AIDPH
AMERICAN INSTITUTE OF DENTAL PUBLIC HEALTH

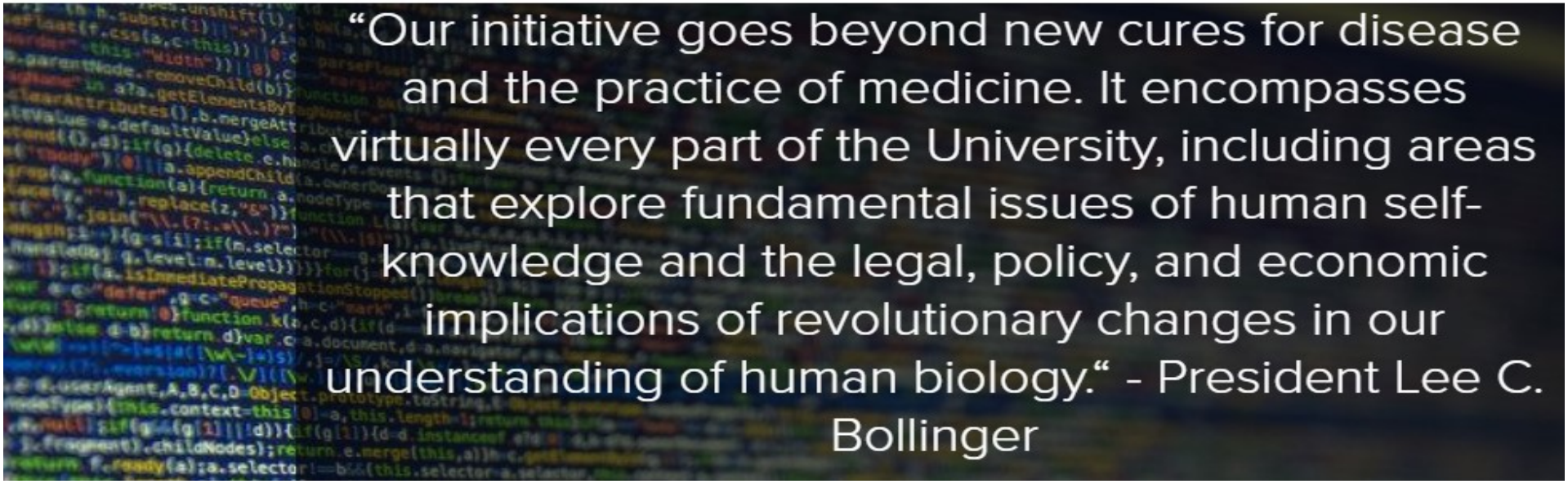
Precision Public Health and the Future of Dental Public Health

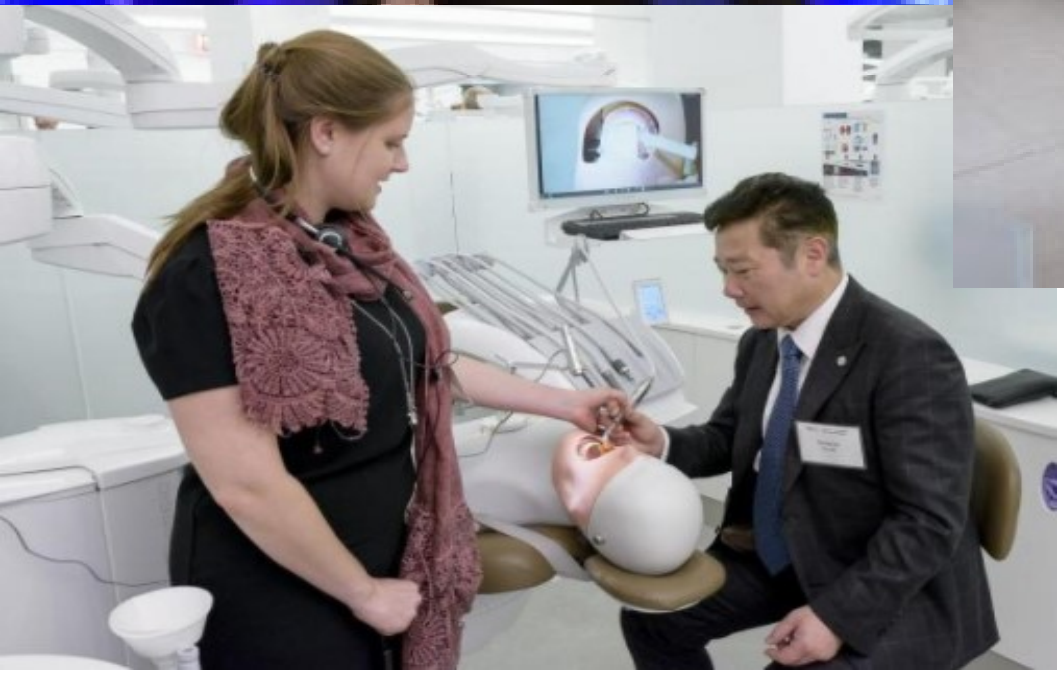
Using Big Data to Promote Precision Health in the Context of Learning Health Systems

Joseph Finkelstein, MD, PhD
Center for Bioinformatics and Data Analytics
Columbia University College of Dental Medicine

COLUMBIA | PRECISION MEDICINE

About ▾ Programs ▾ Clinical Delivery ▾ Precision Medicine and Society ▾ Foundational Research ▾





Center for Precision Dental Medicine

Potential Applications of Big Data in Precision Oral Public Health

Challenge	Solution	Precision Medicine	Oral Public Health
Lack of up-to-date evidence-based guidelines	Knowledge discovery pipelines based on big data and health analytics	X	X
Limited integrative analytical data sets	Intelligent Integrative Informatics approaches	X	X
Slow translation to routine care delivery	Learning Health Systems	X	X

- Updatable Evidence-Based Guidelines
- Verified and Actionable Data Sources
- Effective Implementation Tools
- Proactive Stakeholder Engagement

Call for Evidence-Based Oral Health

The New York Times | THE NEW HEALTH CARE AUG. 29, 2016

The Upshot

Aaron E. Carroll

Surprisingly Little Evidence for the Accepted Wisdom About Teeth

SUMMARY REVIEW/PERIODONTOLOGY

Evidence-Based Dentistry (2005) 6, 5–6.

Insufficient evidence to understand effect of routine scaling and polishing

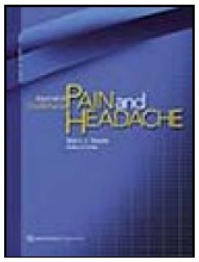
What are the benefits and harms of routine scaling and polishing for periodontal health and do these change with different time intervals?

Conclusions. *The research evidence is not of sufficient quality to reach any conclusions regarding the beneficial and adverse effects of routine scaling and polishing for periodontal health and regarding the effects of providing this intervention at different time intervals.*

GUEST EDITORIAL

Data science at the National Institute of Dental and Craniofacial Research

Changing dental practice



Journal of Oral & Facial Pain Headache

Edited by Barry J. Sessle, BDS, MDS, BSc, PhD, FRSC

Official Journal of the American Academy of Orofacial Pain, the European, Asian, and Ibero-Latin Academies of Craniomandibul Disorders, and the Australian Academy of Orofacial Pain

ISSN 2333-0384 (print) • ISSN 2333-0376 (online)

Publication:
Spring 2014
Volume 28 , Issue 2

EDITORIAL: The Next Frontier: Digital Disease Detection in Cyberspace

Christian Stohler

Page: 105
PMID: 24822233
DOI: 10.11607/ofph.2014.2.e

Editorial

Christian S. Stohler

J Oral **Facial Pain** Headache. 2015 Fall;29(4):321.

Orofacial Pain and the Prospects of Precision Medicine

Big Data Analytics to support evidence-based personalized dental care: circa 1757

A Surprising Cure for the Tooth-Ache.

I am come to you to get Relief for a moſt violent Tooth-Ache.

My Letter, that ſmells ſo very pleaſant, when delivered, is your Relief.

WHICH

Has never been known to fail.

TO the Nobility, Gentry, and Others. If the Pain be ever ſo violent, and if the Teeth are rotted away below the Gums, nay even to the Stumps, the Patients are ſure to get rid of the Pain, cauſed by the Tooth-Ache, and that in leſs than two Hours, after I have delivered to them a ſmall Letter (ſealed up).

This Letter ſmells very pleaſant when delivered, which the afflicted are to put into their Pocket, and as the Tooth-Ache leaves them, this agreeable Smell leaves the Letter. But if not the Tooth-Ache, this reviving Smell will not leave the Letter.

Any one that is not ſatisfied in their own Opinion of the above Cure, and think it impoſſible, I beg leave to mention thoſe Families I have cured, and I believe that will give them the greateſt Satisfaction. I have cured ſeveral Thouſands of the Tooth-Ache, for above theſe Twenty-three Years. But I ſhall only trouble you at preſent to read theſe few Names, and where they live, which are as follow:

Mrs. King and her Daughter, No. 10, Old * Mrs. Crowder, No. 9, Queen's-Head.

Mrs. King and her Daughter, No. 19, Old Bailey.

Mr. and Mrs. More, No, 42, St. James's-ſtreet.

Mrs. Griffiths and Mrs. Richards, Tufton-ſtreet, Weſtminſter.

Mrs. Crowder, No. 9, Queen's-Head-Court, Pater-noſter-row.

Mrs. Jordan, No. 100, St. Martin's-Lane.

Mrs. Salt, No. 21, Panton-ſtreet.

The two Head Cooks of St. George's Hoſpital.

If not cured, nothing is expected; but I am ſure, with God's Bleſſing, to cure every one that comes to me with the Tooth-Ache; and before they go from me, they are deſired to return the ſmall Letter to me again, and on telling me they have no Tooth-Ache, I then leave it to their own Generoſity to ſatisfy me for their Cure.

My Patients often get rid of their Tooth-Ache in leſs than One Hour after coming to me, but I am deſirous that every one who comes to me to be cured, will ſtay at leaſt Two Hours with me. This great Secret is not known to any one but myſelf.

Removed from No. 9, YEOMAN'S-ROW, BROMPTON, to No. 100, ST. MARTIN'S-LANE, oppoſite MAY'S-BUILDINGS, near CHAIRING-CROSS. Where I attend at my Apartments every Day, from Eight o'Clock in the Morning till Eight in the Evening, except Sundays.

☞ For the Good of Mankind, it would be a Charity to let this Bill be put up in ſome Part of your Houſe, that this Cure may be made as public as poſſible to thoſe who have the Tooth-Ache.

N. B. The pooreſt Sort of People cured gratis, from Eight till Ten every Morning.

[1757.]

Personalized high quality care delivery

This Letter ſmells very pleaſant when delivered, which the afflicted are to put into their Pocket, and as the Tooth-Ache leaves them, this agreeable Smell leaves the Letter. But if not the Tooth-Ache, this reviving Smell will not leave the Letter.

