A CALL TO ACTION
Total Exposure Health : A Framework for True Primary Prevention

KIRK PHILLIPS, MS, IH

Kirk Phillips

Managing Principal, HSE Practice Ldr, LJB Inc, Wash DC

Chair, AIHA Total Exposure Health/TWH Advisory Group

LJB Inc. providing HSE services to all segments of industry worldwide including engineering control design.

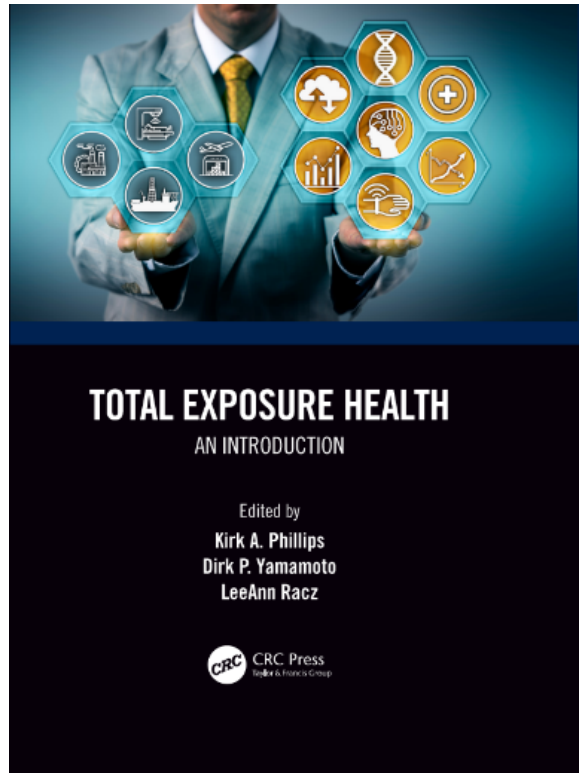
28yr AF Chief for Bioenvironmental Engineering in the Ofc of the Air Force Surgeon General led global OEH

Created Total Exposure Health framework in 2013 to effectively respond to the changing work env, increased sensing capacity and precision health adv

"Total Exposure Health-An Introduction," Editor

MS Eng and Env Management, AFIT, CIH 1991-2009

ASSP TWH Task Force Member



Origins of Total Exposure Health

- Background
  - 29 years measuring exposures and applying risk decisions to promote health
    - Industrial Workers and Community Health
  - Rose through AF medical culminating in leading the 1900+ exposure professionals – Bioenvironmental Engineers
- Constant Challenge
  - How to demonstrate protections were necessary and beneficial
  - Are sensitive "populations" protected
  - What about the "Modern World" we live in. "Industrial Age," "Nuclear Age," "Tech Age." We are in the "4th Industrial Revolution" and on the precipice of the "5th Industrial Revolution".

AIHA – Healthier Workplaces. A Healthier World.

AIHA is the association for scientists and professionals committed to preserving and ensuring occupational and environmental health and safety (OEHS) in the workplace and community….we champion higher standards of health, safety, and professional integrity—positioning the profession to better protect workers, businesses, and the public today and in the future."

- OEL process
- Changing workforce/workplace
- Sensor technology
- Big data
- Demonstrating the business value of OEHS
- Global standard of care

Total Exposure Health/Total Worker Health® Advisory Group

What's in a name?

- **Total Exposure Health** is a CPAG content priority
  - …an embodiment of precision health. Environment and lifestyle factors known as "exposures" are critical to the development of preventive medicine, through precision health. TEH focuses on prevention.
  - TEH is a framework to deliver exposure science as part of the fourth industrial revolution consisting of technology and medical advances.
- **Total Worker Health** is a NIOSH initiative
  - …policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being
  - Already widely utilized term defining this area of practice, would strengthen link between AIHA and NIOSH

