group," a consortium of academics and business leaders, are lobbying to expand Medicaid coverage, arguing that it will improve overall health—and more than pay for itself.

Although it's not enough to address the scope of the problem, the Health Resources and Services Administration announced in June 2016 that clinics in 47 states, the District of Columbia and Puerto Rico will receive an extra $156 million in oral health funding, allowing them to hire about 1,600 new dental professionals to treat 785,000 new patients.

Countries with government-sponsored health coverage don't always fare better. Coverage in Canada, for instance, is very similar to the U.S., Vujicic says, and perhaps not as wide, since there is no equivalent for care to low-income children. The publicly-financed system covers only a specific subset of dental surgeries performed in hospitals, and provides limited benefits for seniors and First Nations people. For the most part, oral care is excluded, and about two-thirds of Canadians pay for private dental insurance. Across the Atlantic, the U.K.'s National Health Service includes most types of dental care, but patients pay half. In fact, dental care is financed through out-of-pocket spending and private insurance in almost all of the world's 35 member countries that are part of the Organization for Economic Co-operation and Development. Only two members, Japan and the Slovak Republic, offer wide, state-funded coverage.

Despite the challenges, dental care is likely to evolve rapidly, the experts say. Some of that progress will come through new technologies, such as breath analyzers that can detect periodontal disease and saliva tests that identify oral infections. Greater understanding of the biology of oral and other diseases—in combination with public education that teaches dental hygiene—will help to diminish rates of dental disease. And some insurance companies are beginning to consider the notion that paying for dentistry may lower medical costs overall by preventing serious, costly conditions. "Things are going to change very rapidly in the next 10, 20 years," predicts the ADA's Summerhays.

Meanwhile, Kadir is collaborating with international organizations from her home base in Malaysia. Her hope: in a decade, most of the world will have the same access to quality dental care that's available to citizens in her own country.

Map by George Retseck

Oral Health
Facts & Stats

Findings from various organizations help give an assessment of the state of oral health, both in the U.S. and around the world. When viewed graphically, the issues that most impact oral health can be quickly identified. This brief selection of data pinpoints some of these problem areas.

Infographic by Lucy Reading-Ikkanda

REASONS FOR VISITING THE DENTIST

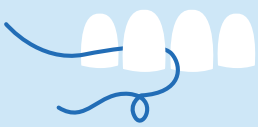
95%
of people believe that regular dental visits keep them healthy

77%
of adults say they plan to visit the dentist in the next year

37%
visit the dentist each year

KEY FACTS

One in four
adults in the U.S. admits they don't brush twice a day



One in three
have never flossed their teeth

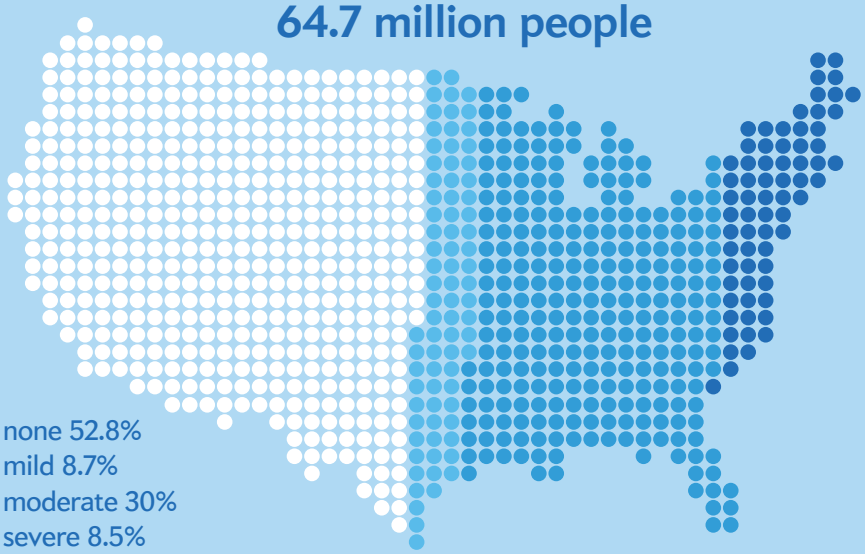
One in four
avoids smiling due to the condition of their mouth and teeth

Worldwide, nearly **100%** of adults have had dental cavities

60–90%
of school children have dental cavities

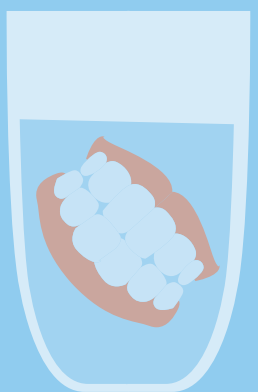
GUM DISEASE

In the U.S., **47.2%** of adults aged 30 and older have periodontitis—
64.7 million people



- none 52.8%
- mild 8.7%
- moderate 30%
- severe 8.5%

AROUND THE WORLD



Globally, about **30%** of people aged 65–74 have no natural teeth

Each year **500,000 new cases** of oral cancer are diagnosed and oral cancer leads to **150,000 deaths**

SOURCES (alphabetical): *American Dental Association, smilemonth.org, The Global Oral Cancer Forum, Journal of Dental Research, Kaiser Health News, National Children's Oral Health Foundation, National Institute of Dental and Craniofacial Research, World Health Organization, U.S. Centers for Disease Control and Prevention*

REASONS FOR NOT VISITING THE DENTIST

59% Cost

22%
Afraid of the dentist

19%
Inconvenient time/location

15%
Trouble finding a dentist

12%
No original teeth

10%
No perceived need

9–10%
Other or no reason

ACCESS TO CARE

Uninsured children are
2.5 times less likely
than insured children to receive dental care

Poor children **suffer twice as many dental caries** as their affluent peers

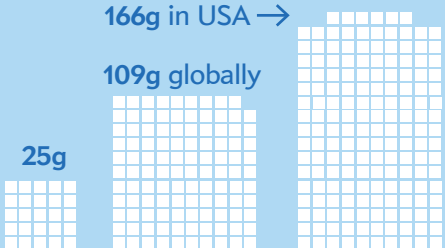
HEALTH RISKS

WHO recommends limiting daily consumption of sugar to 25g.
In 2011, the daily sugar intake was:

166g in USA →

109g globally

25g

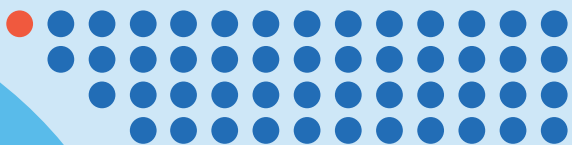


Smokers remain
3 times
more likely than non-smokers to lose all their teeth

COST

In 2010, the cost of dental diseases worldwide was
$298 billion

$1 spent on oral health preventive measures...



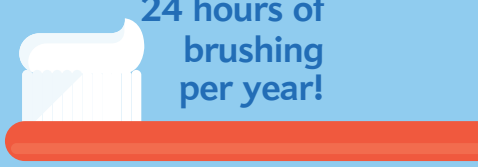
...saves American taxpayers
as much as $50
on restorative and emergency procedures for the under- and uninsured

In 2012, the cost of dental services in the U.S. was
$111 billion

TIME

Hours lost in the U.S. each year due to oral health problems:
51 million school hours and **164 million work hours**

Brushing teeth twice per day for a total of 4 minutes equals
24 hours of brushing per year!



