

# Dental and Craniofacial Science and Education in 2020

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Oral and general health, like many aspects of the human condition, are in the midst of major transitions. The scientific and technological bases of dentistry, medicine, nursing, and pharmacy are expanding rapidly in a world where alternative changes are seen in the management and financing of health care, the demography of our nation, and the public's expectations of "quality of life." Health professional schools, organized around academic health science centers that emerged in the post-World War II period with an unparalleled status, are responding to the challenges and opportunities at this time in human history. In tandem with the emergence of the National Institutes of Health (NIH), over the last fifty years the academic health science centers have become the place where the nation's interests and accomplishments in biomedical research, health profession education and training, and clinical innovations flourish. These coalitions of institutions have made the United States the world's leader in dental and medical education, training, research, and treatment.

And what are the trends that will shape the next generation? And are the mission and organization of the various health professional schools within the academic health science centers positioned for success in the next generation?

Oral, dental, and craniofacial health in the next century can be anticipated by strategically considering where we are today, how we got here, and the linkages between science, technology, health care, and economics in a changing social context.

At the beginning of the twentieth century, seeds were sown that would blossom into how we see ourselves, how we think about infection, physiology, and host response, and how we consider who we are in the context of this biosphere. The year 1900 heralded a new century and such profound changes as the way we think about ourselves and our health, dental and medical imaging and x-ray technology, the scientific founda-

tions of microbiology, the "new" physiology, the emerging concepts of developmental and evolutionary biology, and the units of heredity termed "genes." Scientific understanding began to emerge based upon the scientific and technological discoveries of the eighteenth and nineteenth centuries, and these scientific foundations became the diagnostic and therapeutic science and art of dentistry, medicine, nursing, and pharmacy. This history also served as a roadmap for what was to happen in the twentieth century.

The twentieth century began with increased European and Asian migrations to the United States; by 1900 the U.S. population was ninety million people and the planet earth's population was approaching one billion. Life expectancy in the United States was forty-five years of age. Acute viral and bacterial infections were the primary causes for infant morbidity and mortality. Being edentulous or "toothless" was a normal expectation for mature adults.

Today, a newborn baby can expect to live to be ninety-one years of age if a boy and ninety-seven if a girl. The U.S. population is now 276 million people. The earth's population doubled by 1950, again doubled by 1975, and is estimated to approach six billion people as we approach the next millennium. Today, global communication uses technology that provides for the broadcast and reception of information literally within milliseconds. Public health measures such as improved prenatal care, fluoridated drinking water, dental sealants, and health promotion have profoundly improved oral, dental, and craniofacial health for the vast majority of the population. Science, technology, advances in health professional education and clinical practice, and public health literacy have all continued to improve our lives. Increasingly, senior adults have a full dentition well into the seventh, eighth, and ninth decades of life.

In tandem, the twentieth century also heralded many major public health measures: sanitation, vaccines, antibiotics, improved public education, housing,

air conditioning of our homes and workplaces, fluoridation of drinking water, and the emergence of increasingly more sophisticated diagnostics and therapeutics. X-rays, fluoroscopy, ultrasound, CT, MRI, and PET scans have become the imaging component of the diagnostic language of health professionals and augment DNA fingerprinting, karyotyping, histopathology, and numerous immunoassays. Collectively, these and many other benefits of science and technology have doubled the human life span and profoundly improved the quality of life in less than one hundred years of human history.

Meanwhile, the 1990s have experienced a significant transformation in the financing and management of health care in the United States. This transformation is also influencing oral, dental, and craniofacial health care and is requiring major changes in the professional education, responsibilities, functions, and employment patterns of all health professionals. For most of the twentieth century, the management of health care was centered in the health professions and hospitals. Recently the center has shifted to three marketplace stakeholders: the purchasers of health care, the health care plans, and the health care providers or professionals. According to the Association of Academic Health Centers, the majority of this nation's 121 AHCs—the unique institutions that provide health care for the poor, train health professionals, and conduct biomedical research—are competing effectively in their local markets. The interactions between these three stakeholders, along with changing demographics and patterns of disease, will profoundly shape health care into the near future.