Roles and Responsibilities

The TEH/TWH-AG (herein refenced as "the Advisory Group ") will…

- Identify gaps specific to occupational and environmental health and safety (OEHS) science in existing TWH resources to determine how AIHA might best fill those gaps.
- Establish working relationships with other sciences such at toxicology, epidemiology, engineering, human health risk assessors, occupational health physicians, occupational health nurses, and building envelope scientists
- Establish the processes necessary to allow AIHA's TEH projects and resource curation to be self-sustaining.
- Establish working relationships with each of NIOSH's Centers of Excellence (CoEs) for TWH

Roles and Responsibilities

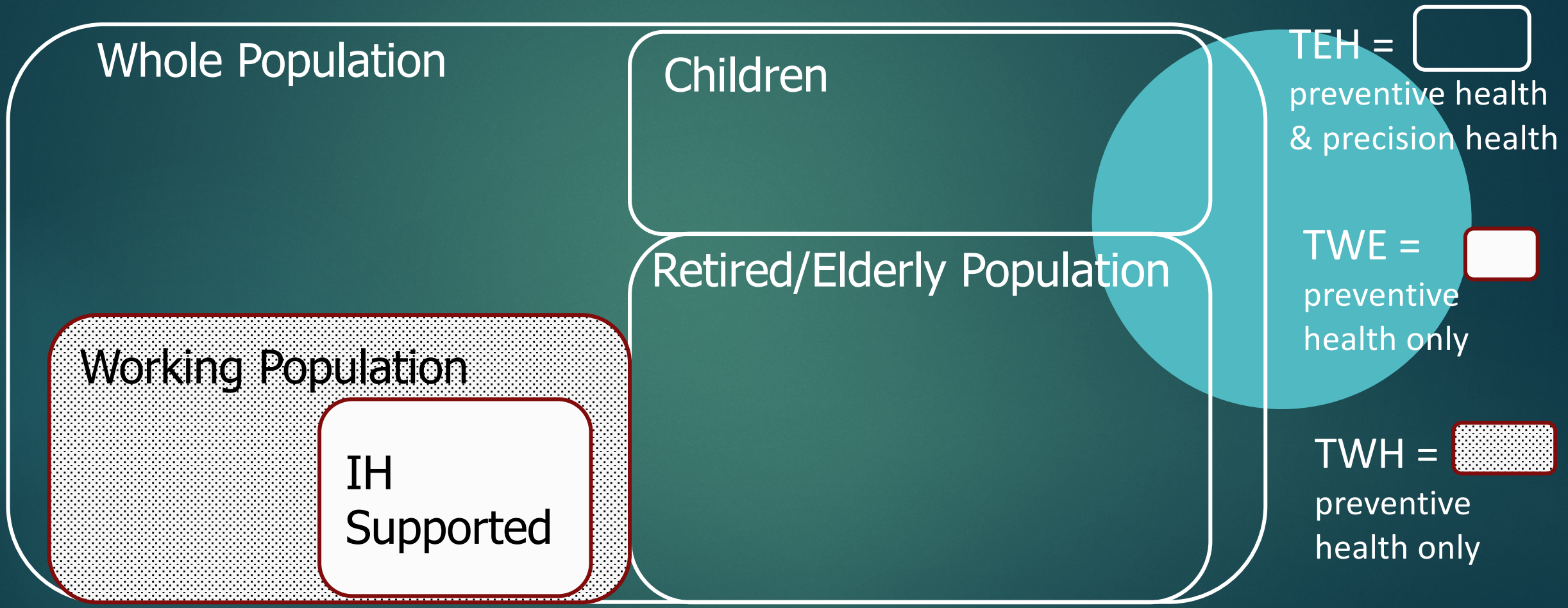
The TEH/TWH-AG (herein refenced as "the Advisory Group ") will…

- Advance AIHA's Content Portfolio Advisory Group (CPAG) Total Exposure Health content priority, keeping CPAG current with the TEH/TWH-AG's projects and progress and ensure the content priority "Total Exposure Health" is aligned with the TEH/TWH-AG's efforts.
- Provide support for AIHA in its role as a NIOSH TWH Affiliate through designated TEH/TWH-AG representatives who participate as AIHA representatives in NIOSH TWH Affiliate meetings and calls
- Bring to the AIHA community a readily accessible set of curated TWH resources that have been developed by other organizations such as NIOSH and its TWH affiliates .