A Gee-Whiz Guide to the Future

Coming Soon: Hi-Tech for Teeth

by Sharon Guynup

The future of dentistry looks very different from today: ***no drills, no injections, greater emphasis on prevention*** *that translates into fewer cavities and less periodontal disease, easier access, and shorter treatment time.*

You awaken in the middle of the night: that tooth that's been a little sensitive lately is throbbing. By morning, you realize you have a real problem. So you head into the bathroom, plug your smart toothbrush into your smartphone—and when you put the brush in your mouth, it scans your teeth. The images automatically upload to the Cloud. They are analyzed by artificial intelligence, which finds a cavity in your aching tooth and a hairline crack in another molar. The scans and preliminary analysis are transmitted to your dentist, who then texts you to schedule an appointment.

Later that day, in the office, the dentist removes the decay that etched a cavity into your tooth—with a laser. It makes the procedure painless: there's no need for novocaine. Much of the cracked tooth is removed and it will require a crown. Then an office technologist does a 3-D ultrasound of the two problem teeth—x-rays, like dental drills, have become a thing of the past—and transmits the scans to two separate devices.

One instantly mixes a "biologically active" restoration to fill the cavity, but it's not the old-time silver mercury or white acrylic. It uses stem cells to rebuild the tooth's dentin—the bony tissue that lies beneath the white enamel. A second machine, a 3-D printer, manufactures a cap for the other tooth while you wait, which your dentist pops right in without the need for adjustments because production has become so precise. These procedures that once required multiple visits are completed in just over an hour.

Sound like a scene out of *Star Trek*? It's actually a peek into the future of dentistry, says Larry Emmott, a dentist and dental technology expert. "Much of this, I think, is possible within the lifetime of dentists practicing today."

Digital Dentistry

The digital revolution that is transforming every aspect of our world is also impacting dentistry and medicine in a multitude of ways, from electronic record-keeping and data analysis to new diagnostic tools, novel prevention methods—and revolutionary treatment options. "The future is wide open," says Emmott.

Experts say that technological innovation will ultimately improve and broaden access to dental care, allowing for same-day care that translates to fewer office visits—making a healthy smile more affordable.

As more high-quality digital information becomes available to researchers, the potential

Kenn Brown, Mondolithic Studios

Notes
SURGEON: John Doe, DMD
Appointments
Surgery Results
Previous Visit
Dental Record

200 Years of Dental Innovation

1815 New Orleans dentist Levi Spear Parmly is credited as the inventor of **modern dental floss.**

1839 Charles Goodyear invents the **vulcanization process for hardening rubber.** This material, Vulcanite, easily molds to the mouth and makes an inexpensive base for false teeth. It will become a dentist's dream material.

1864 Vulcanized rubber is used to make the **Vulcanite denture.** It substitutes for difficult and costly gold dentures, allowing dentists to supply dentures at lower cost.

1866 Lucy Hobbs Taylor is the **first American woman to graduate from dental school.**

Lucy Hobbs Taylor

1875 **The first electric dental drill** is patented by George F. Green.

1884 Carl Koller uses cocaine as a **topical anesthetic.**

CREDITS: Science Photo Library (floss, false teeth base, early dental x-ray); Cocaine bottle courtesy of Paravis; Porcelain crown courtesy of Harvey Passes, D.D.S.

for more precise diagnosis and treatment only continues to grow. Data including your age, medical and dental health history, as well as your genome, will, for example, allow dental professionals to pinpoint your susceptibility to various types of oral disease. In the near future, doctors and dentists will increasingly tailor treatment to your personal genetics, making choices reflecting what has proven most effective for your genome and your particular physiology. Or they may even decide how to best treat you based on the specific bacteria that's causing your problem.

A significant part of this revolution is the ongoing development of diagnostic tools that are able to analyze our physical condition with ever-greater precision. That includes advanced digital imaging, like a currently available system called the Canary. During a three-second scan, an electric toothbrush-sized device emits pulsing red laser light; it may detect cracks and caries that are too small to show up on an x-ray. Another device, the "S-Ray," ultrasonically maps both teeth and gums in 3-D to find cavities and disease. Upon approval from the U.S. Food and Drug Administration, experts think s-rays may be cheaper than x-rays. What's more, neither of the two systems expose patients to harmful radiation.

Next-Generation Diagnosis and Treatment

Lasers are now being used in both diagnosis and treatment. Dentists are using "soft tissue lasers" for minor gum surgery—but down the road, they may hand these procedures over to computers. "Hard-tissue lasers" could ultimately replace whining high-speed dental drills, removing tooth decay with the aid of tiny, digitally-controlled mirrors. However, the hefty price tag on these devices will have to come down before they are widely used.

New breakthroughs are creating "biomaterials" to fill cavities. For example, a joint project between Harvard and the University of Nottingham has created a synthetic biomaterial that could essentially allow a cavity to heal itself, a development with the potential to greatly reduce tooth deterioration that leads to expensive, painful root canals.

Some advances will allow initial ***scanning to be done at home*** *or at a community health clinic with a smartphone*

Earlier detection of oral cancer—the sixth deadliest form of cancer—is now possible. The "VELscope" device uses CSI-style blue lights to pick up tissue changes that can't be seen with the naked eye, highlighting potential problems that may call for a biopsy.

A more futuristic outlook could include nanobots. Some of these microscopic machines might restore or straighten teeth, deliver anesthesia during oral surgery, diagnose diabetes and other diseases, or treat oral cancer. Others may fight bacteria with products like a "wearable toothpaste" made of antimicrobial carbon nanotubes. But nanotech research is complex, and these developments lie far in the future, as human clinical trials would be necessary to determine both efficacy and safety.

Bioprinting

Even with these advances, teeth will sometimes need to be replaced with a cap, crown or a bridge. Current technology uses

Willoughby Dayton Miller, an American dentist in Germany, notes the **microbial basis of dental decay** in his book *Micro-Organisms of the Human Mouth*. This generates an unprecedented interest in oral hygiene and starts a worldwide movement to promote regular toothbrushing and flossing.

1890

Colgate introduces its **toothpaste in a tube** similar to those used today.

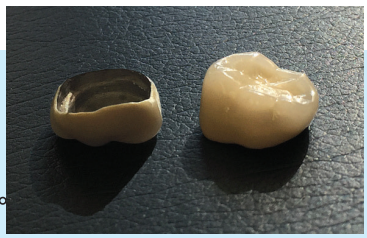
1896

Charles Edmund Kells

New Orleans dentist Charles Edmund Kells takes the **first dental x-ray of a living person** in the U.S.

1899

Edward Hartley Angle classifies the various forms of malocclusion. Credited with making orthodontics into a dental specialty, Angle also establishes the **first school of orthodontics.**

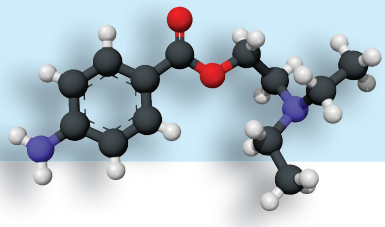


1903

Charles H. Land fashions the **porcelain jacket crown.**

1905

Alfred Einhorn, a German chemist, formulates the **local anesthetic procaine**, which is later marketed under the trade name **Novocain.**



Computer-Assisted Design/Computer-Assisted Manufacture (CAD/CAM) to mill a tooth from a 3-D scan. 3-D printing is the next phase, with a frenzy of research reaching for this Holy Grail. Some, like a group at the University of Groningen in the Netherlands, are working with recipes that could add tooth decay-fighting chemicals to 3-D printed teeth.