Big data analytics

I have cured ſeveral Thouſands of the Tooth-Ache, for above theſe Twenty-three Years. But I ſhall only trouble you at preſent to read theſe few Names, and where they live, which are as follow:

HIPAA violation

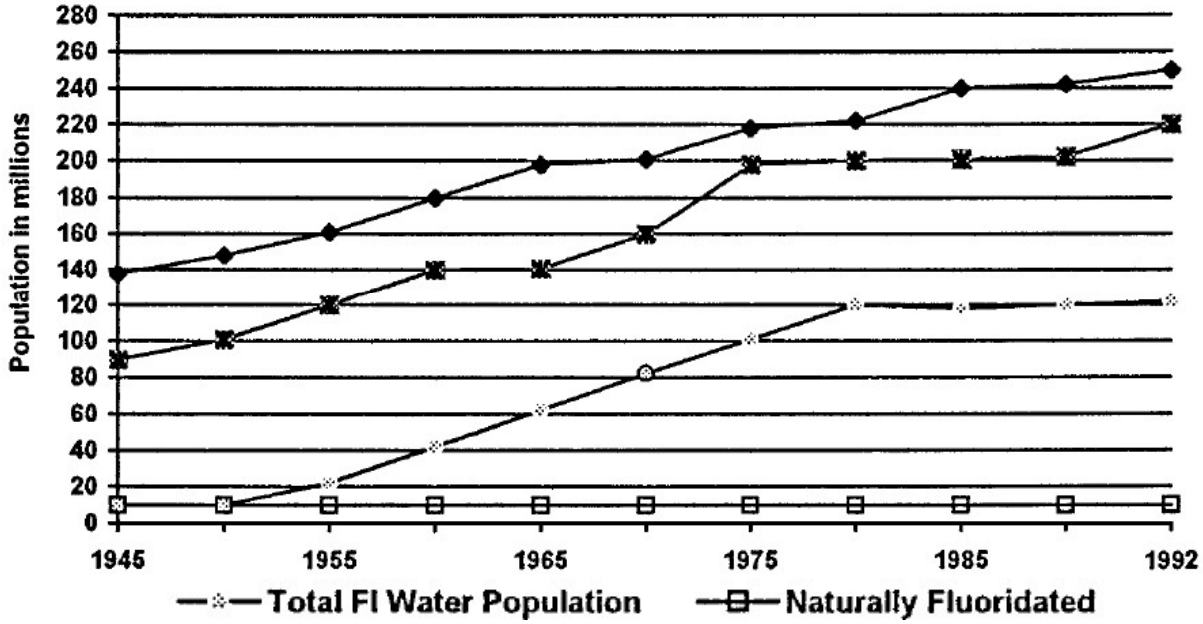
Mrs. King and her Daughter, No. 19, Old Bailey.
Mr. and Mrs. More, No, 42, St. James's-ſtreet.
Mrs. Griffiths and Mrs. Richards, Tufton-ſtreet, Weſtminſter.
Mrs. Crowder, No. 9, Queen's-Head-Court, Pater-noſter-row.
Mrs. Jordan, No. 100, St. Martin's-Lane.
Mrs. Salt, No. 21, Panton-ſtreet.
The two Head Cooks of St. George's Hoſpital.

Motivating Example: Fluoridation

•Series of epidemiological studies in 1930s demonstrated the dental caries prevention benefits from naturally occurring fluoride

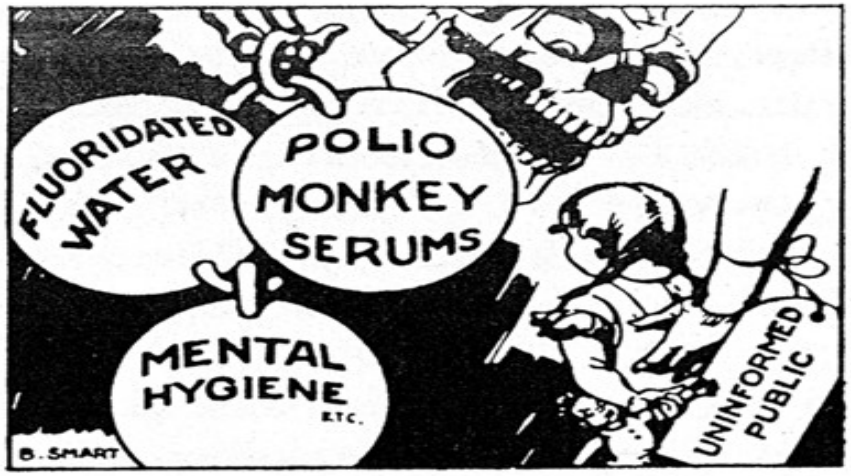
•The first community water fluoridation took place in Grand Rapids in 1945

•The presence of fluoride prevents the net los of tooth minerals and decreases the rate at which episodes of demineralization occur



Fluoride “Warfare”

At the Sign of THE UNHOLY THREE



Are you willing to PUT IN PAWN to the UNHOLY THREE all of the material, mental and spiritual resources of this GREAT REPUBLIC?

FLUORIDATED WATER

1—Water containing Fluorine (rat poison—no antidote) is already the only water in many of our army camps, making it very easy for saboteurs to wipe out an entire camp personel. If this happens, every citizen will be at the mercy of the enemy—already within our gates.

POLIO SERUM

2—Polio Serum, it is reported, has already killed and maimed children; its future effect on minds and bodies cannot be guaged. This vaccine drive is the entering wedge for nation-wide socialized medicine, by the U. S. Public Health Service, (heavily infiltrated by Russian-born doctors, according to Congressman Clare Hoffman.) In enemy hands it can destroy a whole generation.

MENTAL HYGIENE

3—Mental Hygiene is a subtle and diabolical plan of the enemy to transform a free and intelligent people into a cringing horde of zombies.

FIGHT COMMUNISTIC WORLD GOVERNMENT by destroying THE UNHOLY THREE ! ! ! It is later than you think!

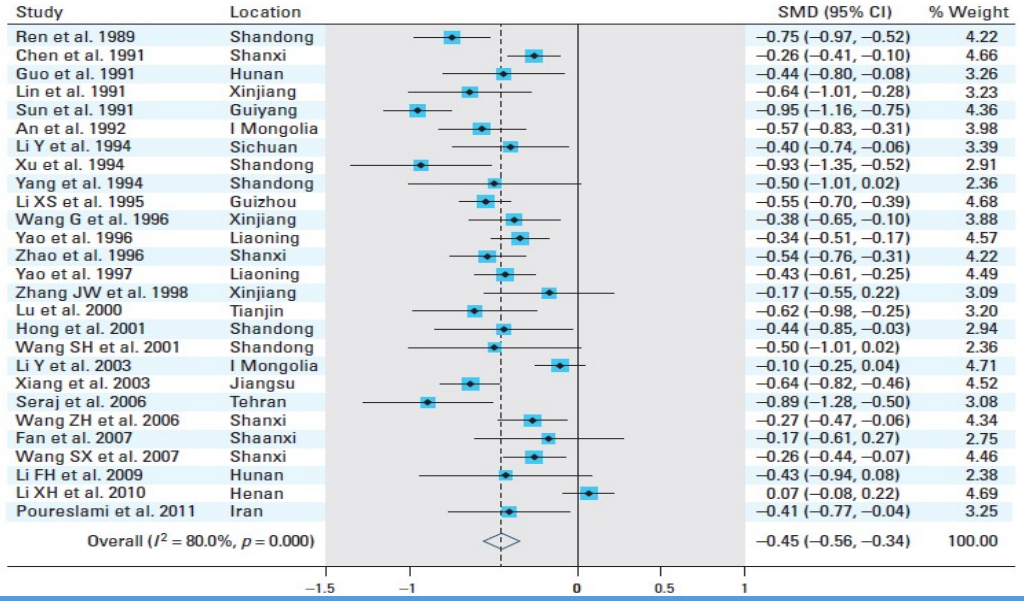
KEEP AMERICA COMMITTEE
Box 3094, Los Angeles 54, Calif. H. W. Courtois, Secy. May 16, 1953

Putin Bans Fluoride In Russia

August 12, 2017 Baxter Dmitry News, World 5

Share 20K Share Tweet submit

Vladimir Putin has banned fluoride from Russia, stating that the *“toxic poison”* that was *“force fed to prisoners of war during Soviet times”* should not *“under any circumstances, now or in the future, be considered for use on the people of the Russian Federation.”*

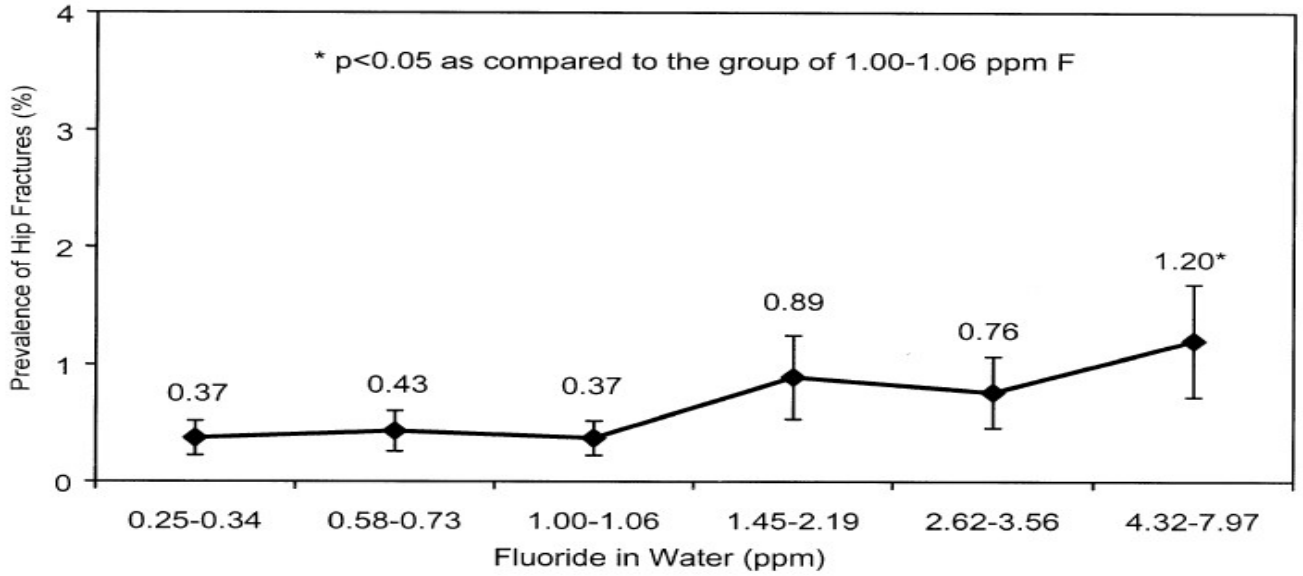


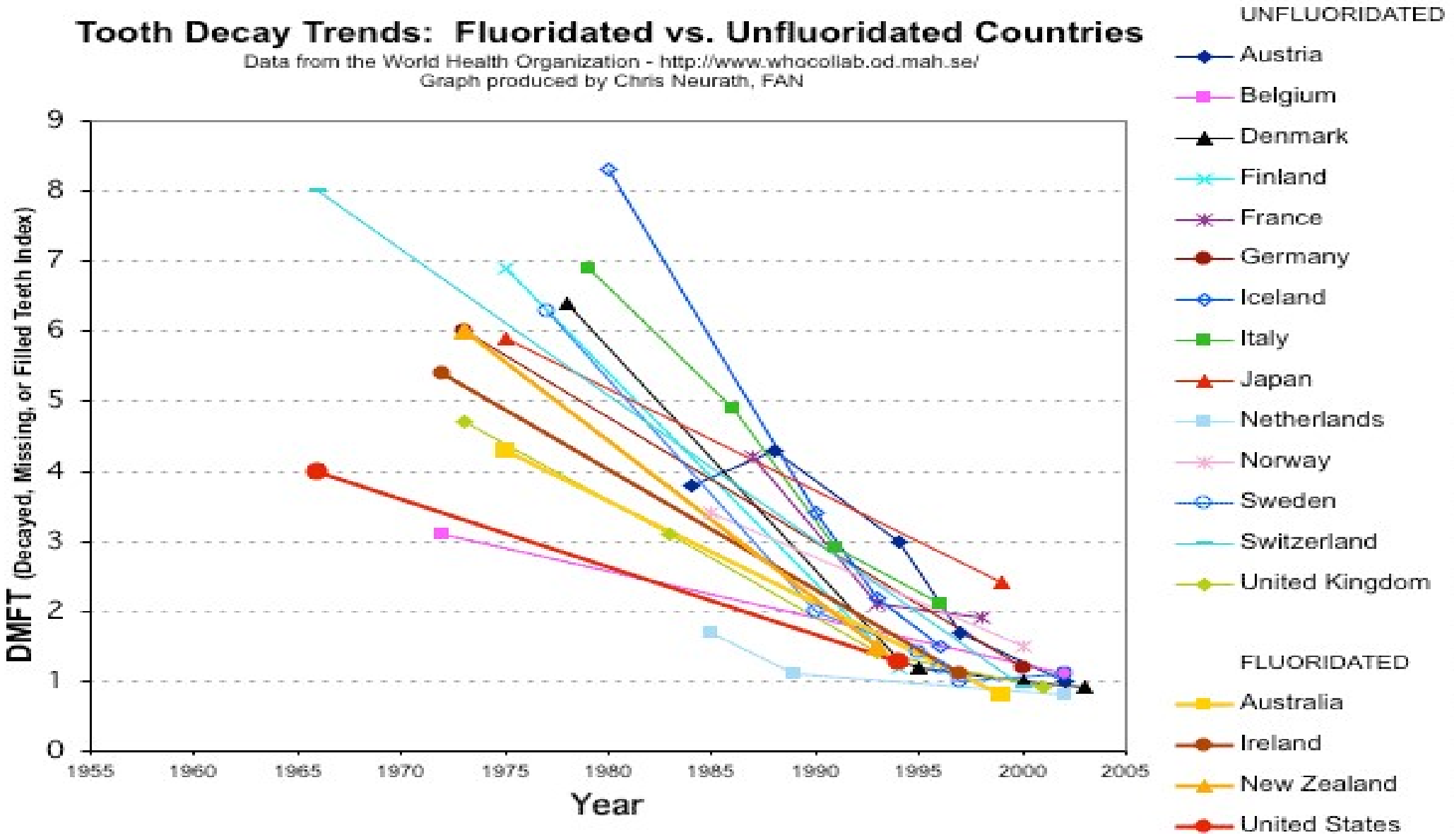
Child's intelligence score was inversely associated with high exposure to fluoride

Developmental Fluoride Neurotoxicity: A Systematic Review and Meta-Analysis. Environ Health Perspect 2012;120:1362–1368.