Within the social context of health care, curiously our current system of dental health care depends upon the independent judgment of essentially private sector professionals, often working in solo private practice, without collegiate peer review on daily decision-making, and within a system essentially based upon fee-for-services reimbursement. One major effect of this professional autonomy has been to create professions that define the limit or scope of practice. Recent research indicates a wide range of variation in diagnosis, treatment, and prognosis of many diseases and disorders as well as the costs for these health services. Current trends suggest a movement towards increased science evidence-based decision-making, increased community-based needs assessments, increased emphasis upon information and information technology, and increased emphasis upon “quality of life” expectations of patients, families, and communities. Moreover, these trends are complemented by increased understanding

of psychosocial-behavioral aspects of disease, disorders, and illness.

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## Demography Is Destiny

The beginning of this astonishing twentieth century marked at least a couple of profound transitions: 1) an agricultural society became an increasingly industrial society with the attendant growth of urbanization; and 2) a chiefly Protestant Anglo-Saxon society evolved into a polyglot amalgamation of all the world's races and creeds. In tandem, several public health accomplishments (e.g., sanitation, improved housing, transportation, education, antibiotics, and vaccination) influenced the longevity of our nation's population, including reduced infant morbidity and mortality and a significant reduction in the incidence and prevalence of acute infectious diseases throughout the population. In 1900, within the U.S. population of near ninety million people, expectations were for a life span of only forty-five years of age due to acute infectious diseases. Accomplishments from the public as well as private sectors have resulted in approximately 4.2 million births each year during the 1990s, an almost doubling of the human lifespan, and the current projection that one out of every five Americans will be sixty-five years of age or older by the year 2010.

More people living longer than ever before also presents an increase in chronic and disabling diseases and disorders—arthritis, cardiovascular diseases, cerebrovascular diseases, chronic facial pain, chronic fatigue syndrome, dental caries (root surfaces), depression, diabetes, fibromyalgia, oral and pharyngeal cancer, osteoarthritis, osteoporosis, periodontal diseases, salivary gland diseases and disorders, and temporomandibular diseases and disorders.

Demographers predict that by 2050 there will be no single racial majority in the United States. And, as this nation becomes increasingly diverse, a number of health-related issues will become even more apparent. This is especially evident within the patterns of disease and disorders of African-American, Hispanic, and American Indian communities. Disparities in educational advancement, job opportunities, income and wealth, housing and neighborhood characteristics, health access and status, and involvement in the criminal justice system among various sub-populations will continue unless previous trends are altered.

Of particular interest is the federal legislation that has enabled individual states to meet the health needs

of children. As of 1997, more than eleven million children—one in seven—are estimated to be uninsured in the United States. Most of these children reside in families with working parents who have jobs that do not provide health insurance and who arguably are unable to purchase health care insurance for themselves and their children. Nationally, one out of six African-American children and one in four Hispanic children are uninsured, compared with one in ten Caucasian children. This limited health care access is extremely significant when considering oral health. Future progress can be made through improved prenatal care and early childhood development, school readiness programs, improved K-12 education with an emphasis on health literacy, improved transportation and child care, culturally appropriate health services, and better use of information technology to improve access and utilization of oral health services.

Hamish McRae argues in his excellent treatise *The World in 2020* (Harvard Business School Press) that science is the fuel for technology and that advances in technology will enable enhanced utilization of human and natural resources with an expanding world population over the next twenty-two years. McRae identifies the lags between the invention of technology and its adoption into popular use, and then argues that “we can be reasonably sure that the everyday technologies of 2020 already exist in some form or other today.”

The “biological revolution” is a superb example of McRae’s argument. The Human Genome Project was formally created in 1988 with a mission to determine, by the year 2003, the complete nucleotide sequence of the approximately 100,000 structural and regulatory genes that comprise the human genetic lexicon. This remarkable partnership among federal agencies, universities, and private industry is providing a knowledge database that will soon reveal the entire genetic lexicon of being a human being. In addition, the genomes of many significant microbes and animals—viruses, bacteria, yeast, parasites, animals, and humans—are also being deciphered. These are also revolutionizing how we think about biology and human diseases.