Other types of "bioprinting" are also on the horizon. A team at Wake Forest University in North Carolina has printed out human body parts from a mixture of live cells and gel that is laid down in layers to construct living human tissues. They successfully "built" a jawbone—and while use in patients is years away, such an innovation could benefit those who develop oral cancers.

Across the globe in Australia, periodontist Saso Ivanovski from Griffith University in Queensland has engineered replacements for eroded jaw bone and gum tissue from a patient's own cells. Up until now, dental surgeons have had to remove bone and tissue from the hip or skull for restoration procedures. Pre-clinical trials will begin in 2017.

Innovating Prevention

A host of dental care innovations focus on prevention. For example, manufacturers are now designing toothbrushes with all kinds of gizmos: cameras and location tracking technology that show you the parts of your mouth where you're not brushing enough; a timer that keeps track of how long you brush and syncs with apps that keep you entertained for the two minutes you're supposed to brush; and pressure sensors that warn if you're brushing too hard. Other innovators are attempting to create sensors that could detect various diseases from saliva or mouth tissue, could monitor heart rate, detect blood alcohol levels—or sense bad breath.

A mouthpiece outfitted with a pH sensor could detect acidic saliva—a risk factor for tooth decay and gum disease—without having to send a sample to the lab and wait for results or pay costly fees. Testing chemicals in your breath could diagnose possible diabetes, which is not only a serious illness in its own right, but also exacerbates gum disease.

Democratizing Dental Care

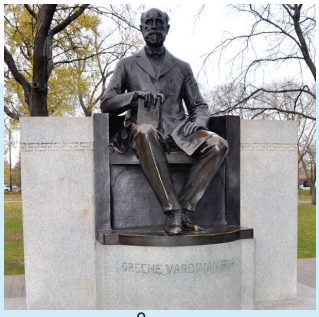
Some advances will allow initial scanning to be done at home or at a community health clinic with a smartphone. These technologies will democratize dental care, allowing quick diagnosis of basic problems for people anywhere—even those who live in remote areas or in places where there are few dentists. Ultimately, someone living in a developing country could upload their information and get the same initial analysis as a New Yorker who sees a high-end Madison Avenue dentist.

With the advent of these techno-innovations, basic imaging and other diagnostics won't need to be done by highly-trained professionals. Soon, technologists will become an integral part of a dental practice, and dentists will focus on the complex, difficult procedures that require their expertise. This should ultimately lower costs.

The future of dentistry looks very different than the practice of today: no drills, no injections, easier access, and shorter treatment time. Overall, there will be a greater emphasis on prevention that translates into fewer cavities and less periodontal disease. The predictions: dentistry will increasingly provide nice, white, healthy smiles.

As Emmott says, "The future is coming, and it will be amazing!"

200 Years of Dental Innovation



Greene Vardiman Black

1908

Greene Vardiman Black, the leading reformer and educator of American dentistry, publishes his monumental two-volume treatise *Operative Dentistry*, which remains the essential clinical dental text for 50 years. Black later develops techniques for filling teeth, standardizes operative procedures and instrumentation, and develops an improved amalgam.

1917

Connecticut resident Irene Newman receives the **first dental hygienist license.**

1937

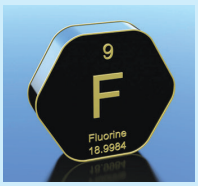
Alvin Strock inserts a **dental screw implant made of Vitallium**—an alloy of cobalt, chromium and other substances—which becomes the first successful biocompatible implant metal.

1938

The first **nylon toothbrush** appears on the market.

1945

Grand Rapids, Michigan, becomes the first city in the world to **fluoridate drinking water.**

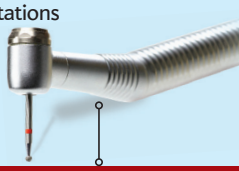


1955

Michael Buonocore formulates **white (composite) fillings**. He also details a method of bonding resin to tooth enamel, enabling dentists to repair cracked enamel on front teeth.

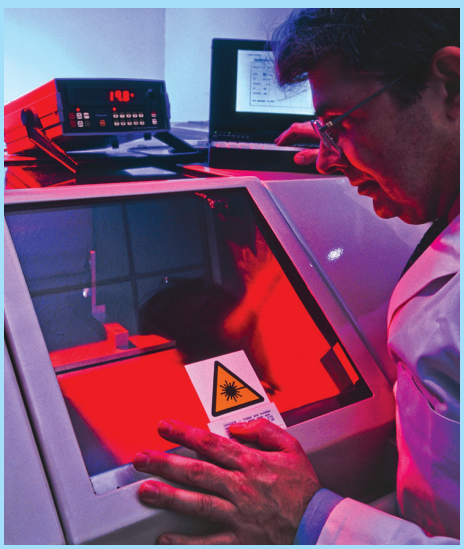
1957

John Borden invents a **high-speed, air-driven hand drill**, increasing drill power from the traditional 5,000 rpm (rotations per minute) to 300,000 rpm.



Tech Gallery

No longer a fantasy, these products and technologies are available



HARD TISSUE LASERS

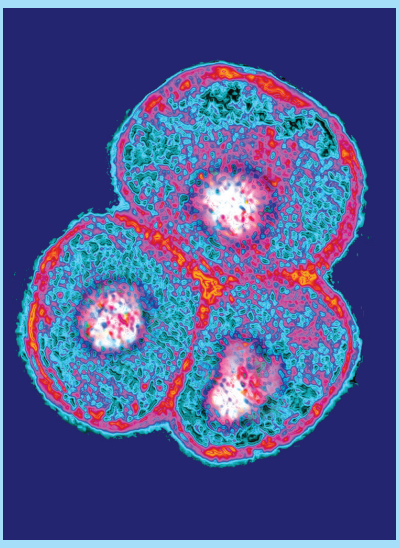
WHEN Currently in use, although limited

USE Gum surgery using soft tissue lasers is relatively painless and heals rapidly. Hard-tissue lasers are now being introduced to treat tooth decay—and may someday replace today's high-speed dental drills.

SMART TOOTHBRUSHES

Currently in use

Sensors and microchips now track the amount of time spent brushing, pressure used, brushing habits, and more, and send data to smart electronic devices via Bluetooth. Smart brushes may soon be able to detect certain diseases as well.



BIOMATERIAL

Currently under development

A new type of filling made of synthetic biomaterial stimulates the growth of stem cells in the pulp of decayed and drilled teeth—essentially regrowing teeth.

CREDITS: Timeline – Science Photo Library (dental screw implant, nylon toothbrush, high-speed drill
Gallery – *Science Photo Library (lasers, bomaterial, nanobots); ONVI (smart toothbrush)*

1958 — The **first fully reclining dental chair** is introduced, allowing patients greater comfort and enabling the dentist to use an assistant to help with procedures.

1960 — **The electric toothbrush,** invented in Switzerland post–WWII, is introduced in the U.S.

1960s — **Sit-down, "four-handed" dentistry** becomes common as most dentists engage dental assistants to help with procedures

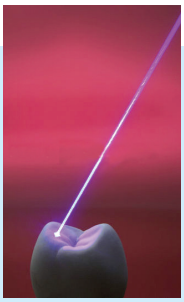
1965 — Per-Ingvar Brånemark inserts a **titanium dental implant** into a volunteer patient who has no bottom teeth. By 1980, he proved that titanium could be successfully integrated into living tissue.

Early panoramic radiograph of a titanium implant.

1989 — The first commercial **at-home tooth bleaching** product goes on the market.