Hip fracture prevalence was positively associated with high exposure to fluoride

Prevalence of hip fractures and fluoride concentration. J Bone Miner Res. 2001;16:932-9.




Tooth Decay Trends: Fluoridated vs. Unfluoridated Countries
Data from the World Health Organization - http://www.whocollab.od.mah.se/
Graph produced by Chris Neurath, FAN
DMFT (Decayed, Missing, or Filled Teeth Index)
0
1
2
3
4
5
6
7
8
9
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
UNFLUORIDATED
Austria
Belgium
Denmark
Finland
France
Germany
Iceland
Italy
Japan
Netherlands
Norway
Sweden
Switzerland
United Kingdom
FLUORIDATED
Australia
Ireland
New Zealand
United States

Classification Models in Precision Health

Traditional Model

Traditional population-wide demographics

Emerging Model

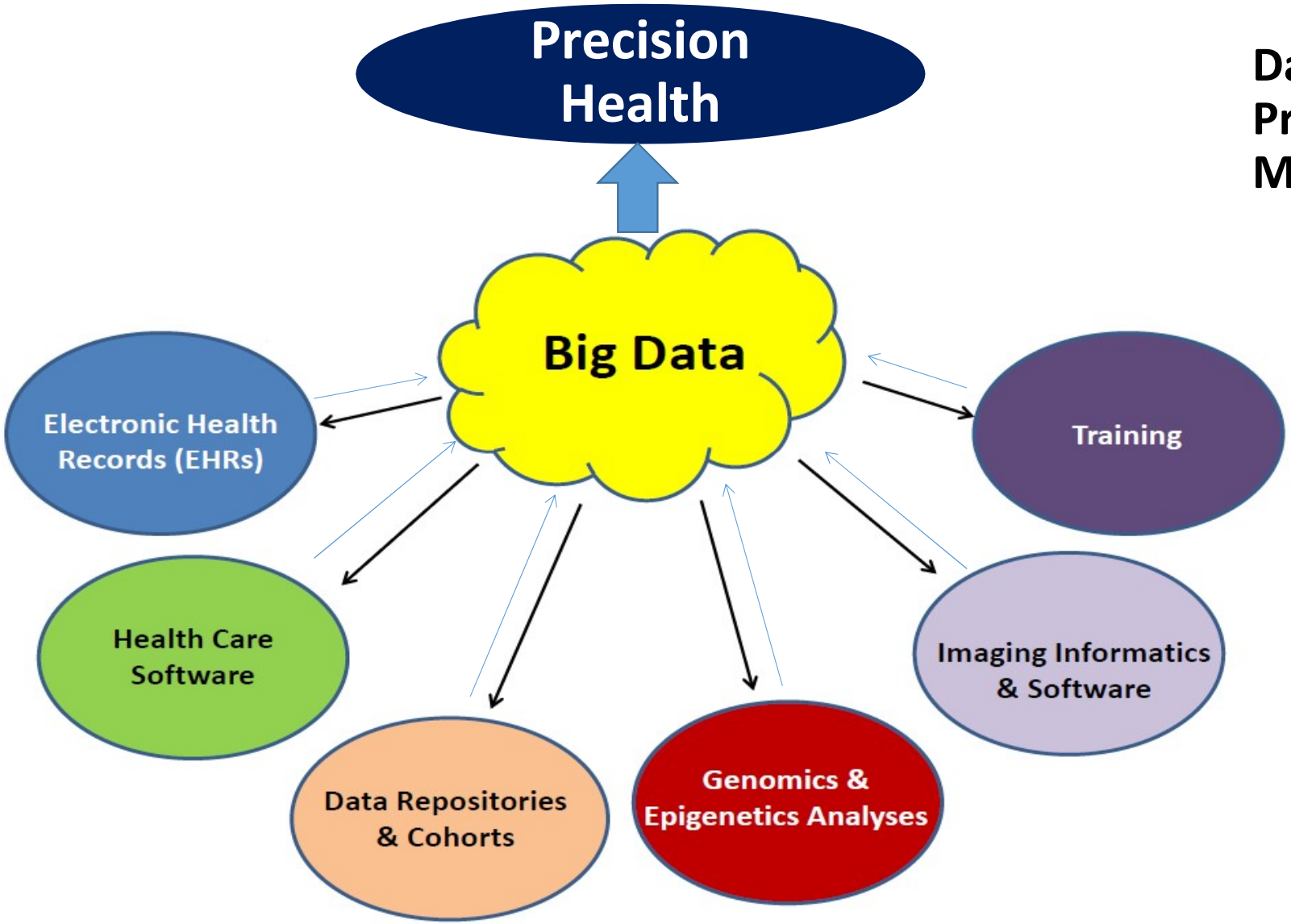
Cohort-relevant measures: socio-economic status, haplotype, enterotype, exposome, etc

Future Model

Individual N=1

Swan, 2012

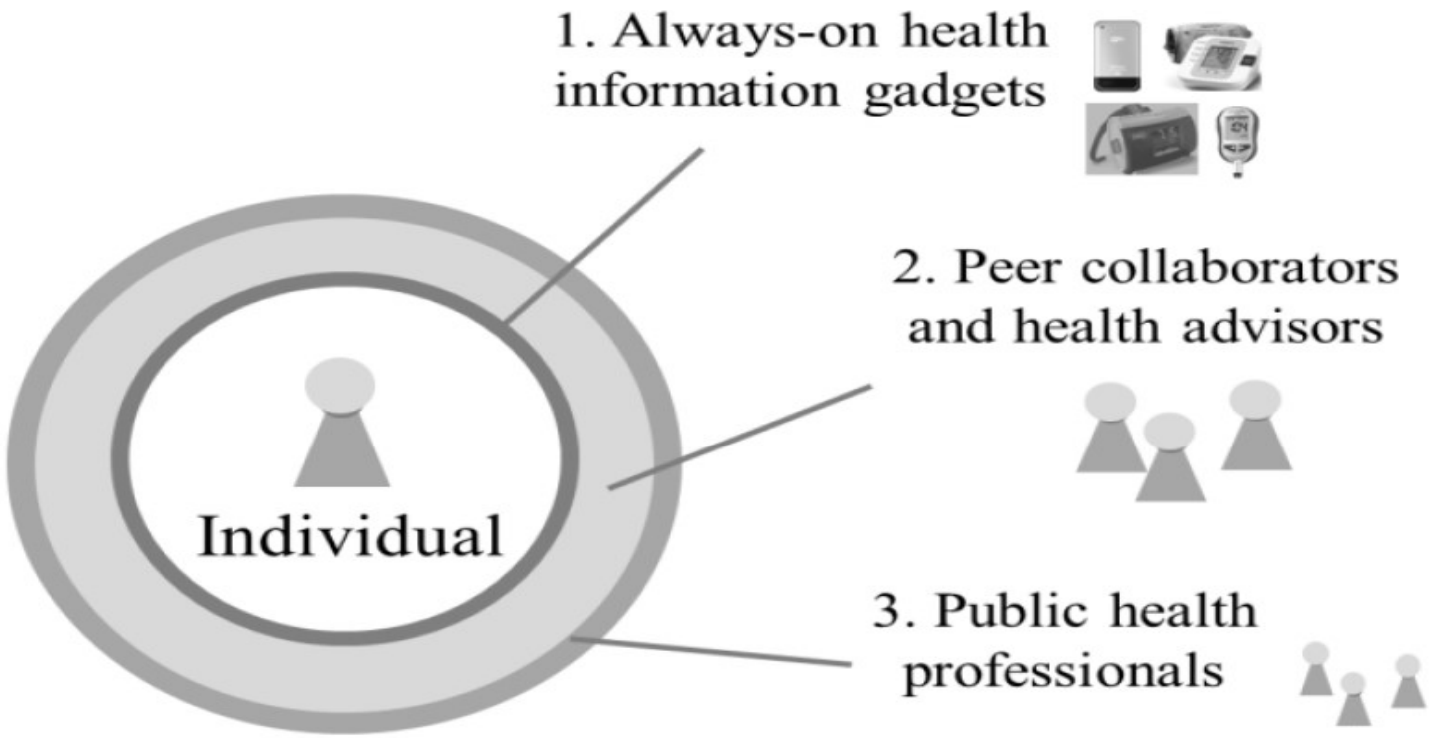
Data Streams in Precision Dental Medicine



Big Data and Precision Health

Swan, 2012

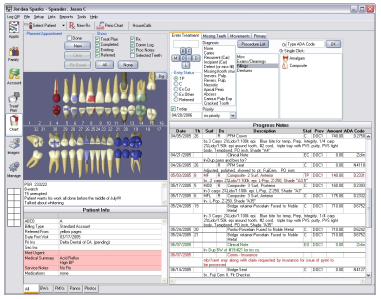
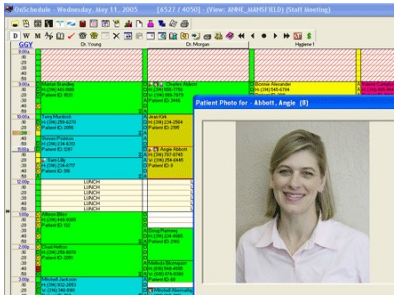
Health Outcomes: Physical and Mental
Self-expression
Enhancement
Longevity
Prevention
Normalization
Baseline and Variability
Improvement
Cure



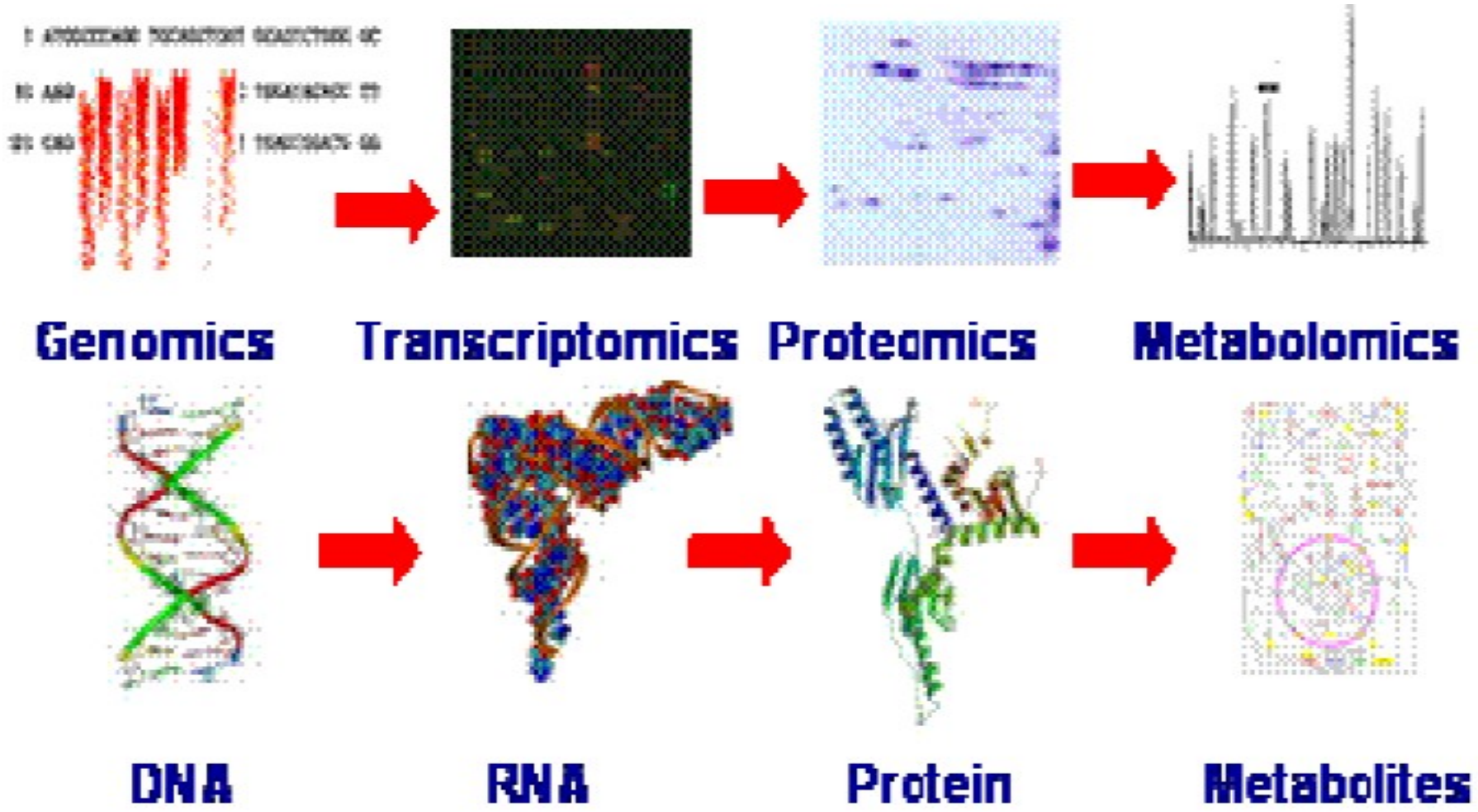
Personal Health Informatics: Integrated Data Streams	Genome (SNP, WGS, Epigenetics)	Expression Data (Transcriptome)	Metabolome	Microbiome
	Personal and Family History, Blood Test Data, Prescriptions		Environmentome	Diseasome