TEH/TWH AG Members

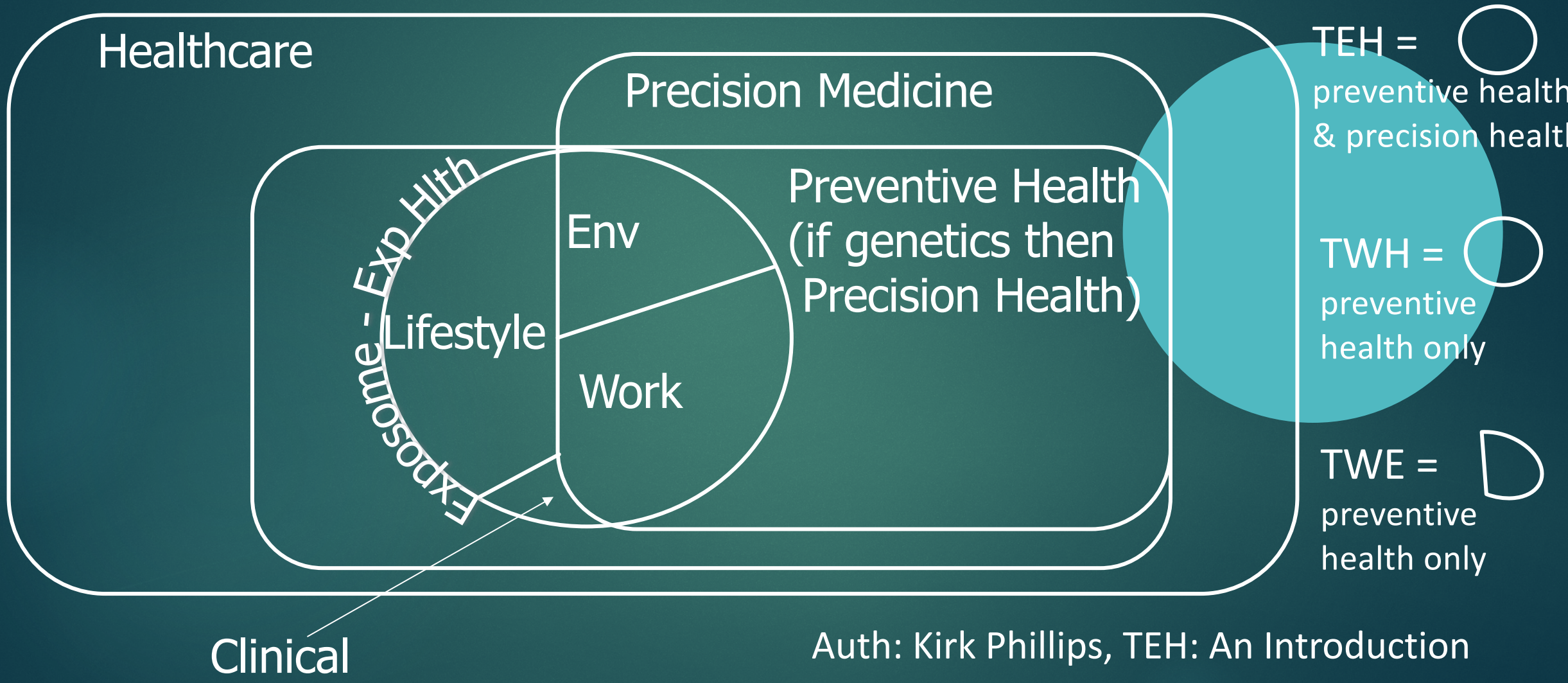
- Task force members will continue to serve on the advisory group
- Kirk Phillips will serve as Chair
- Fred Boelter will serve as Vice-Chair
- Ann Lori, CPAG liaison
- Chia-Chia Chang, NIOSH ex-officio