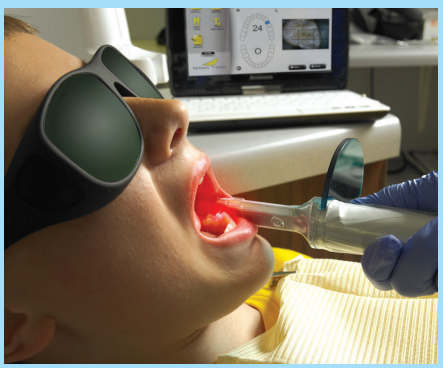
1990s — The **first effective "invisible" braces** made of clear plastic are invented, offering an alternative to traditional braces.

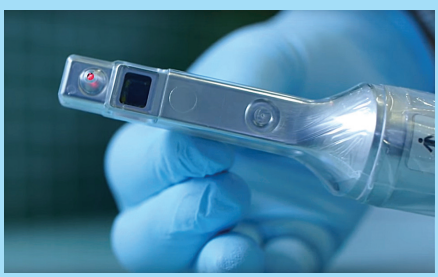
1996 — **Hard tissue lasers** are approved by the U.S. Food and Drug Administration for use on enamel and dentin to treat tooth decay.



2000s — A growing body of **research correlates oral health to overall health.**

now, or will soon be here.





3-D PRINTED TEETH

Entering use

3-D printers can manufacture a crown, tooth, bridge or orthodontic appliance in minutes—and new research is seeking to incorporate antibacterial chemicals into replacement teeth that will fight decay.

TOOTH DECAY-DETECTING LASERS

Currently in use

The Canary is an advanced digital imaging tool. This electric toothbrush-sized device emits pulsing red laser light that may detect cracks and caries that are too small to show up on an x-ray—in about three seconds.

NANOBOTS

Twenty years or more

In the coming decades, nanodentistry may turn to microscopic, computer-directed nanorobots to diagnose or treat oral cancer and other diseases, destroy cavity-causing bacteria, deliver anesthesia, clean, repair, fill and straighten teeth, replace damaged bone—or other things we haven't yet imagined.

CREDITS: Timeline – Science Photo Library (electric toothbrush; invisible braces; hard tissue laser); Harvey Passes, DDS (four-handed dentistry)
Gallery – *123RF, Alexander Kharchenko (3-D printed teeth); The Cannary System (decay-detecting laser)*

Healing Thyself

Power to the Patient

By Monica Heger

The dentist's office of the future will have little resemblance to the small private practices that many people visit today: offices staffed by one or two dentists and a handful of hygienists who may have treated the same families for generations. Within a decade, dentistry will become increasingly digitized, flexible and mobile—not just in industrialized countries, but around the world. Dentists who are part of the Millennial generation are already approaching their practice in a vastly different manner than their predecessors. Dentistry is going through a big transition, says Marko Vujicic, chief economist and vice president of the American Dental Association's Health Policy Institute.

While dentists may continue to spend most of their time practicing in an office, they will increasingly rely on new technologies, cameras, an Internet connection, and greater collaboration. They will need to coordinate with professionals who perform cleanings and take x-rays at schools, in the homes of the sick or elderly, at pharmacies, and in community centers, assisted living facilities or mobile dental clinics.

It is a diverse set of patients with differing needs and motivations who are unwittingly driving these changes to the practice of dentistry, from the youngest to the oldest: children, Millennials, and the elderly. Early intervention has become a major focus, with a strong emphasis on preventing damage to children's teeth. At the other end of the spectrum, while more elderly people are growing old with most of their teeth intact, many cannot afford dental care or have difficulty getting to a dentist's office. For Millennials, there are a completely new set of issues: this generation is proving to be less loyal to a specific dentist than their parents have been, and will shop around for a practitioner who charges what they want to pay, is nearby, offers a broad slate of appointment times, and meets their expectations of care.

Together, these various patient populations are moving dentistry towards a more accommodating, on-demand model. Within this new paradigm, there is a greater emphasis on prevention and innovative modes of treatment, which experts say will ultimately reduce cost and bring care to hard-to-reach patient populations.

The Uberization of Dental Care

Consumers increasingly want instant everything, from takeout food and TV shows to taxis, and that list now includes oral health care. "It's not a matter of if, but when dentistry becomes 'Uberized,'" says Lynn O'Connor Vos, CEO at greyhealth group, a healthcare communications company.

Vos says that many, especially Millennials, are demanding more convenient dentistry, including evening and weekend appointments. She predicts that soon, some patients will want home visits, which could be possible via telemedicine.

The Millennial generation finds—or changes—a dentist almost as they would locate a restaurant: by reading reviews on Yelp or ZocDoc, says Vujicic. He notes that it's a growing trend, and many patients do online research before making a choice. "Savvy patients today are looking at quality and cost information before they're even picking up the phone to call providers," he says.

It's a global phenomenon. Filippo Graziani, a periodontist and a professor at the University of Pisa in Italy, says that the percentage of new patients who find him on the web has jumped from about four percent a decade ago to 15 percent today. Having an online presence and using social media to communicate with patients is becoming increasingly important, he says.

How has the empowering of patients affected dentistry? And what technologies have fueled it?

The answers are both surprising and encouraging.

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An unintentional benefit of "Uberized" dentistry is the impact on those who live far from a dentist—and the importance for older patients. People are living longer, and seniors, along with many people living in rural areas, are often physically unable to get to a dentist. However, Vos says, in many cases, "teledentistry" can help, with a patient or caregiver texting or emailing cell phone pictures of a problem tooth to a dentist, who then may be able to make a diagnosis from these images and recommend the next steps in treatment. Dentists can also use FaceTime or Skype to monitor a patient's recovery following a serious procedure.

Already, there are examples of mobile dental care in the U.S. Mark Driscoll, a 59–year-old who lives in Montana, is wheelchair-bound due to multiple sclerosis. A dental hygienist visits him quarterly. She brings a "portable dentist" machine that resembles—and is about the size of—a carry-on roller suitcase. Driscoll says the hygienist worked with him to improve his daily oral care habits and helped him find a dentist who was able to handle more complex procedures—like removing his wisdom teeth. "We all deserve a nice smile," he says.

Another potential way to reach elderly patients is through partnerships with pharmacists, says Ann Spolarich, director of research at the Arizona School of Dentistry and Oral Health. While older adults may not see a dentist consistently, many do go to a pharmacy on a regular basis, she says. Spolarich is currently training pharmacists to counsel older adults on oral health, and envisions drug stores one day becoming community centers for dental care. She pictures a situation where dental hygienists offer basic cleaning and preventative care, along with vaccines, screenings and other minor treatments currently offered at drug stores. "Pharmacists are optimally positioned to partner with dentists," she says.

Google 'Gum Disease'

A simple Internet search now gives patients a wealth of information on oral health. Joshua Austin, a 36-year-old family dentist in San Antonio, says it's not uncommon for his patients to show up for an appointment with their own ideas about how to treat—or not to treat—their dental problems.

Sometimes a patient comes to him for a second opinion, armed with paperwork detailing another dentist's recommendations. That's great, he says, because they care about their health and want to weigh all possible treatment options. He welcomes the opportunity to discuss the alternatives. "Any time you empower someone to make a decision, it's in everyone's best interest because they have some buy-in and accountability," he says.

The sheer number of websites and blogs devoted to oral health care has changed the conversation with patients, says Chris Salierno, another Millennial dentist who is based in New York. While he generally finds that background research is beneficial, he cautions that there is a lot of misinformation online. For example, he's had a "small subset" of patients who cannot be convinced that a root canal doesn't cause cancer—a myth that patients sometimes stumble across in web searches.