Digital Dentistry

- Electronic Dental Record
- CAD/CAM and intraoral imaging — both laboratory- and clinician-controlled
- Caries diagnosis
- Computer-aided implant dentistry — including design and fabrication of surgical guides
- Digital radiography — intraoral and extraoral, including cone beam computed tomography (CBCT)
- Electric and surgical/implant handpieces
- Lasers
- Occlusion and TMJ analysis and diagnosis
- Photography — extraoral and intraoral
- Practice and patient record management — including digital patient education
- Shade matching

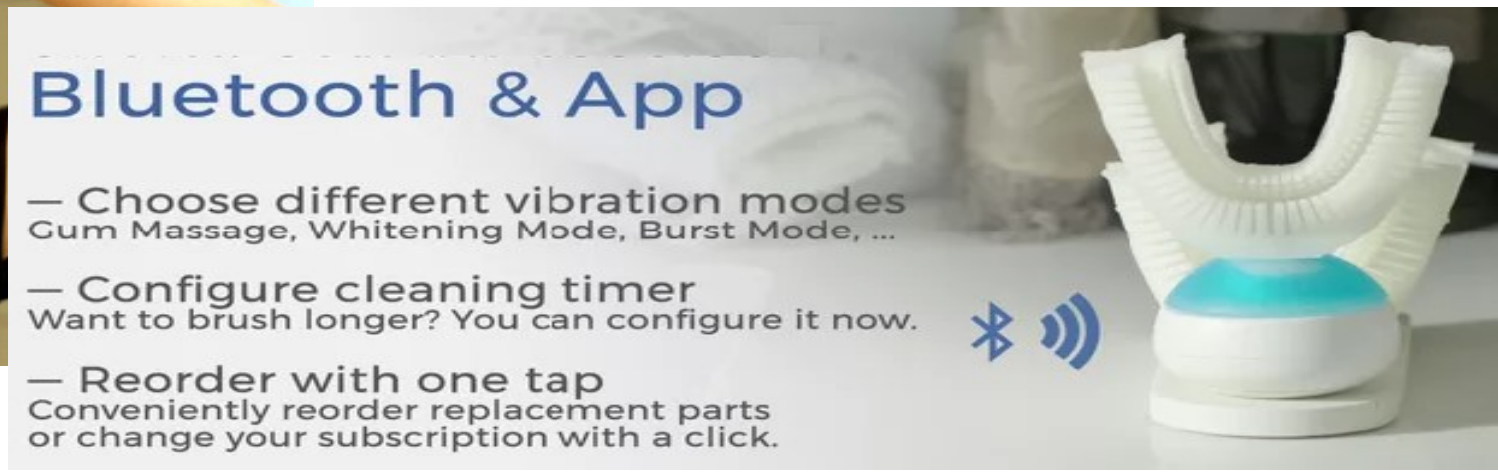
Omics Data Streams



Mobile Oral Health

Marcon, et al 2016

Oral Mobile Health



Social Media: Learn and Intervene

Discovering foodborne illness in online restaurant reviews

Thomas Effland,[1] Anna Lawson,[1] Sharon Balter,[2] Katelynn Devinney,[2]
Vasudha Reddy,[2] HaeNa Waechter,[2] Luis Gravano,[1] and Daniel Hsu[1]

Is Social Network Diversity Associated with Tooth Loss among Older Japanese Adults?

Jun Aida[1]*, Katsunori Kondo[2,3], Tatsuo Yamamoto[4], Masashige Saito[3,5], Kanade Ito[6],
Kayo Suzuki[7], Ken Osaka[1], Ichiro Kawachi[8]

Accounts of bullying on Twitter in relation to dentofacial features and orthodontic treatment

A. CHAN*, J. S. ANTOUN*, K. C. MORGAINE† & M. FARELLA* *Department of Oral Sciences, Sir John Walsh Research Institute, Faculty of Dentistry, University of Otago, Dunedin, and †Department of Preventive and Social Medicine, University of Otago, Dunedin, New Zealand

Social marketing: an appropriate strategy to reduce oral health inequalities?

Paul R. Brocklehurst[a]*, Phil Morris[b] and Martin Tickle[a]

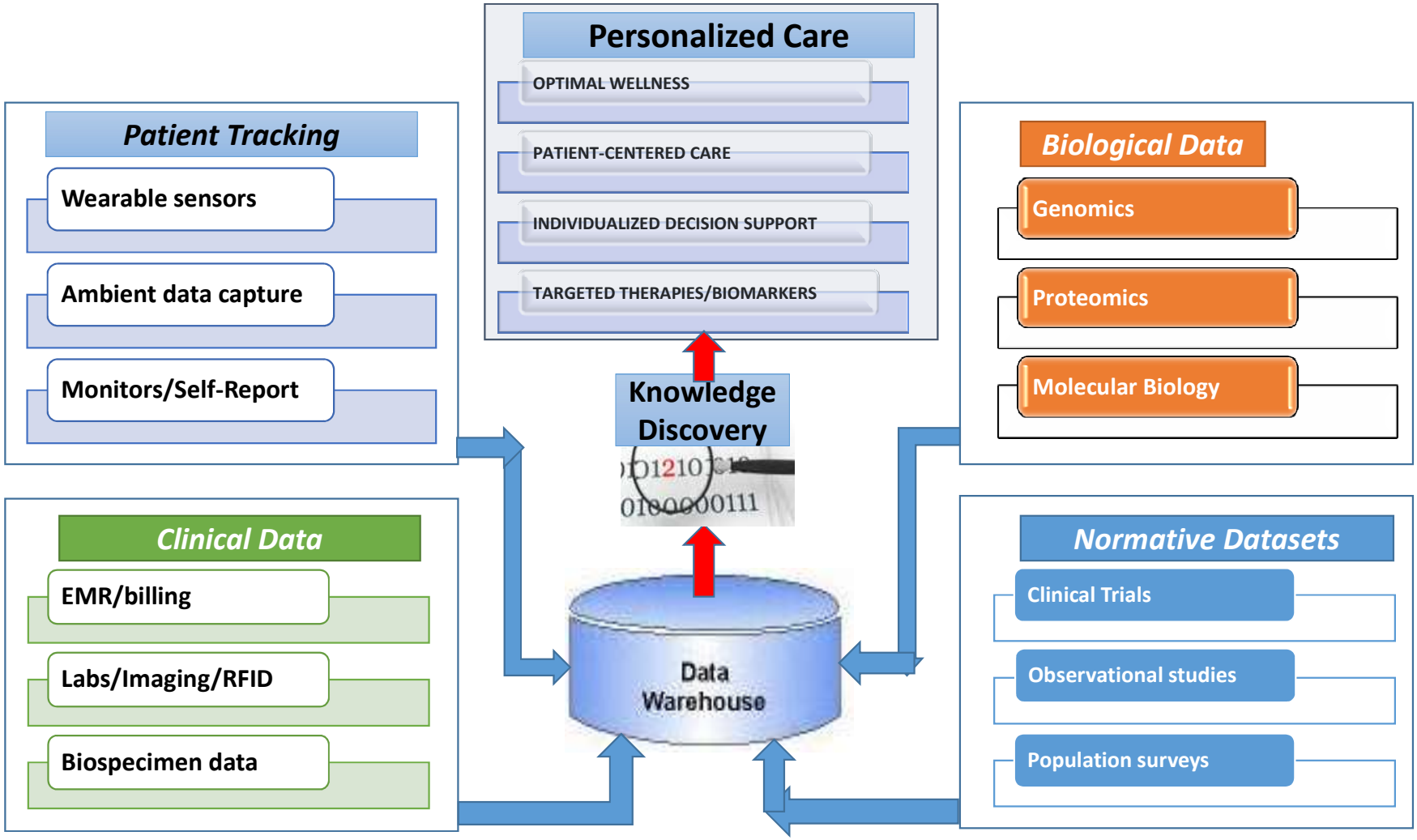
[a]*Department of Dental Public Health and Primary Care, School of Dentistry, University of Manchester, Coupland 3, Oxford Road, Manchester M13 9PL, UK;*
[b]*Department of Social Marketing, Knowsley PCT, Liverpool, UK*

Social Marketing in Oral Health

- Position oral health as essential to overall health
- Add immediate rewards (better breath, more fit)
- Frame it as easy, important and cost-effective
- Be fun and informative, not “preachy”

Goal: Change knowledge, attitudes and behavior

Data Aggregation for Precision Health



OHDSI

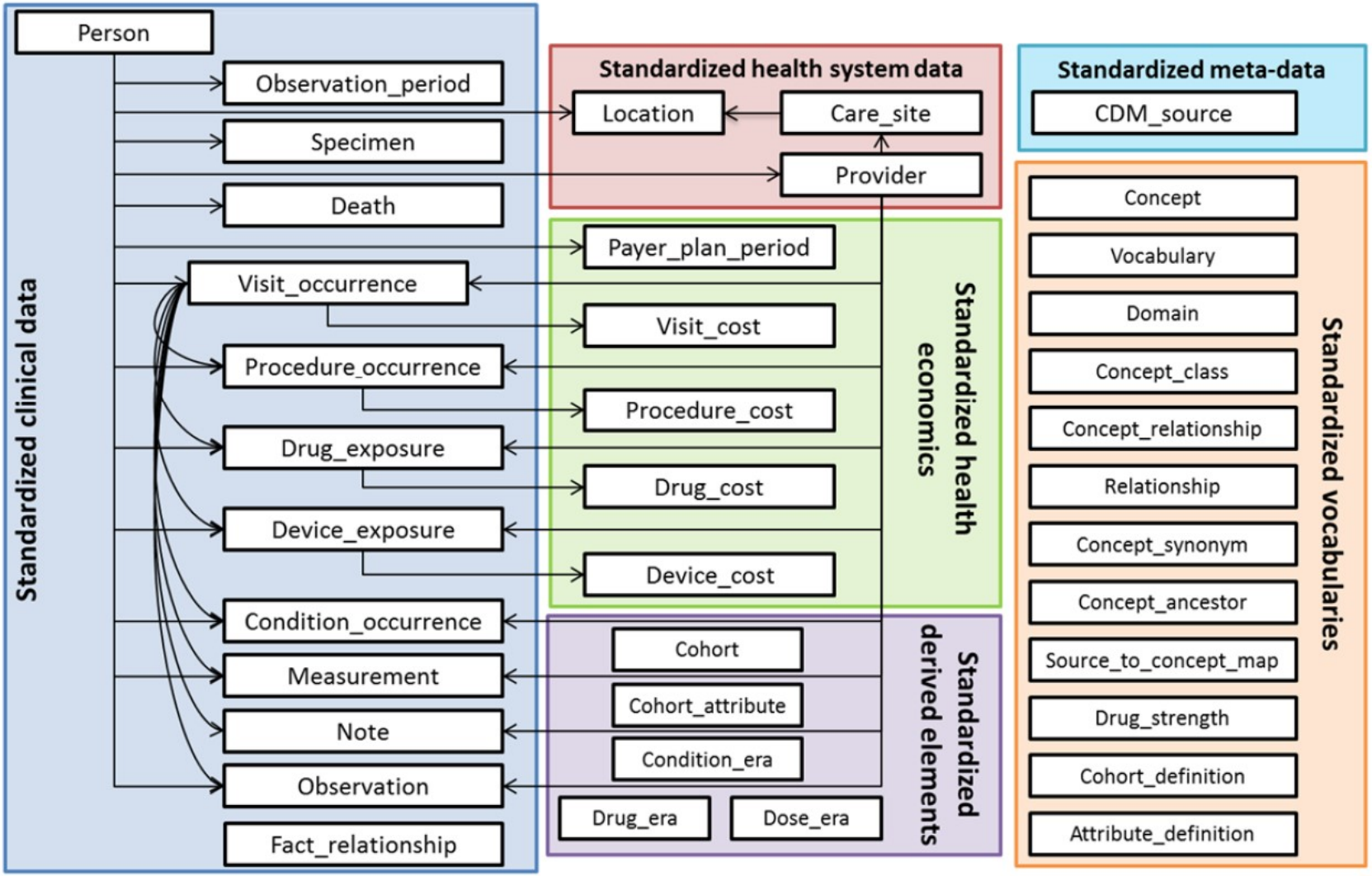
OBSERVATIONAL HEALTH DATA SCIENCES AND INFORMATICS

Welcome to OHDSI!