Totals according to Population



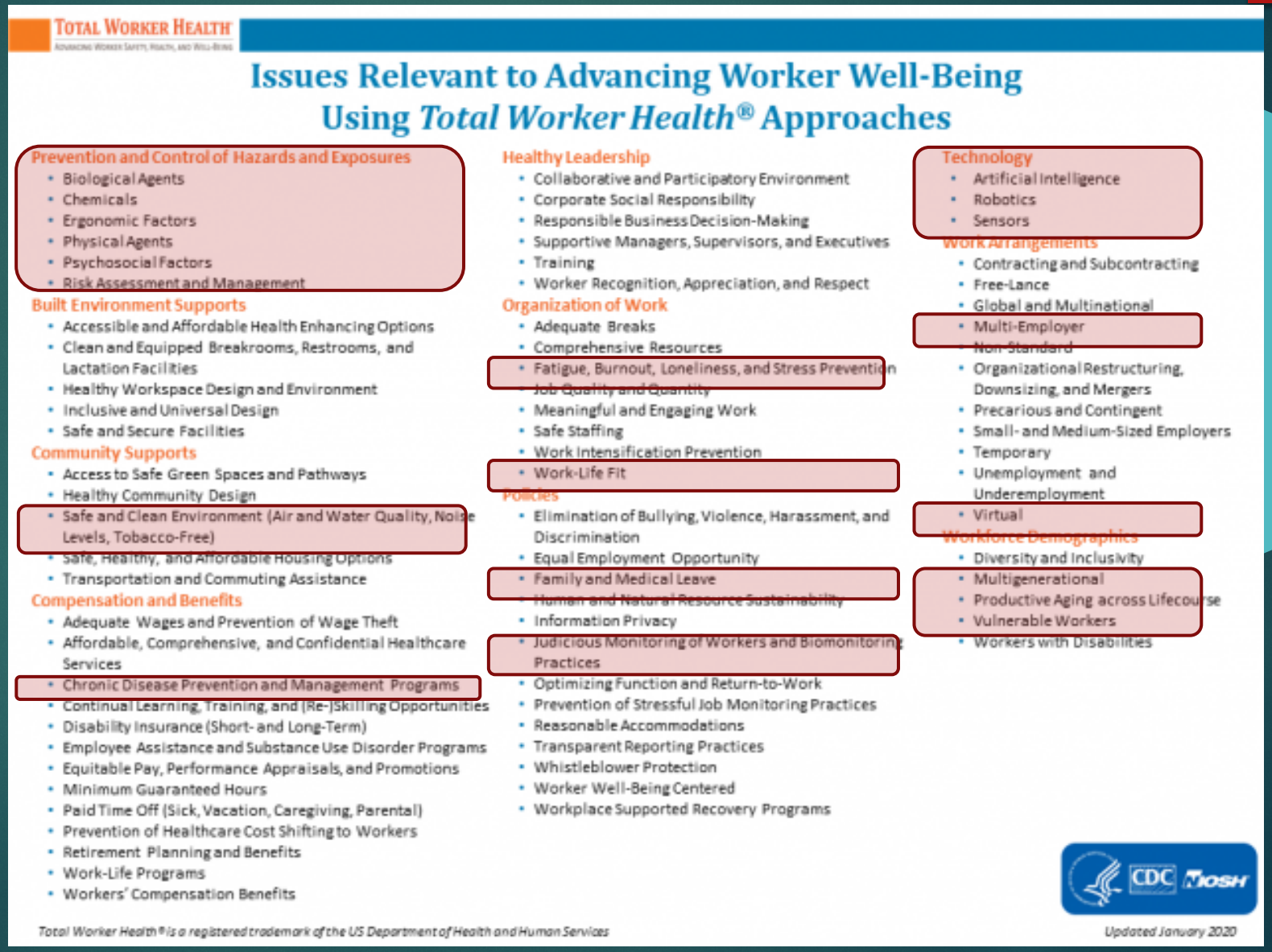
Auth: Kirk Phillips, TEH: An Introduction

Totals according to "health"



Auth: Kirk Phillips, TEH: An Introduction

TEH within TWH



TOTAL WORKER HEALTH

Issues Relevant to Advancing Worker Well-Being Using *Total Worker Health*® Approaches