In general, practitioners are trying to encourage people to take a more active role in their oral health. One method uses "motivational interviewing" that asks patients lifestyle questions on diet, brushing habits, whether or not they smoke, and more. This method engages them directly, which is more effective than simply telling patients to brush or floss more, says Colin Reusch, senior policy analyst of the Children's Dental Health Project. The reason: it empowers individuals to take positive steps to improve their own health, he says, and because of this, motivational interviewing has the potential to shift the paradigm. A study published last year in the *Dental Research Journal* found that plaque and gum disease were lower in children whose families were engaged in this kind of education. Another recent study, published in *Frontiers in Psychology*, found that adults who receive motivational interviewing floss more frequently.

Reaching Underserved Communities

The needs of patients have always influenced health care. For example, in the 1960s the Australian government realized that kids, particularly those living in remote parts of the country, did not get adequate dental care and only saw a dentist when they had problems. Building on a model developed in New Zealand in the 1920s, the government soon opened the first dental therapy schools in Tasmania and South Australia, training dental therapists to offer routine care to children. The program then stationed therapists within underserved populations, sometimes basing them in schools to do checkups, cleanings and fill cavities.

Julie Barker, who is the former president of the Australian Dental and Oral Health Therapists' Association, says she was drawn to the profession because of the focus on prevention and patient education. "When I was a kid, I only went to the dentist when I had a toothache," she says. "Not once did my dentist tell me that cavities were preventable."

The success of that model brought the realization that dental therapists could provide services in many other settings, says Julie Satur, an associate professor of oral health at the University of Melbourne. In the 1990s and 2000s, Australia passed legislation expanding the role of dental therapists. Training, which up until then had been done by the government, moved to universities in an "oral health therapist" program that enabled graduates to work autonomously in private practices and to work on adults. Dentists still address patients with more complex needs.

But even those living far from the nearest city in the vast

Illustrations by Michael Glenwood Gibbs

Outback or other remote areas can now get regular care for their teeth: more than 1,000 registered dental therapists and nearly 1,300 oral health therapists now work across Australia. Satur predicts that with increasing demand, that number will only continue to grow.

Both therapists and hygienists are trained to clean teeth, provide preventative care and assess oral health. Dental therapists can typically also perform some restorative work, and may have more autonomy, although their exact roles vary by country. Currently, dental therapists operate in 54 countries, from Canada to South Africa, and Thailand to Hong Kong and the Pacific Islands, predominantly treating children. Europe lacks dental therapy programs, with the exception of the U.K. and the Netherlands. However, some hygienist programs in Europe are now considering expanding their curriculums to include training in restorative care.

In the U.S., the need for affordable, accessible care is real. More than 100 million Americans don't have dental insurance. Medicaid offers little care for low-income Americans and Medicare does not offer dental coverage for older adults. In 2009, Minnesota became the first state to allow licensing of dental therapists; by April 2016, 56 were practicing. Maine passed a law allowing dental therapists to practice in 2014, followed by Vermont in 2016, and a handful of other states are considering similar rules. Oregon and Washington both have pilot programs. In Alaska, dental therapists work within the Alaska Native Tribal Health Consortium under a federal program. Each of these states stipulates that dental therapists serve primarily underserved populations, working in schools, hospitals, public health clinics, or if in private practices, they must see a certain percentage of low-income patients. A study conducted by the Minnesota Department of Health found that clinics employing dental therapists are able to care for far more patients while providing the same quality of care people would receive in a traditional dentist's office.

Therapists also serve an educational role. When they were first licensed in Minnesota, Sylvonna Jackson's parents brought her to a dental therapist for basic care. Sylvonna, who's now 18, still sees the same woman. She says that in addition to performing cleanings and fillings, she "gave me good advice on what I should do to stay healthy."

A global review of dental therapy by the W. K. Kellogg Foundation in 2012 found that overall, it's helped increase access to oral health care. In 2015, 228 dental therapists worked in schools and other public sector practices in Singapore, and in Hong Kong, more than 95 percent of children participated in dental therapist-run school programs. Countries without dental therapists are trying to reach those in need of care through free clinics, the use of teledentistry, and other methods, but in many nations, there is still a big gap.

Flormaria Batista, a doctor of oral medicine at Pontificia Universidad Católica Madre y Maestra in the Dominican Republic, has provided dental care to poor communities for the last five years. "I was surprised to see that the majority of my patients were largely unaware of basic dental hygiene techniques," she says. Across the country most people do not receive preventative care and only see a dentist when they have a serious problem, which, she notes, "is very detrimental to patients."

However, there has been a push to promote education, and both private and public institutions are reaching out to low income communities, says Batista. For example, universities have set up inexpensive clinics throughout Santiago, the second-largest city, to provide services at about a third of the cost of a private clinic. Although teledentistry is not yet widespread, Batista says they are exploring ways to utilize technology to reach patients. One possible model is in use in neighboring Puerto Rico, where dentists are using webcams to follow up with patients after they've had a tooth removed or had other surgical procedures to make sure they are healing properly, she says.

Many countries lack comprehensive oral hygiene education. In India, a 2012 survey conducted by the Indian Market Research Bureau found that only half of Indians brushed with a toothbrush and toothpaste. The survey also revealed a huge disparity in oral health between urban and rural populations because dentists in India are disproportionately concentrated in cities. There is one dentist for every 10,000 people in India's cities, but that ratio drops to one in 150,000 in the countryside. The Indian Dental Association is now using traveling dental vans and free dental camps as part of a national campaign to improve oral health by 2020.

With growing global attention on prevention, and dentistry becoming more mobile and flexible in order to better serve the next generation, it is somewhat surprising that Betsy Woodson-Myles, a semi-retired 71-year-old in Washington State embodies the dental patient of the future.

Woodson-Myles prioritizes her health and still exercises five days per week. She does not have dental insurance, but gets regular cleanings for $92 from a hygienist who brings portable dental services to the Anacortes Senior Center, and she visits a traditional dentist when she needs more extensive work. She also takes an active role in her own care, asking her hygienist specific questions about the state of her mouth, like whether her chipped tooth has started to decay. She says her hygienist also informs her about various types of treatment. Woodson-Myles then brings that knowledge to her dentist, which facilitates communication about her options with better understanding of treatment recommendations and those procedures—such as a recent discussion on the pros and cons of getting a crown versus a composite filling. Empowered, indeed.

All Hands on Deck!

Attention on Prevention

by Renee Morad

Karen Sokal-Gutierrez has observed babies given soda in baby bottles, and learned of young children who were given ***"candy for breakfast, a chocolate bar for lunch and a bag of chips for dinner."***

In January 2010, 11 men and women boarded a flight from New York to the tiny island of Grenada, a palm-treed Caribbean paradise ringed by white sand beaches and a crystal turquoise sea. But the group wasn't on vacation. This was a team from New York University's College of Dentistry, and they'd come to assess the dental health of Grenada's children. For the next two weeks, they dragged tanks of compressed air, lights and other equipment into schools, transforming classrooms into makeshift dentist offices. They examined 1,075 kids from two age groups—six- to eight-year-old elementary school children and young teens, 14 and 15 years old—and they made an alarming discovery. Eighty-three percent had cavities. And not just one, but an average of nine: Grenada had one of the highest rates in the world.

There were a host of reasons. Many of the country's 26,000 children had never seen a dentist and didn't own a toothbrush, or if they did, they didn't brush regularly. With a growing junk food industry, they drank lots of soda and ate sugary snacks—which were even sold in schools. The country had no water fluoridation program.