The Observational Health Data Sciences and Informatics (or OHDSI, pronounced "Odyssey") program is a multi-stakeholder, interdisciplinary collaborative to bring out the value of health data through large-scale analytics. All our solutions are open-source.

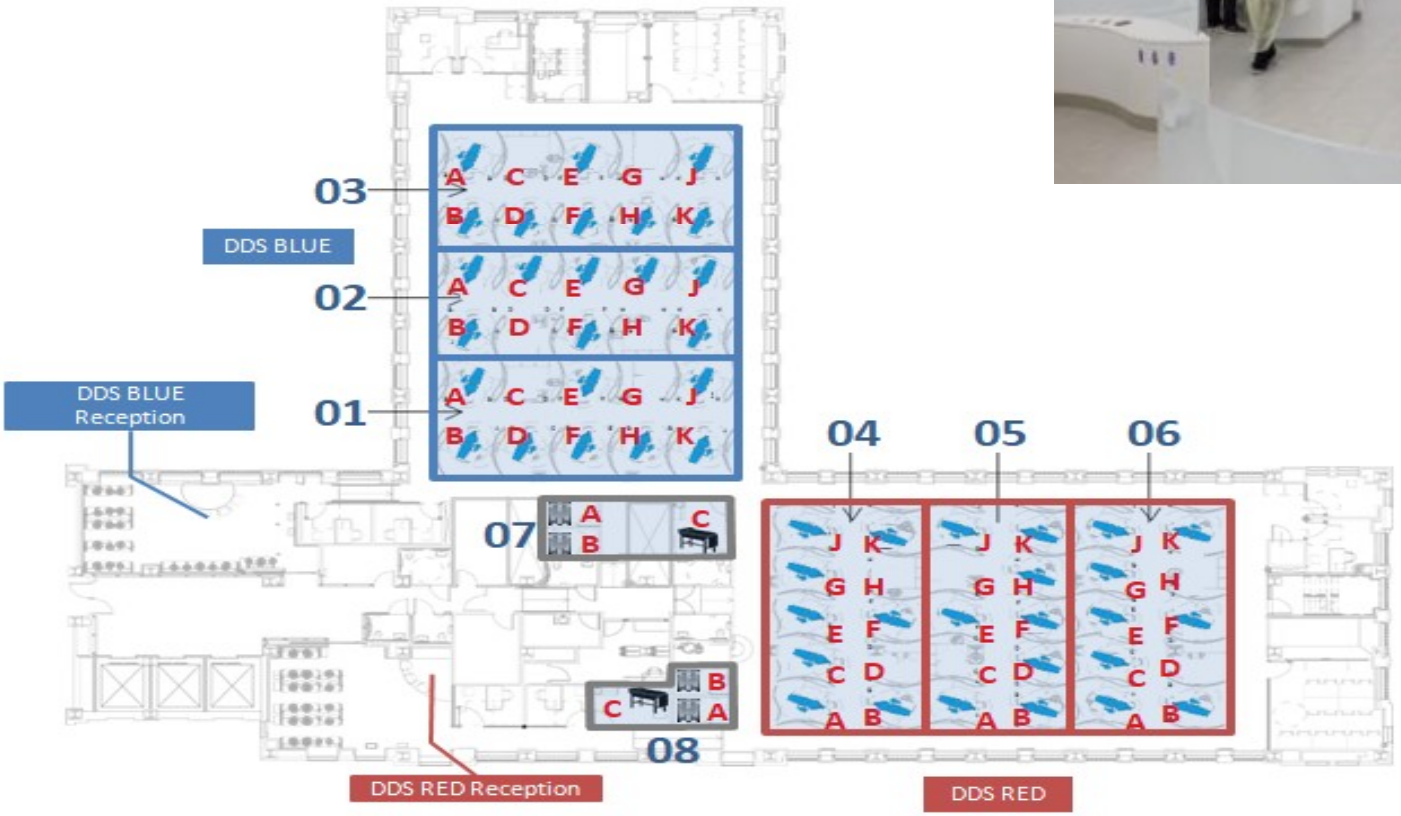
OHDSI has established an international network of researchers and observational health databases with a central coordinating center housed at Columbia University.

Big Data Analytics: Common Data Model



Center for Precision Dental Medicine

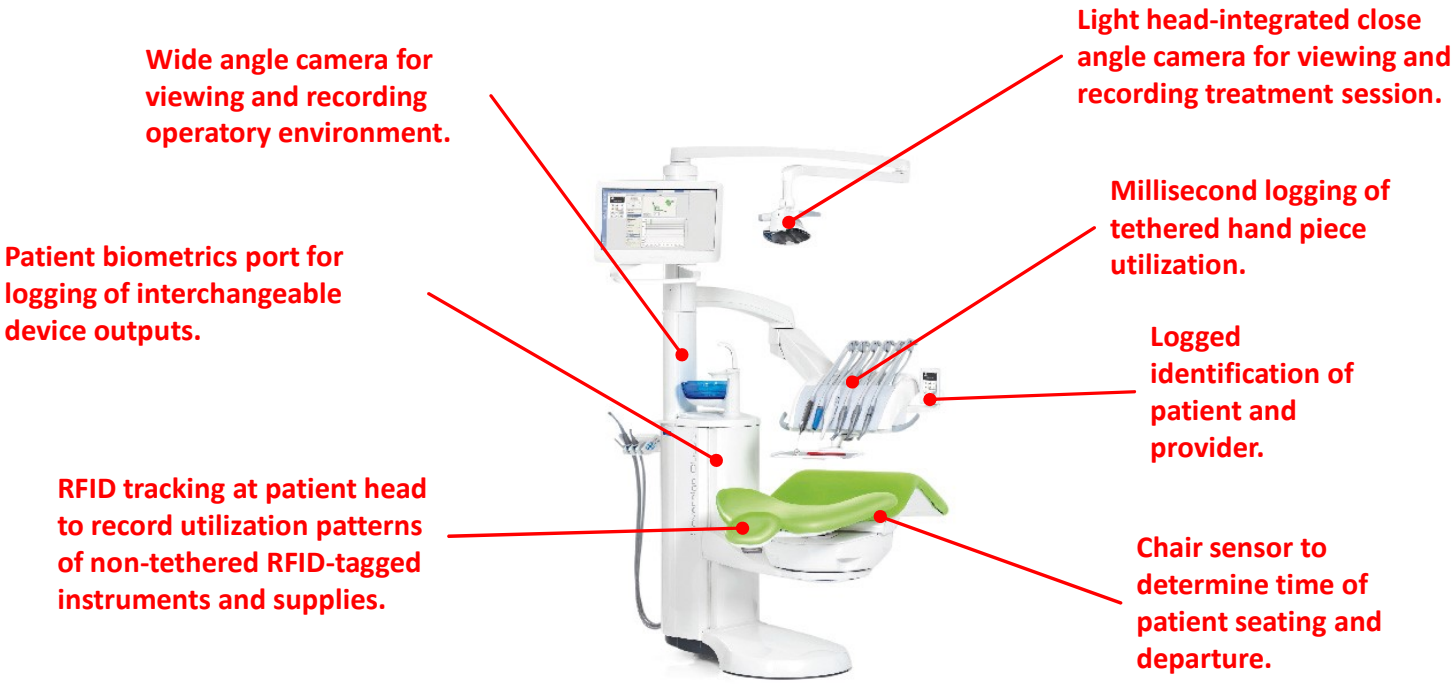
Dental Internet of Things



- 16,000 square feet
- 2 wings
- 48 dental chairs (24 in each wing)
- Radiology, Exam Rooms, IPE, Financial Advising
- Central Supply Chain with decentralized supply cabinets in each row
- Faculty Touchdown spaces in each row

Dental Chair as Data Collection Hub

- **Planmeca Sovereign Classic** unit enhanced with new data gathering systems
- Comprehensive logging of patient encounter for real-time and post-hoc analytics

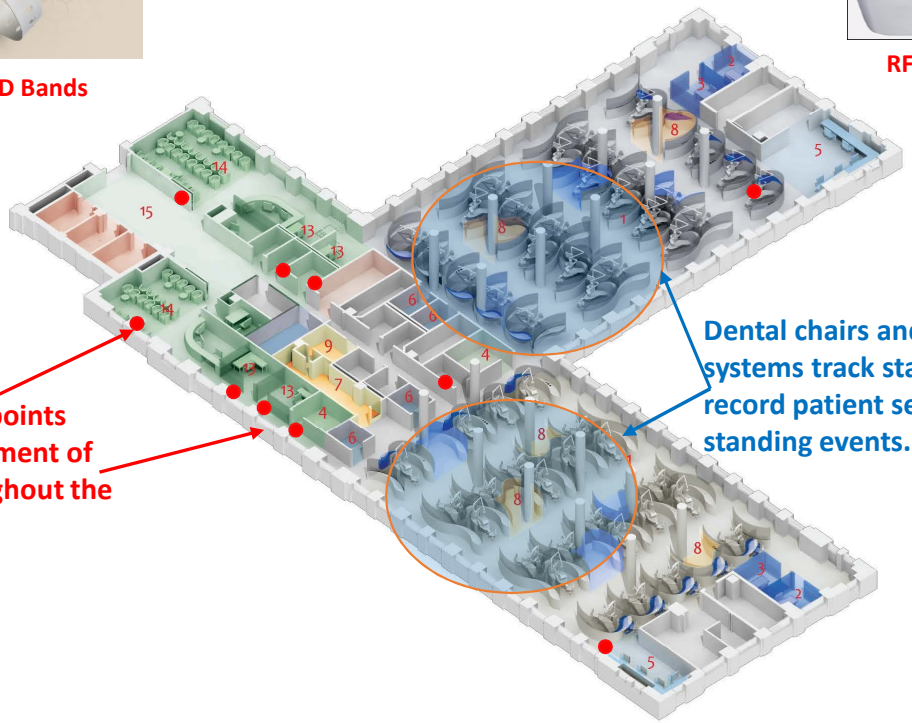


Radio Frequency Identification (RFID) of Patient, Provider & Staff Activity

- Passive tracking of personnel and patient flow
- Calculation of patient wait times and encounter intervals
- Automatic reporting of chair utilization
- Ceiling-based RFID readers focused on reception areas, central support, patient serving rooms and digital design lab
- Other RFID readers will read supply cabinets and hand-held instruments used in operatory environment

Patient RFID Bands

RFID Reader



RFID tracking points monitor movement of persons throughout the clinic

Dental chairs and imaging systems track staff usage and record patient seating and standing events.