Perhaps with the sole exception of trauma, all human diseases are genetic. Genetic dentistry and medicine are based upon the paradigm that changes or mutations in individual genes or alleles result in inherited diseases. For example, mutations in the amelogenin gene located on the human X and Y chromosome can produce X-linked dominant or recessive amelogenesis imperfecta; mutations in the fibroblast growth factor receptor 2 gene can produce Crouzon syndrome as well

as other craniofacial syndromes with craniosynostosis; or mutations in a number of transcription factors that regulate development can produce craniofacial syndromes. These and other scientific discoveries are rapidly defining single gene mutations, mapping these individual genes in their precise positions on human chromosomes, and being used to diagnose inherited clinical phenotypes throughout the human lifespan. Moreover, these advances in human molecular genetics are identifying candidate genes for developing targeted gene-mediated therapeutic approaches to many oral health diseases and disorders ranging from passive immunization for dental caries, to induction of bone and cartilage, to regeneration of periodontal tissues, to synthetic saliva for xerostomia.

Gene mutations also define not only the virulence of microbes (viruses, bacteria, yeast, and parasites), but also the fidelity of the human immune system. Of course, microbial as well as human genes are extremely sensitive to environmental “stress” and can and do mutate or change resulting in multi-drug and/or antibiotic resistance. The genetic variance within microbial genomes such as that of the yeast *Candida albicans* may also be closely aligned with the host changes associated with many medically compromised patients. The HIV viral genome is another particularly useful model for considering viral mutation frequency within the human population. These discoveries provide the required foundations for gene-based diagnostics from disease detection, to drug therapeutic developments for the management of chronic facial pain, to osteoarthritis as related to temporomandibular joint disease, to osteoporosis associated with periodontal diseases.

Moreover, genes are the foundation of even more complex human diseases. First, multiple mutations that are acquired can produce cancers. We now appreciate that all cancers are genetic and that most cancers are not inherited but rather result from acquired multiple mutations. Oral and pharyngeal cancers are the sixth most common neoplastic disease: one American dies every hour of oral cancer. The major “risk factors” for oral cancer are tobacco products and alcohol.

Second, we are beginning to understand that variations or polymorphisms in multiple genes confer susceptibility or resistance to chronic and disabling diseases and disorders such as osteoporosis, periodontal diseases, and temporomandibular diseases and disorders. Such polymorphisms are now well defined in pharmacogenetics, and describe how the human organism responds to environmental insults through variations in the metabolism of teratogens, mutagens, and

carcinogens. In these examples, multiple genes and multiple gene/environment and gene/gene interactions are associated with the molecular pathophysiology of the human disease process.

These microbial and human databases will provide remarkable opportunities for the identification, design, and production of a new generation of biomarkers for diagnostics, innovative biomaterials for repair and regeneration, and the development of highly sensitive and specific drugs and vaccines to improve the health of the American people.

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## Oral Infection and Systemic Disease: A Paradigm Shift

An association between oral infections and systemic diseases has been suspected for centuries. In the last few years, a growing body of scientific evidence suggests an exquisite association between oral infection (e.g., viruses, bacteria, yeast) and systemic diseases (e.g., atherosclerosis, cardiovascular disease, cerebrovascular disease, premature and low birth weight, and pulmonary diseases and disorders), and also between systemic diseases (e.g., arthritis, diabetes, HIV, osteoporosis) and oral, dental, and craniofacial diseases and disorders.

Transmissible and opportunistic microorganisms are responsible for dental caries. Transmissible and opportunistic microorganisms are also responsible for periodontal diseases. In the case of periodontal diseases, the microbial-induced infection presents a substantial infectious burden to the entire body. Further, specific microorganisms within the microbial ecology associated with the disease process release toxins, which invoke an inflammatory response. Bacteria, bacterial toxins, localized tissue response cytokines, and other inflammatory mediators enter the vascular circulation and subsequently may activate a systemic response. The subsequent pathogenesis of the disease process reflects gene-gene and gene-environment interactions. Nested in a complex interaction of host susceptibility, external exposures, and lifestyle behaviors, the management of health and disease will require interdisciplinary strategies and care. These scientific advances will forge a new paradigm.