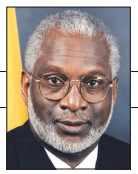
The situation amounted to a crisis that the island's dozen or so dentists could not fight alone. But there was hope. Grenada had a fairly sophisticated health network, a strong educational system, and had the political will to turn the situation around.

So NYU worked with the Ministries of Health and Education, dental professionals, and others to design a national "Smile Grenada" program focused on early-childhood prevention—that would turn schools into dental health centers.

Professor Mark Wolff, who spearheaded the initiative, realized early on that the success of the program relied on teachers. So he and his team went into schools, training hundreds of teachers on how to lead a daily, two-minute tooth brushing regimen with their students and encourage healthy eating. They also demonstrated how to apply fluoride varnish to students' teeth, which was done three times a year to protect against the acids that cause cavities. Students were given toothbrushes, which were kept at school. Each academic year, Colgate-Palmolive donated 26,000 toothbrushes, 52,000 tubes of toothpaste, and 78,000 doses of fluoride varnish to the program.

Workshops for dental and medical professionals and forums for parents helped to make oral hygiene a priority nationwide, and dental exams revealed the program's astonishing success in just two and a half years. The incidence of new cavities in school-aged children had dropped by a whopping 75 percent. "It was the perfect meeting of the willing educator and the child in need," Wolff says, adding that tooth decay is essentially a disease

Illustration by Michael Glenwood Gibbs



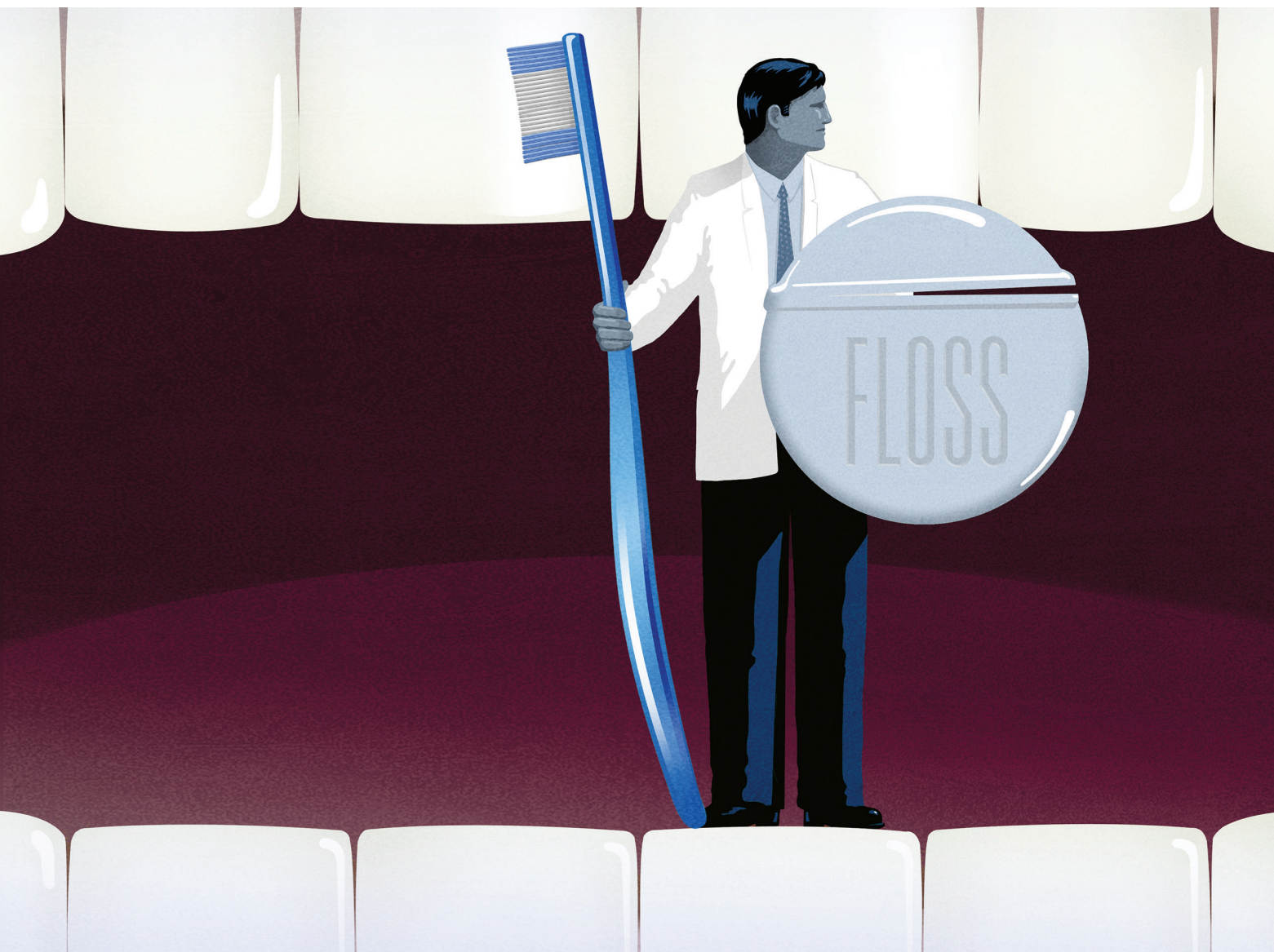
of ignorance—and changing dental habits is key. The program is now being replicated in the Philippines and in China.

The Scope of the Problem

Despite being largely preventable, dental disease is a global scourge that affects 60 to 90 percent of schoolchildren and nearly all adults, according to the World Health Organization—and plaque is the enemy. The mouth naturally teems with some 500 species of bacteria. These microorganisms form communities, melding with bits of food to cover teeth and gums in sticky plaque also known as "biofilm." The microbes produce acids that rot teeth, and some types can invade and inflame the gums, creating tiny ulcers. Left unattended—without a regimen that includes brushing with bacteria-fighting toothpaste, flossing and rinsing—invader bacteria advance further into the gums, creating severe periodontal disease that destroys both gum tissue and bone. Worldwide, periodontal disease causes up to 20 percent of adults from 35 to 44 to lose teeth—and has been implicated in broader health problems. It's been shown to affect the ability of diabetic patients to control blood sugar, has been correlated with heart disease, complications during pregnancy, and other conditions.

Tooth decay brings its own set of health impacts, impairing the ability to eat. In the United Kingdom, cavities send more children to the hospital than any other ailment. In 2014 and 2015, English children under the age of nine had 179,218 teeth pulled, according to the British Dental Association. In Africa, as many as four out of five school-aged children have both cavities and gum disease, according to WHO estimates. In Greece, 86.8 percent of 5-year-olds suffered dental problems.

In the U.S., tooth decay remains the most common chronic



Early Childhood Prevention: *The Smile Grenada Program*

MARK WOLFF, professor and chair of NYU's Department of Cariology and Comprehensive Care goes through patient files on the inaugural 2011 outreach to Grenada (left). Rebekah Browder applies sealant to a child's first permanent molars (right). Michael Le provides oral health instruction to schoolchildren (bottom right). All children received toothbrushes and toothpaste that were kept at school (below).

childhood disease: more than half of teenagers have had cavities. Meanwhile, many seniors are forced to delay or forego dental treatments because of cost. According to a 2013 survey from the American Dental Association's Health Policy Institute, amalgam fillings cost $86 to $326, porcelain crowns run from $962 to $1,070 and root canals range from $511 to $1,274. About 114 million Americans lack dental coverage; 67.7 million are under age 65; 70 percent of adults 65 and older are uninsured.