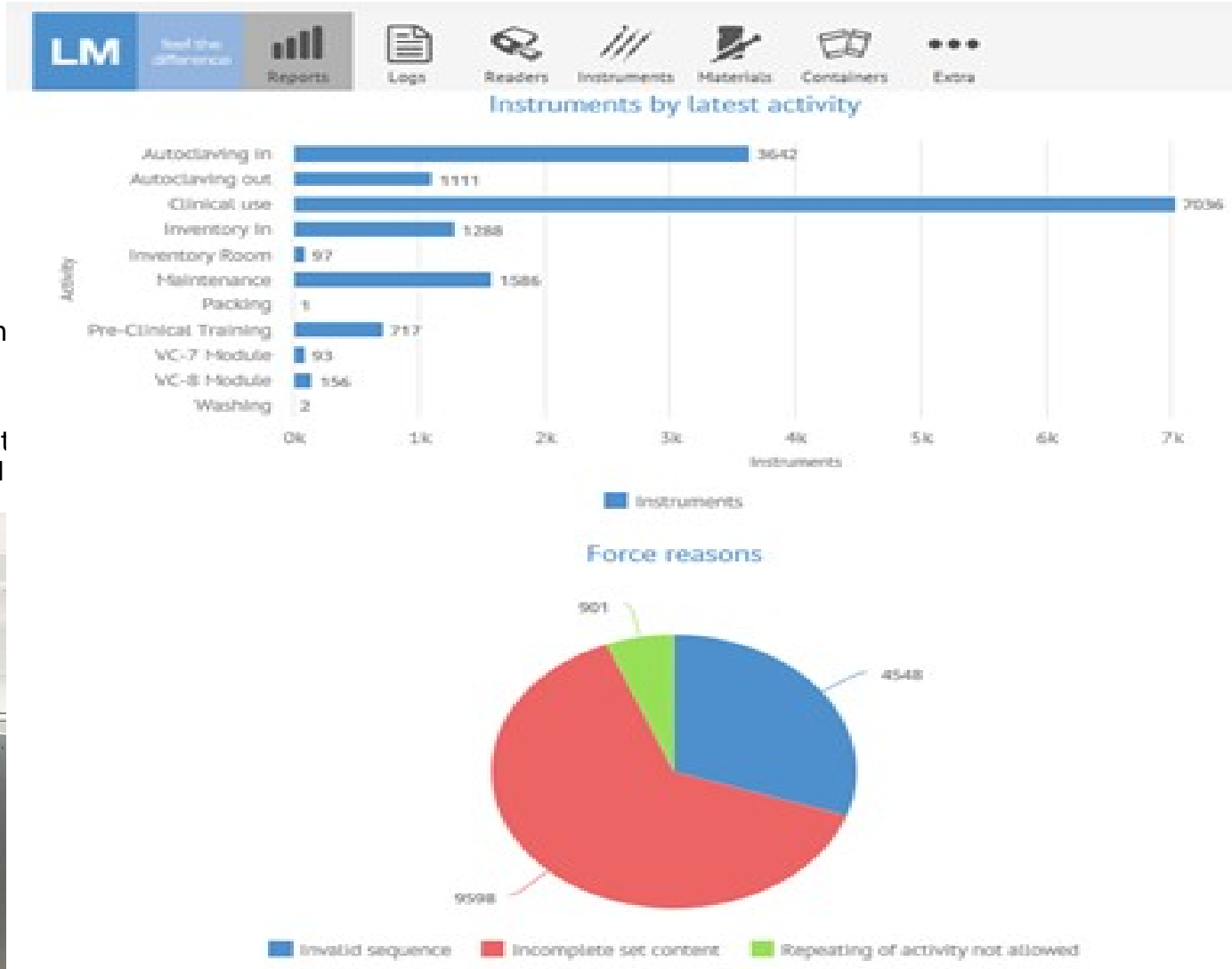
Radio Frequency ID Cabinets

•Locked cabinet activated with ID badge.

•Bins containing procedure-specific instruments/materials in lower cabinets.

•All other materials in the top cabinets and coun top.

•Anticipated future use: link scheduled appointment types for surrounding operatories t determine contents of prepared bins in each RFI cabinet



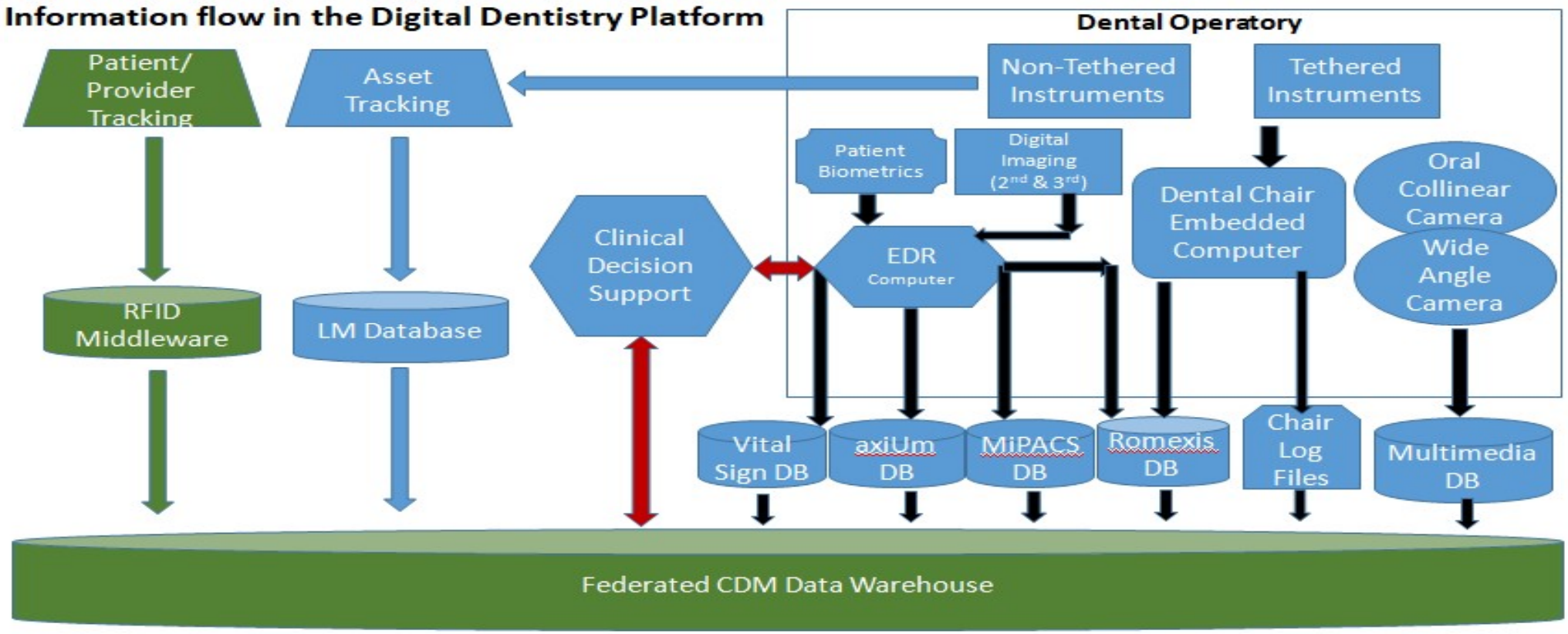
Objectives

- Implement comprehensive digital infrastructure for research and development in dental health aggregating multiple heterogeneous data streams pertinent to oral health
- Develop decision support tools for digital dental office based on input from multiple sensors and EMR
- Support big data analytics for quality improvement and patient safety
- Implement decision support analytics for RFID-based dental tracking system to optimize dental care delivery and facilitate dental education
- Build central data repository to support big data analytics in oral health in compliance with major standards for health information exchange and medical ontologies
- Incubate important new digital technologies, apps, sensors, and systems, and bring them to market via collaborations with start-ups and industry and capital partners.
- Provide informatics support to faculty interested in research in this area

Data Analytics Roadmap

- Data Aggregation
  - -Data assessment
  - -Data modeling
  - -Semantic normalization
  - -Data platform implementation

- Data Analytics
  - -Initial Use Cases: Minimally Viable Product (MVP)
  - -Deep Phenotyping
  - -Decision Support
  - -Knowledge Discovery


Information flow in the Digital Dentistry Platform
Dental Operatory
Patient/ Provider Tracking
Asset Tracking
Non-Tethered Instruments
Tethered Instruments
Patient Biometrics
Digital Imaging (2nd & 3rd)
Oral Collinear Camera
Dental Chair Embedded Computer
Wide Angle Camera
Clinical Decision Support
EDR Computer
RFID Middleware
LM Database
Vital Sign DB
axiUm DB
MiPACS DB
Romexis DB
Chair Log Files
Multimedia DB
Federated CDM Data Warehouse

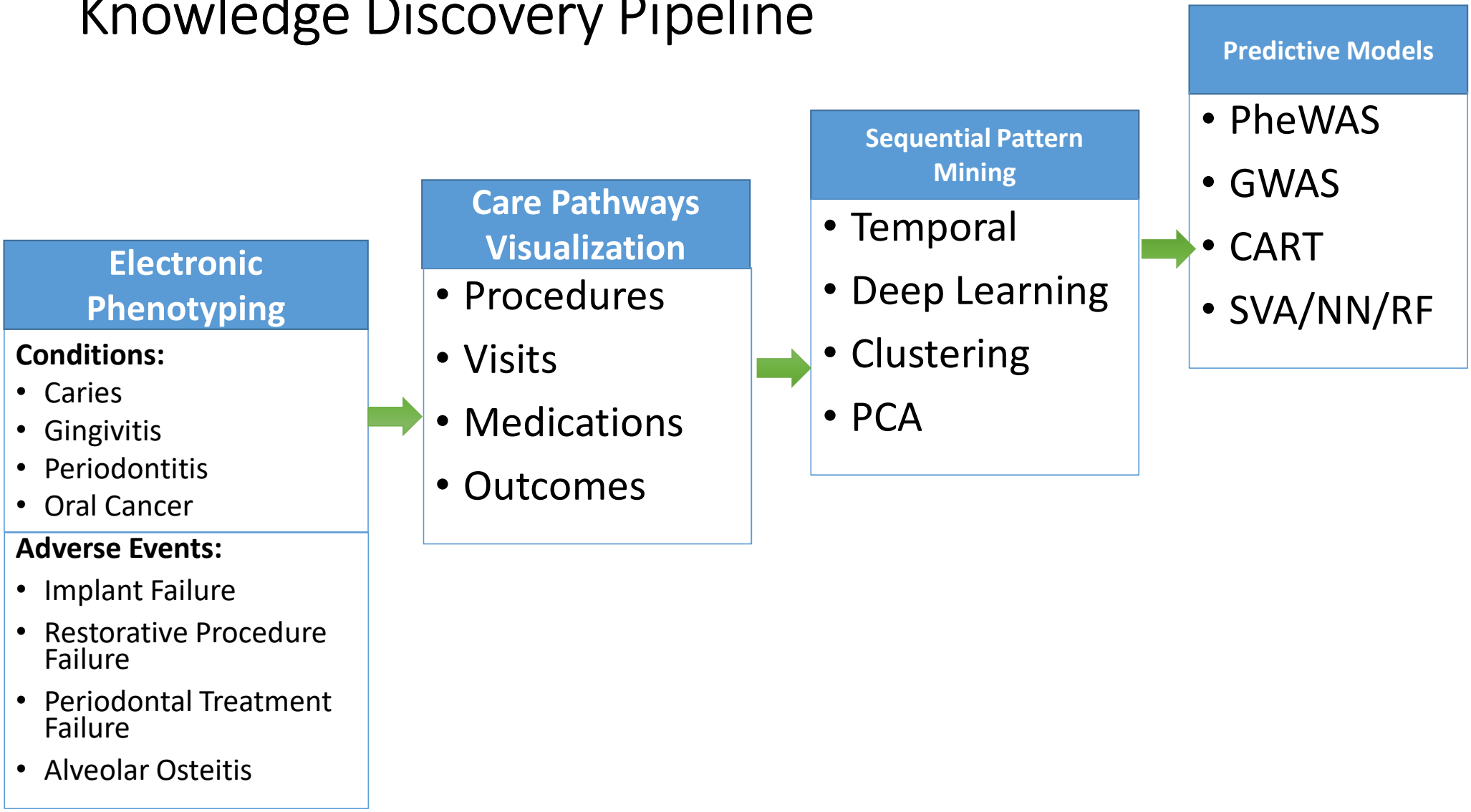
Data Collection and Analytic Functionality