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## Science, Technology, and Oral Health Education

The biological and information revolutions, the changing demographics and patterns of disease, and the quality of life expectations mandate fundamental changes in oral health science, education, and clinical practice. The complexities of “the new human biology” offer new directions for scientific research to improve the health of the American people. The new human biology requires major reform in the health profession educational pipeline. Students and clinicians alike need to be prepared to appropriately adopt evidence-based health care. Today and tomorrow, students must be well versed in epidemiology, biometry, bioinformatics, molecular biology, bioengineering, and so much more. In addition, they must be prepared for new preventive strategies, comprehensive and molecular-based diagnostics and therapeutics, cost-effective community-based health care, and all the challenges that promotion of health demands. Clinical science or scientific evidence in the next millennium will continue to evolve into molecular dentistry and medicine with the attendant opportunities for behavioral sciences and bioethics. We must prepare clinicians for the nuances and complexities of modern clinical research-based results.

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## The World of 2020

The new millennium will be the “the biology century”—an era of genomics and functional genomics, bioengineering, innovative imaging, analytical diagnostic assays, aggressive interventions to promote health, and the century of molecular dentistry and medicine based upon scientific evidence for health care policies and management.

By 2000, a number of viral, bacterial, and yeast genomes will be completed. Accelerated efforts will complete the fruit fly as well as the mouse genome. By 2003, the human genome will be completed. In tandem, bioinformatics and the second generation of the high-speed Internet will revolutionize the rates of scientific and health care communication. Computer-assisted analyses of genomic databases will increase the identification and discovery of novel gene sequences of enormous utility for clinical dentistry, medicine, nursing, and pharmacy, as well as the allied health professions. Combinatorial chemistry will increase the

rates of discovery of novel molecules for diagnostics, therapeutics, and a broad array of novel biomaterials.

In the first decade of the twentieth century, dentistry was the first specialty to adopt x-ray technology immediately into clinical practice. Today and into the next century, computer-assisted technologies coupled with functional MRI and PET will revolutionize the visualization of normal as well as abnormal cell, tissue, and organ functions in “real time.”

This period also will herald the advent of “biochemistry laboratory on a chip” as body fluids, cells, and tissues are used to diagnose diseases and disorders. The so-called “chip technology” will enable identification, quantification, and complex analyses on surfaces no larger than one centimeter square coupled to laser optical reader systems and computer-assisted informatics. Prototypes are already available, and applications to saliva, cervical fluids, buccal mucosal cells, and blood are being developed. This technology should revolutionize saliva-based diagnostics and prognostics.

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## What Might Go Right?

The present and projected trends enthusiastically support science-based and evidence-based health care for the twenty-first century. The growing societal desire to reduce health-related costs yet increase the quality of and access to health care for all Americans will remain the dominant issues for the near future. It will further become increasingly clear that improved attention to prenatal care, early childhood development, school readiness, and K-12 education are major determinants for improved quality of life, science, mathematics, and health literacy for all Americans.

What is becoming increasingly evident is that literacy, especially science, math, and health literacy, are prerequisites for the support of a nation engaged in a global economy that is dependent upon knowledge-based services and technologies. The competitive advantage over the next twenty to twenty-five years is to have a workforce that is better educated, better informed, and healthier.

In tandem, health promotion, disease prevention, and smarter and more specific diagnostics and therapeutics will foster major reforms in health profession education and training and will further require reforms in continuing dental, medical, nursing, and pharmacy education for clinicians and paraprofessionals throughout this nation. The health workforce will increasingly engage in knowledge-based decision-making and community-based health care management. Such educational reforms will require major reforms in the mission and organization of the institutions that will provide and improve didactic and clinical approaches to epidemiology, social anthropology, inherited and acquired genetic diseases, infection and immunity, principles of internal medicine and oral medicine, the connections between oral infections and systemic disease, neoplastic diseases, multi-drug resistance and antibiotic resistance, chronic disabling diseases and disorders, and the remarkable complexities of human behavior in multicultural societies.

Novel immunity approaches will enhance efforts to target specific populations at risk for certain types of diseases. Innovations in biomimetics, bioengineering, and tissue engineering will yield improved biomaterials as well as therapeutic approaches for tissue and organ regeneration and transplantation, especially in the context of an ever-increasing mature and very mature adult population and the need for body parts.

By 2020, society will experience many scientific and technological breakthroughs, many triumphs over disease, the genetic targeting of disease, advances in bioengineering, increased capacity to promote health, and significant increases in life expectancy. What remains uncertain is the opportunity to obtain optimal health promotion and care for all people, appropriate cost containment, and optimum health care delivery and to have the ability to manage the profound ethical, social, political, and legal issues that accompany the anticipated “biology century.”