Taking the Team Approach

Dealing with a public health problem of this magnitude requires innovative, creative, collaborative solutions. Some efforts focus on specific issues, like cavities. Traditionally, when decay etches a cavity into a tooth, it's required drilling and a filling. Now, some dentists are trying to intervene sooner. Tooth decay occurs slowly enough that it can be stopped, or even reversed, before acids secreted by mouth bacteria erode calcium from tooth enamel. Ions dissolved in saliva naturally replace lost minerals, but if acids abound and decay begins, simple "re-mineralization treatments" like fluoride varnish can reverse the process.

In a study that tracked 1,000 high-risk patients, Sydney University researchers found that if decay was caught early and a high-concentration fluoride varnish used, the need for fillings fell by 80 percent.

But there is also a broader, sweeping shift in the way healthcare is now being defined that is bridging the long-standing divide between dentistry and medicine. With mounting research linking the health of the mouth with that of the entire body, there is a growing realization that oral care is a health issue that needs to be considered by all health practitioners, says Caswell Evans, associate dean for prevention and public health sciences at the University of Illinois at Chicago.

In 2000, when former U.S. Surgeon General David Satcher put oral health care on the national agenda with his landmark report, *Oral Health in America*, dentistry sat within its own silo. Most medical personnel, public health professionals and educators included little, if any, consideration of oral health in their practices, standards or curriculums. "That has begun to change in some very dramatic ways, with a lot of attention now being paid to cross-silo education," Evans says. As a result, the barriers between the two disciplines are slowly coming down, with professionals from nurses and pharmacy staff to social workers now including oral health in their service regimens.

"Inter-professional" education is changing the game. Since 2014, New York University has convened nursing, dental and medical faculty and students to jointly assess the mouth—the teeth, gums, tongue and palate—to learn diagnosis and treatment of oral-systemic health issues, such as diabetes. Their studies include classroom learning, simulations and hands-on clinical experiences. In another program at the University of California, San Francisco, 149 first-year medical students "cross-trained" during the fall of 2015, learning how to do basic oral health screening and apply fluoride varnish.

David Satcher says that there are broader social and public health implications. Integrating primary medical care and dentistry would improve oral health for many, including those who

"*It was the perfect meeting of the* ***willing educator and the child in need.***"

—*Professor Mark Wolff, Smile Grenada program organizer*

need it most. That list includes both the young and old: low-income children whose parents can't afford to take time off from work to bring them to the dentist and elderly patients who can't drive and need help getting to appointments. Within an integrated model, community healthcare centers could offer both primary medical services and basic dental care. But for the moment, the challenge is determining who will pay for it.

Early intervention could start in the pediatrician's office. "Young children see a pediatrician about eight times or more before ever visiting a dentist, which is oftentimes too late, as cavities may already be present," says Margherita Fontana, a professor at the University of Michigan School of Dentistry. Her department developed a questionnaire to identify toddlers who are most at risk for cavities, which is currently being tested in four states. As part of a normal well-child visit, parents fill out an assessment sheet, answering questions on how often they brush their child's teeth, what their kids snack on, whether the bottle their child takes into bed at night contains juice, water or another drink, and more. This clearly identifies problems and gives doctors the opportunity to discuss healthy habits with parents.

Planting the Seed for Better Nutrition

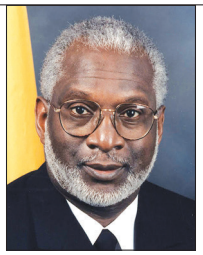
In his report, Satcher emphasized the importance of diet in preventing oral disease, which he says remains a major challenge today. He noted that poor oral health is exacerbated by smoking and high intake of sugar and alcohol. But nutrition affects oral health from birth, and socioeconomics is a big factor. "Children living in poverty are less likely to get the kind of nutrition that's important for development of their teeth," he says—and it's a global problem.

Beginning in 2001, Karen Sokal-Gutierrez saw the effects first-hand while volunteering as a public health physician with a community health organization in rural El Salvador. She'd worked in similar Latin American villages in the Peace Corps in Ecuador from 1978 to 1980, but in the intervening 20-some years, sugary processed snacks and drinks had replaced fruits and other locally-produced foods in the markets. When she arrived in El Salvador, she was shocked by the difference: many children had blackened teeth. In her old Peace Corps photos, the kids had pearly smiles.

By 2004, she'd launched the Global Children's Oral Health and Nutrition Program with private donations and a small grant from the University of California Berkeley's School of Public Health, where she is a clinical professor. When she and her team did their first community-wide assessment, they discovered that 85 percent of the children had untreated tooth decay, and nearly half suffered mouth pain. So they targeted prevention for babies and young children—and educated local community health workers, parents and children on both oral health and nutrition. They also engaged the kids in creative ways. A community health worker became the "Bottle Fairy," donning a shimmering dress with wings and a wand to "fly in" during community dental camps to encourage toddlers to trade in their bottles for a new sippy

Q&A

former U.S. Surgeon General David Satcher



Scientific American Custom Media: As Surgeon General in 2000, you published the *Oral Health in America* report. What inspired you to address this issue?

David Satcher: I grew up in a situation where we didn't have access to oral health care, and I've paid a price for that throughout my life in terms of tooth decay and needing dental work. But also, there was a growing movement…pushing for a report on oral health. There had never been [one].

SACM: What were the main issues at the time—and today?

DS: Children who live in poverty in this country and around the world…don't get good oral health care. If they are eating too much sugar and not enough fruits and vegetables, they're more likely to have tooth decay. Tooth decay is among the leading causes of days missed from school. Also, there are kids in this country… where [oral health] supervision is not up to par, like making sure children brush their teeth on a regular basis.

SACM: Since your report was published, what steps have been taken to improve oral health in the U.S.?

DS: Something I'm excited about is the integration of primary care and oral health care. We have problems with reimbursement…but I think ultimately it will make a world of difference to take your child to the pediatrician and know that child will get oral health care that he or she needs in the same facility and with the same team. Also, people underestimate the impact that smoking has on oral health. The smoking [rate] continues to go down [in the U.S.]—now at 15 percent, compared to 43 percent in 1964. That, in and of itself, is great for oral health. The other thing is that people are improving

cup, which can limit tooth decay.

The program has since expanded. Sokal-Gutierrez, her colleague Susan Ivey, and undergraduate and graduate student volunteers now carry duffle bags of toothbrushes, toothpaste, and a big pink-and-white teaching model of a mouth to Ecuador, Nepal, Vietnam and India. These countries, too, were in need of assistance. For example, in Nepal, two-thirds of the children had untreated tooth decay and some 40 percent were malnourished. (In response, some educators have now banned junk food from school.)

In Ecuador, many children had bad teeth and also carried a dual legacy of poor diet: obesity and malnutrition. Sokal-Gutierrez recounted the case of a five-year-old boy she examined in a small Ecuadorian town. All of his 20 baby teeth were decayed and he weighed about as much as an American two-year-old, so thin, pallid, and lethargic that he "looked like a child dying of AIDS," she said. His parents owned the village *tienda* and he had limitless access to the candy shelves. She has also observed infants given soda in baby bottles. In the slums of Mumbai, India, health workers told her about young children who were given "candy for breakfast, a chocolate bar for lunch and a bag of chips for dinner."

Raising awareness about nutrition and oral health has had lasting impact, Sokal-Gutierrez says. Six years into the El Salvador program, kids were brushing their teeth and eating less junk. Decay dropped to 50 percent, pain to 22 percent, and malnutrition fell from 16 percent to two percent. In each country, the programs are being transferred to nonprofits and government agencies.