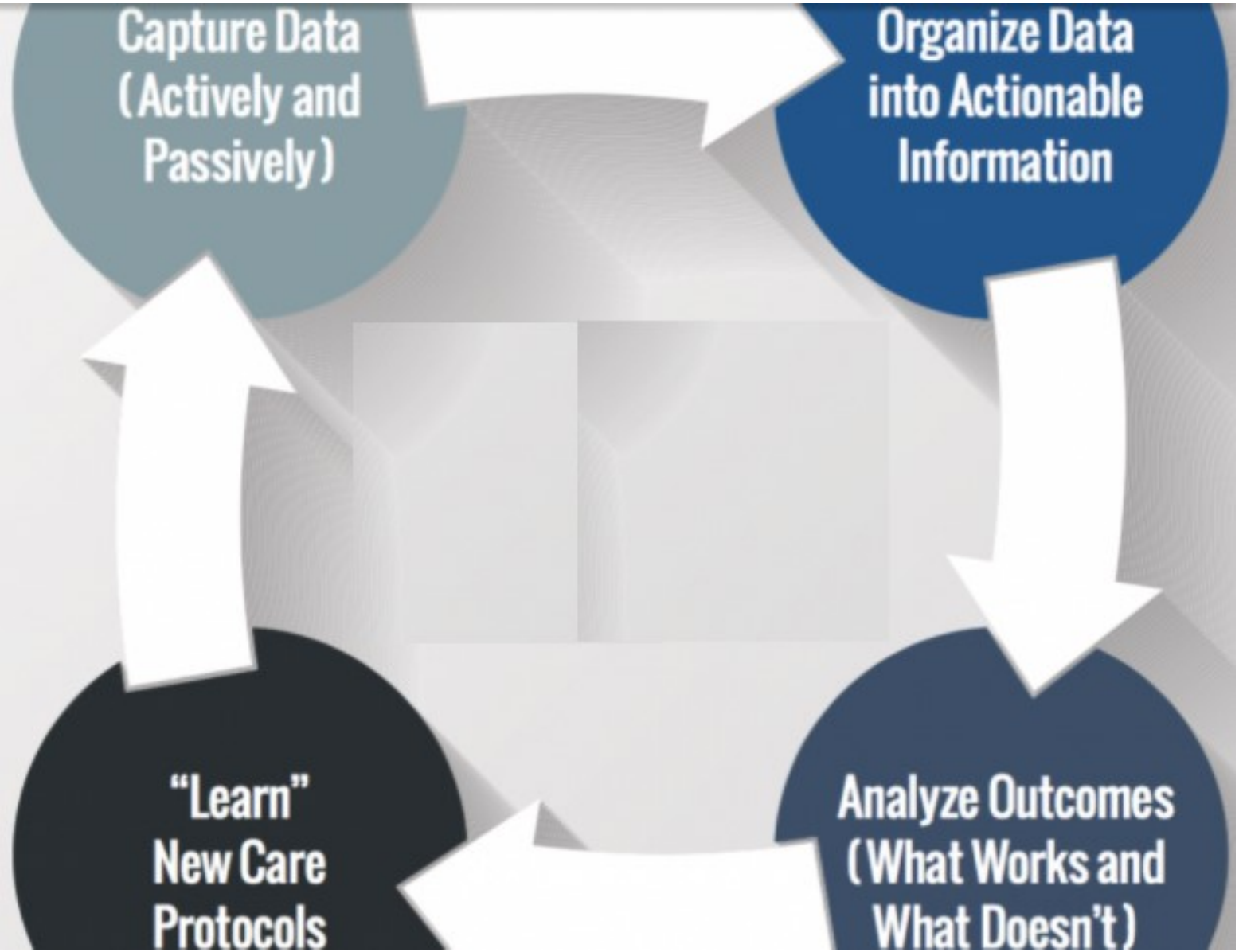
Data	Function
RFID	Clinical management
Instruments (Tethered / Non-tethered)	True cost of care
Patients & Providers	Quality & Safety
Chair	Efficient utilization
Supply cabinets	Efficacy of procedures
Medical Images	Preemptive teaching
EDR	Resiliency / stress
Video	Total health / precision medicine

Predictive Modeling

- Identification of optimal procedures
- Prediction of oral health outcomes
- Stratification of risk groups
- Classification of systemic diseases
- Deep phenotyping of dental conditions
- Disease trajectory analysis
- Health outcomes research
- Workflow optimization
- Asset management
- Quality improvement
- Productivity and financial performance
- Enhancement of dental education process

Knowledge Discovery Pipeline





Continuous knowledge discovery and quality improvement cycle

Research Objectives

Predictive Modelling

- Identification of optimal procedures
- Prediction of oral health outcomes
- Stratification of risk groups
- Classification of systemic diseases
- Deep phenotyping of dental conditions
- Disease trajectory analysis
- Health outcomes research

Dental Care Delivery

- Time-motion studies – cost of care modeling
- Analysis of educational strategies and outcomes
- Quality metrics /Patient safety / Adverse events
- Value-based reimbursement modeling
- Pursuit of the Triple Aim
- Management of chronic disease and **Total** Health
- Evidence-based dental care / clinical decision support

Precision Oral Health

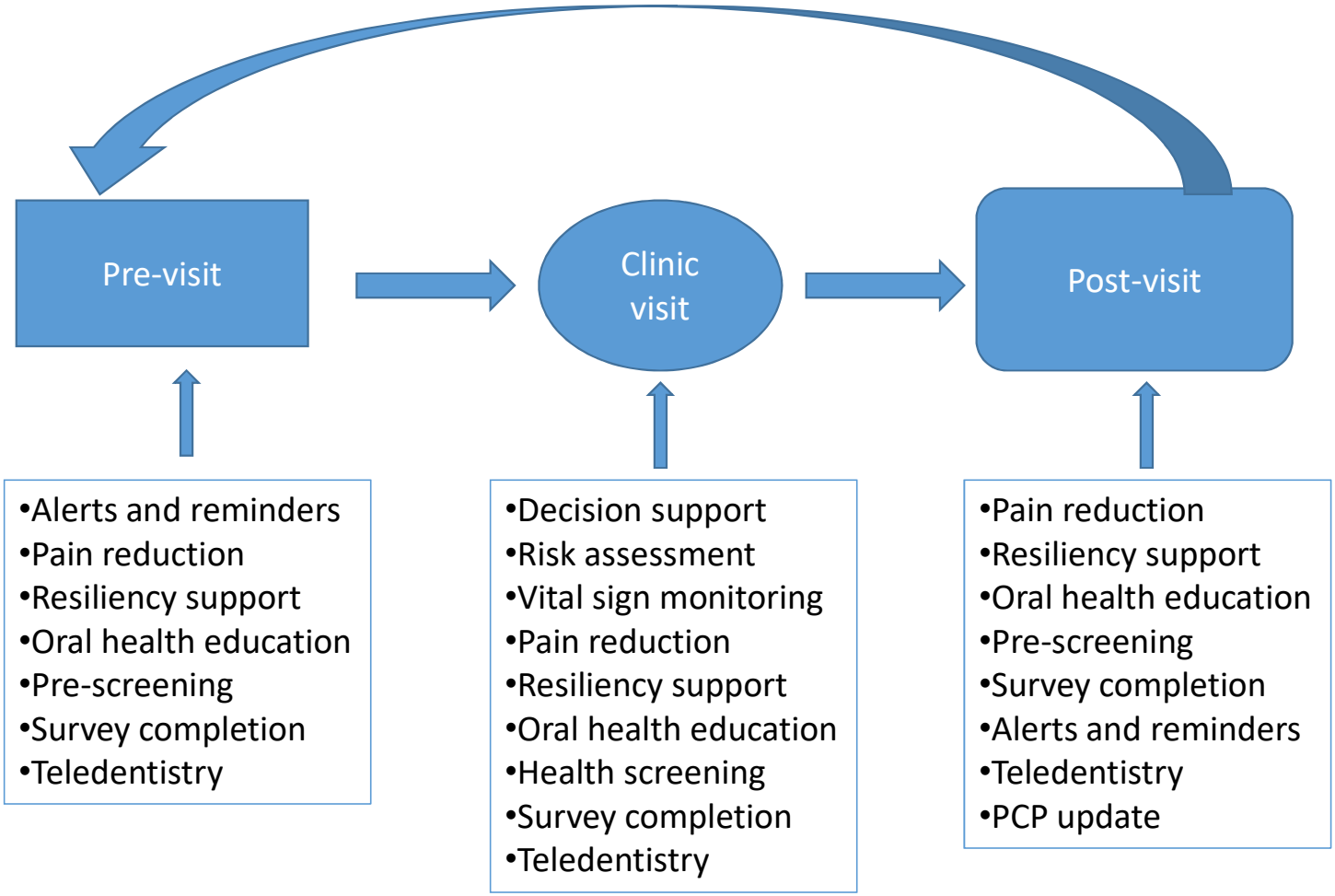
Translational Projects

- Pain attributes and measures
- Pain management with pharmacogenetics
- Stress Resiliency and relationship to chronic disease
- Oral health and multimorbidity

Patient Engagement

- Oral health education
- My Oral Health Scorecard
- Patient portal for Oral Health
- Decision Aids
- Virtual reality and simulation tools
- Mobile apps / gaming education
- Alerts and reminders
- Social media

Precision Oral Health



Big Data Analytics Domains for Precision Dental Medicine

- In the ***clinical domain***, multiple research opportunities exist to study precision dental care delivery tailored to specific patient profiles. Development of real-time decision support tools for individualized diagnosis and treatment planning based on multitude of relevant factors provided before, during and after the dental encounter will significantly improve the quality of dental care and patient satisfaction.
- In the ***socio-behavioral domain***, identifying oral health risk factors specific to particular population subgroups and delivering targeted preventative interventions using digital media will greatly facilitate individualized oral health on a population-based level.
- In the ***basic science domain***, research on how the wired digital operatories access and utilize data from outside streams, including a patient's genetic traits and microbiome to facilitate personalized care delivery will be supported by OHDSI framework.
- In the ***educational domain***, research on utilizing multiple data streams to better monitor student performance and identify areas for personalized improvement will promote personalized education and individualized student support tailored to individualized performance profile.

Health Disparities in Hispanic Community

- More than half of Hispanics ages 64 and older will suffer from untreated tooth decay; three times more than non-Hispanic seniors.
- More likely to experience delay in care and unmet dental need
- 51% are more likely to die from diabetes
- 24% less-controlled high blood pressure
- Hospitalized children of Spanish-speaking families are more likely to experience an unexpected medical event that involves the risk of death or serious injury with a fivefold increase in the length of stay
- Greater chance of hospital readmission for certain chronic conditions

Latino oral health

A research agenda toward eliminating oral health disparities

FRANCISCO RAMOS-GOMEZ, D.D.S., M.S., M.P.H.; GUSTAVO D. CRUZ, D.M.D., M.P.H.; MARIA ROSA WATSON, D.D.S., M.S., Dr.Ph.; MARIA TERESA CANTO, D.D.S., M.P.H.; AUGUSTO ELIAS BONETA, D.M.D., M.S.D.

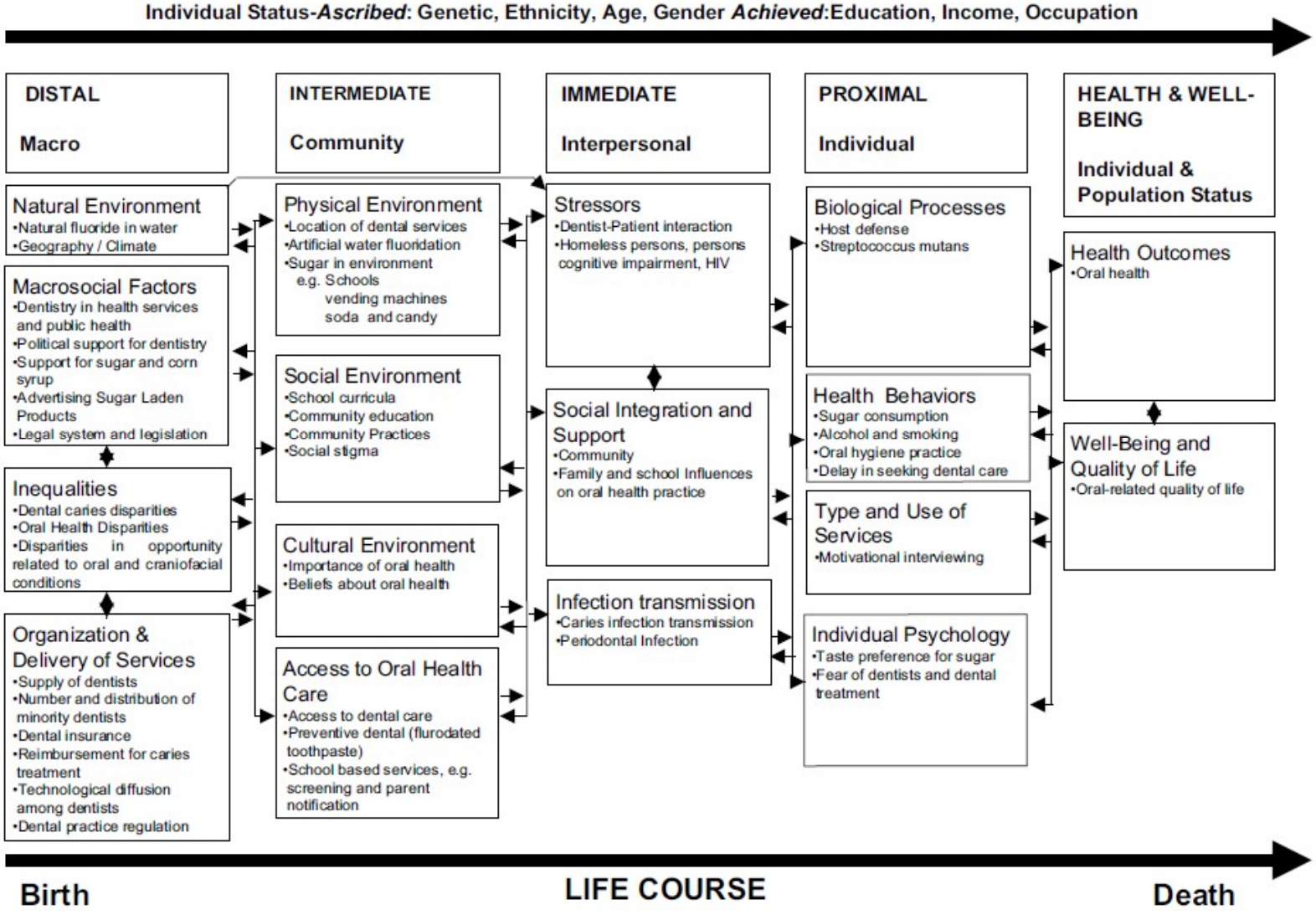
A 2000 report by the U.S. surgeon general found that minority populations bear a disproportionate burden of oral disease in the United States. That same year, the U.S. Census Bureau reported that Hispanics had become the nation's largest minority group. In the context of this landmark demographic shift, the Hispanic Dental Association (HDA) and the University of Puerto Rico School of Dentistry, San Juan, convened a workshop in October 2004 to develop an agenda to guide future research on Latino oral health issues and to promote collaboration in this area.

JADA 2005;136:1231-40

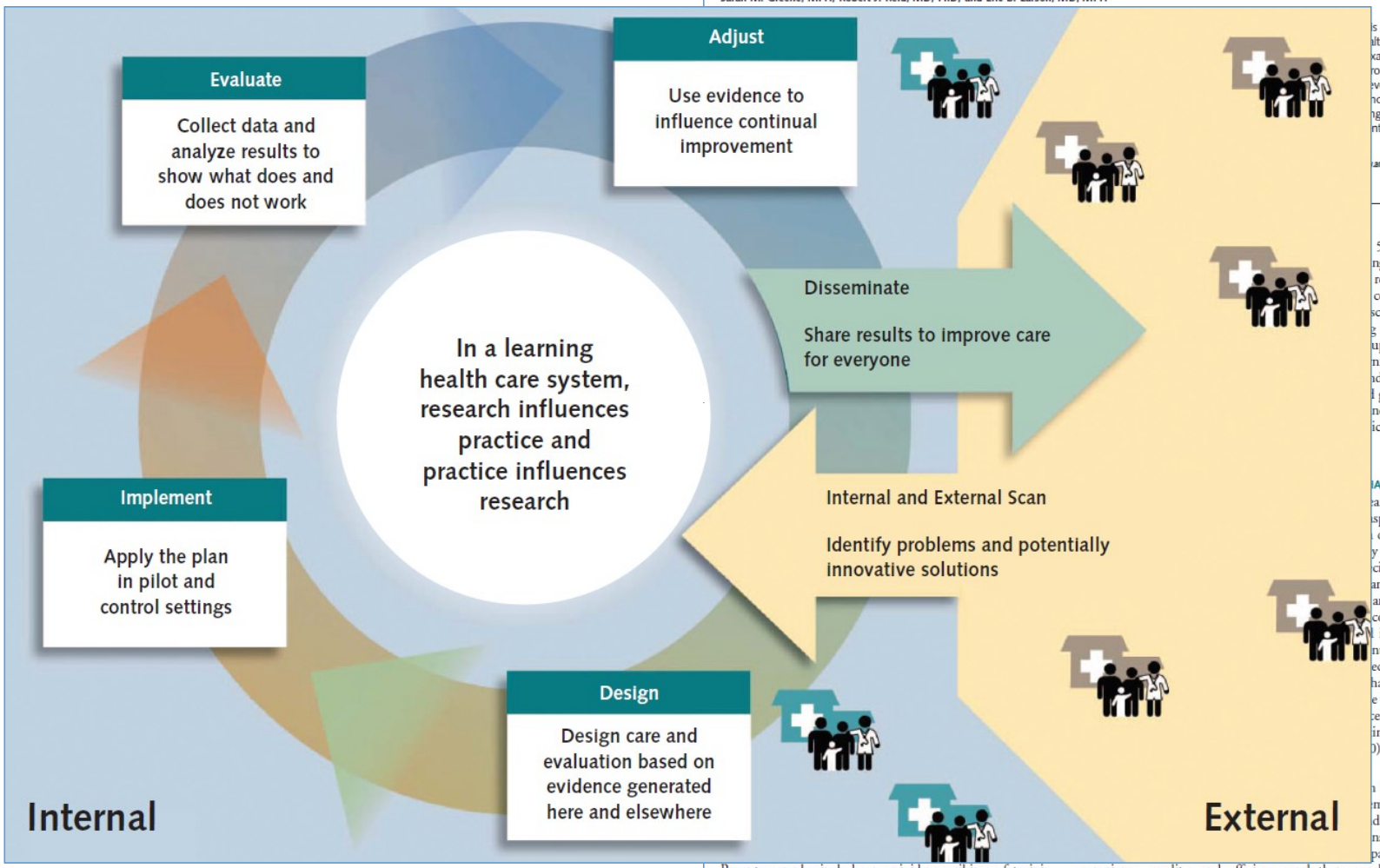
Urgent research priorities to meet the oral health care needs of Hispanic patients:

- population-based studies;
- social and behavioral sciences;
- health promotion and communications;
- gene-environment interactions;
- research training and workforce development.

Influences on Oral Health and Oral Health Disparities



Learning Health System:
A Continuous Cycle of Care Improvement to Address Gaps in Care, to Improve Outcomes and Patient Satisfaction



Annals of Internal Medicine | Medicine and Public Issues

Implementing the Learning Health System: From Concept to Action

Sarah M. Greene, MPH; Robert J. Reid, MD, PhD; and Eric B. Larson, MD, MPH

Recent examples include an opioid-prescribing safety ini- experience, quality, and efficiency and then search for

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Learning Health System

- The **goal** of a learning health system is to deliver the best care every time, and to learn and improve with each care experience.
- Data collection and monitoring are crucial components of a learning health system
- Big Data Analytics contribute to a learning health system by identifying the best-known evidence, promoting continuous learning, and allowing for knowledge generation as a natural by-product of patient care delivery.
- A learning health system advances quality and improves patient safety and satisfaction by providing best available care tailored to individual patient needs, values, and clinical profile

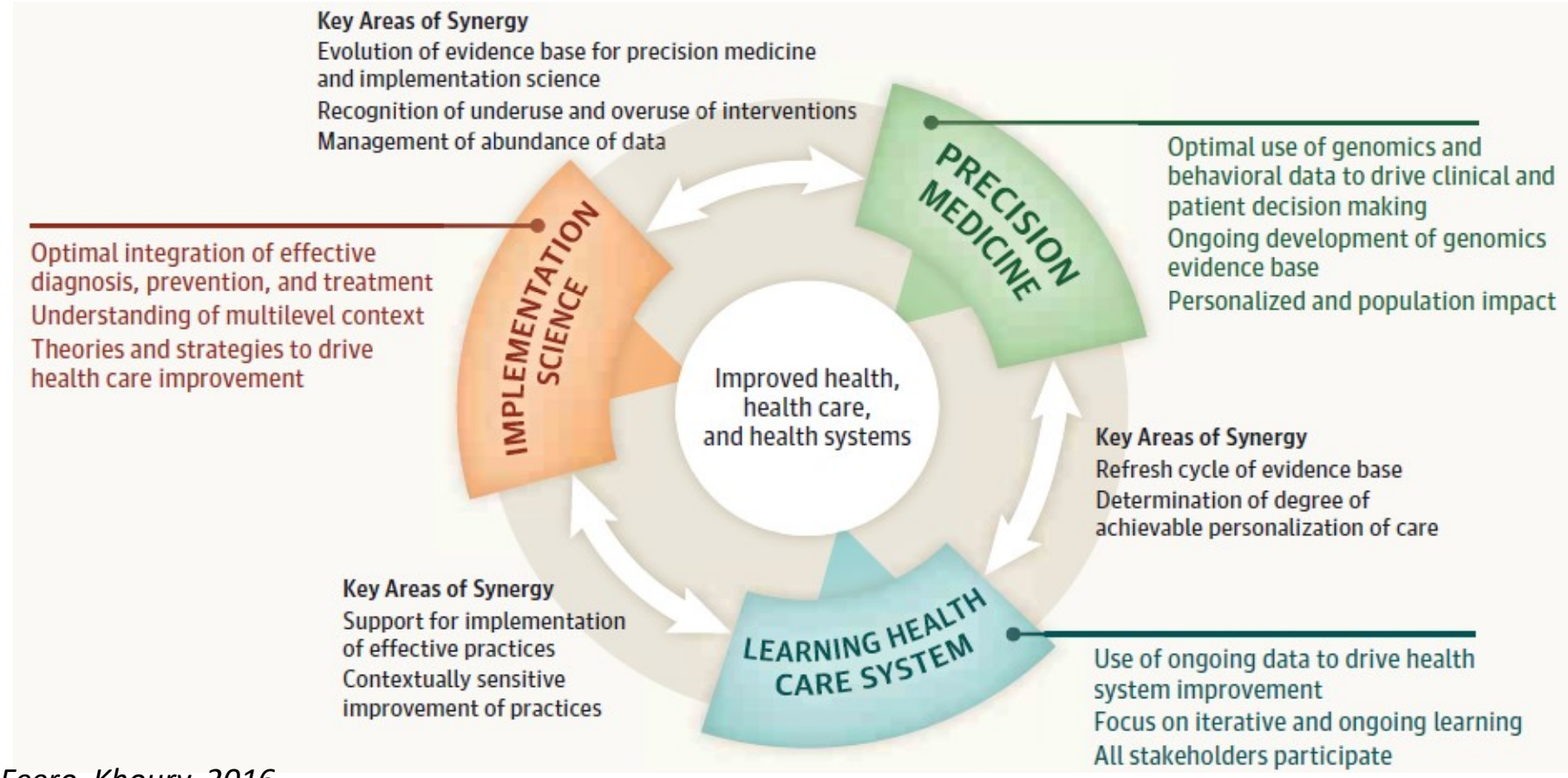
Source: Engineering a Learning Healthcare System: A Look at the Future. IOM Workshop Summary

Benefits of Learning Health System for Population Health

- Every patient's characteristics and experience are available for study
- Best practice knowledge is immediately available to support decisions
- Improvement is continuous through ongoing study
- This happens routinely, economically and almost invisibly
- All of this is part of the culture

Charles P. Friedman, PhD, Professor of Medical Education, Chair of the Department of Learning Health Sciences
Professor of Information and Public Health, University of Michigan

Contributions of Implementation Science, Learning Health Care System, and Precision Medicine



Chambers, Feero, Khoury, 2016

Establishing Leadership of Dental Professionals in Precision Health

Data Science Training for Dental Professionals:

- Elective in Data Science for pre-doctoral students:

DDS Squared: Digest in Data Science (DDS) for Doctors of Dental Surgery (DDS)

- Summer research experience in data science project
- Research assistantship in data science
- Informatics infrastructure to support faculty research in data science

Conclusion

Precision dental medicine

- Translates heterogeneous big data into valuable healthcare information to improve quality, lower costs and facilitate precision health
- Creates evidence to support optimal tailored dental care delivery protocols affecting oral and overall health
- Promotes creative thinking and innovation for care delivery and reimbursement models

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