Q&A *with former U.S. Surgeon General David Satcher*

continued from previous page

their eating habits—and things that are generally good for prevention of chronic diseases like cardiovascular disease and diabetes are also good for oral health. Sugar, tobacco and alcohol [consumption] are major factors in oral health care.

SACM: What are the major disparities in dental care today—and what do we need to do to improve oral health in the future?

DS: The figures that were in our report are still fairly true: 80 percent of oral health problems affect about 20 percent of the population—the poor and minorities in this country. The fact that we still have the only health system [among developed countries] that doesn't provide universal access to care is really unfortunate. I'm supportive of the Affordable Care Act but critical of the fact that while…it improves oral healthcare access for children, it does not for adults. Our health system has to incorporate easy access to oral health care.

Also, too many children are not getting the nutrition [they need] for good oral care. If we can reduce sugar intake for children and increase intake of fruits and vegetables…it will have a dramatic effect on reducing tooth decay, and ultimately, periodontal disease. The same things we are doing to reduce childhood obesity are going to be good for oral health.

The most important thing is to improve [dental care], and parents and children need to be educated about the importance of oral hygiene and regular tooth brushing.

Prevention for an Aging Population

The elderly are another highly underserved demographic. In the U.S., about 10,000 baby boomers turn 65 each day—and many who have dental insurance lose it when they retire. One-fifth of people over 75 haven't seen a dentist in five years, and globally, almost a third of people aged 65 to 74 have none of their original teeth.

Some countries are now creating incentives for dentists to be proactive. "The real challenge now is to… reward the maintenance of really good health through prevention that is research-based," says Jimmy Steele, professor at Newcastle University School of Dental Sciences. The United Kingdom's National Health Service is doing just that, offering financial rewards to dentists for preventing cavities and oral disease. Singapore also recently made great strides: its National Dental Centre just opened a Geriatric Special Care Dentistry Clinic that can accommodate bedridden and wheelchair-bound patients, and the Ministry of Health is now offering scholarships to train dentists in geriatric and special needs care.

In the U.S., the nonprofit Center for Oral Health is currently assessing dental problems among California's elderly. Preliminary results show that 38 percent of people in the state's long-term care facilities have lost all of their original teeth; nearly half have at least one untreated cavity; and about one in seven need urgent care.

In some states, including Oregon and California, elderly patients who can't drive or are too ill to visit a dentist can get care from a dental hygienist at home. Desiree Strawn, who runs Amor Dental Hygiene Mobile Service in Culver, Oregon, explains that before seeing her, many of her patients hadn't received regular cleanings—and their inflamed gums were exacerbating a range of other health issues. During house calls, she cleans teeth and encourages good oral hygiene, including brushing, flossing and rinsing. Her work sometimes involves physical therapy of sorts, like helping elderly patients relearn how to maneuver a toothbrush.

Many new avenues are bringing forth novel ways to prevent oral disease, but for now, there is a growing, universal urgency to address the current crisis. In the U.S. alone, nearly 30 percent of 15,000 adults surveyed across all income levels said life is "very often" or "occasionally" less satisfying because of the condition of their mouth or teeth. Nearly one in four adults said they avoid smiling because of the state of their mouth, according to a June 2016 American Dental Association Health Policy Institute report. The authors urged policymakers to re-evaluate the separation of the mouth from the rest of the body in both state and federal healthcare policy—and to consider the growing data linking oral health to physical, social and economic well-being. As Caswell Evans explains, much more can be done to improve the state of oral health around the world. "A lot of progress has been made, but there's a lot of room for improvement," he says.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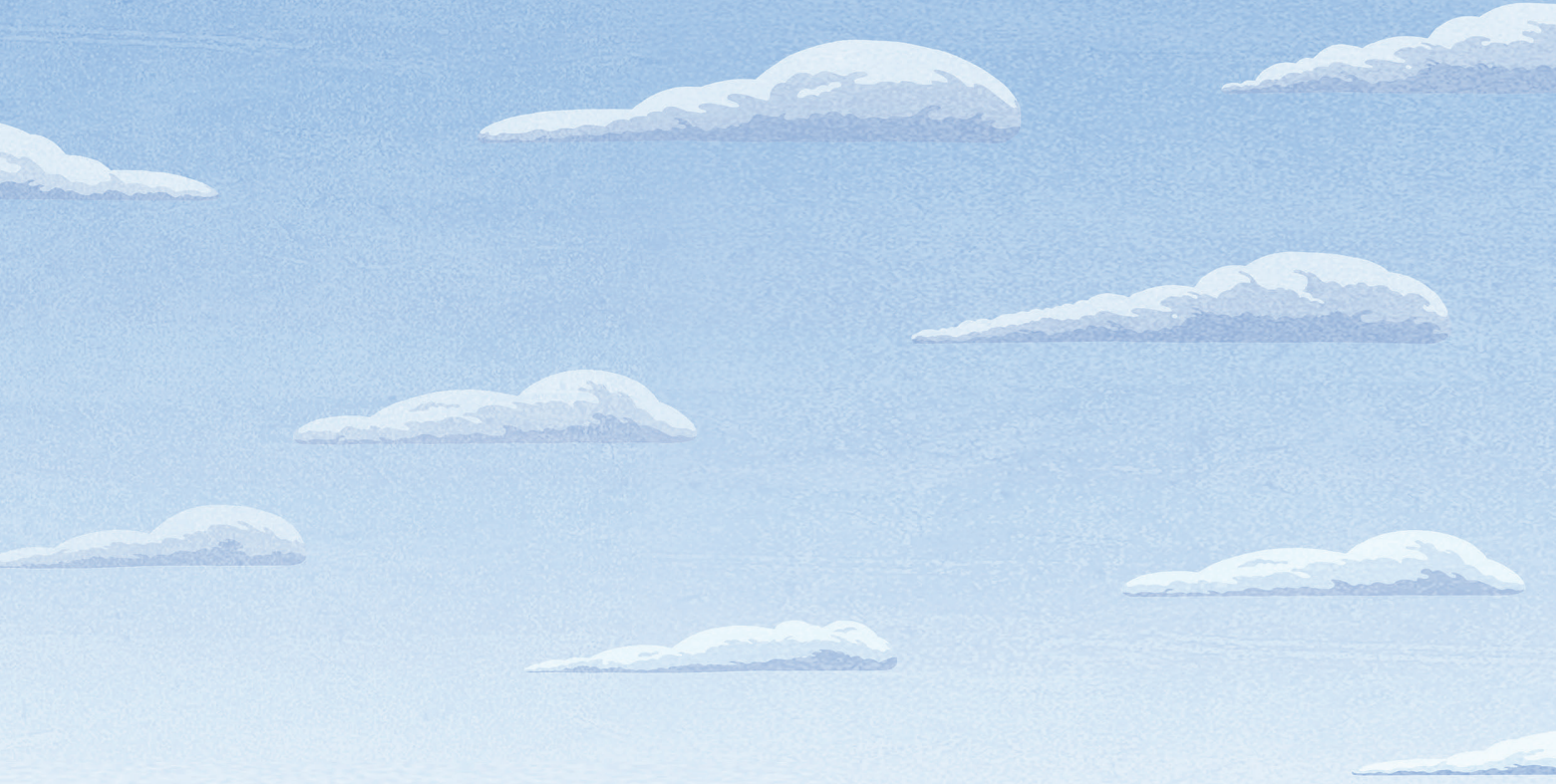

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