Prevention and Control of Hazards and Exposures
- Biological Agents
- Chemicals
- Ergonomic Factors
- Physical Agents
- Psychosocial Factors
- Risk Assessment and Management

Built Environment Supports
- Accessible and Affordable Health Enhancing Options
- Clean and Equipped Breakrooms, Restrooms, and Lactation Facilities
- Healthy Workspace Design and Environment
- Inclusive and Universal Design
- Safe and Secure Facilities

Community Supports
- Access to Safe Green Spaces and Pathways
- Healthy Community Design
- Safe and Clean Environment (Air and Water Quality, Noise Levels, Tobacco-Free)
- Safe, Healthy, and Affordable Housing Options
- Transportation and Commuting Assistance

Compensation and Benefits
- Adequate Wages and Prevention of Wage Theft
- Affordable, Comprehensive, and Confidential Healthcare Services
- Chronic Disease Prevention and Management Programs
- Continual Learning, Training, and (Re-)Skilling Opportunities
- Disability Insurance (Short- and Long-Term)
- Employee Assistance and Substance Use Disorder Programs
- Equitable Pay, Performance Appraisals, and Promotions
- Minimum Guaranteed Hours
- Paid Time Off (Sick, Vacation, Caregiving, Parental)
- Prevention of Healthcare Cost Shifting to Workers
- Retirement Planning and Benefits
- Work-Life Programs
- Workers' Compensation Benefits

Healthy Leadership
- Collaborative and Participatory Environment
- Corporate Social Responsibility
- Responsible Business Decision-Making
- Supportive Managers, Supervisors, and Executives
- Training
- Worker Recognition, Appreciation, and Respect

Organization of Work
- Adequate Breaks
- Comprehensive Resources
- Fatigue, Burnout, Loneliness, and Stress Prevention
- Job Quality and Quantity
- Meaningful and Engaging Work
- Safe Staffing
- Work Intensification Prevention
- Work-Life Fit

Policies
- Elimination of Bullying, Violence, Harassment, and Discrimination
- Equal Employment Opportunity
- Family and Medical Leave
- Human and Natural Resource Sustainability
- Information Privacy
- Judicious Monitoring of Workers and Biomonitoring Practices
- Optimizing Function and Return-to-Work
- Prevention of Stressful Job Monitoring Practices
- Reasonable Accommodations
- Transparent Reporting Practices
- Whistleblower Protection
- Worker Well-Being Centered
- Workplace Supported Recovery Programs

Technology
- Artificial Intelligence
- Robotics
- Sensors

Work Arrangements
- Contracting and Subcontracting
- Free-Lance
- Global and Multinational
- Multi-Employer
- Non-Standard
- Organizational Restructuring, Downsizing, and Mergers
- Precarious and Contingent
- Small- and Medium-Sized Employers
- Temporary
- Unemployment and Underemployment
- Virtual

Workforce Demographics
- Diversity and Inclusivity
- Multigenerational
- Productive Aging across Lifecourse
- Vulnerable Workers
- Workers with Disabilities

CDC NIOSH

Total Worker Health® is a registered trademark of the US Department of Health and Human Services

Updated January 2020

Critical Observations

- Occupational and Community Health methods not significantly changed (ref 1867 Handbook on Industrial Hygiene) while….
  - Exposures (levels) going lower and lower
    - Fewer and fewer arguments for need to measure exposures in most cases
    - Exposure to disease mechanism using population studies can appear to return opposite conclusions (drinking wine, drinking coffee, low dose radiation, etc)
  - Science professions and understanding humans rapidly changing – Leaping forward
    - Genetics, Toxicology, Molecular Biology,
  - Humans less likely to be in work with high exposures (ref video Humans Need Not apply) comments by Dr Howard

Human's Need Not Apply

Observations

- Can't have the healthiest population by treating the ill; you must prevent the disease
- True behavior change requires personal buy-in
- Disease still manifests even when exposures are "controlled"
- Every human is unique
- Gene expression changes based on "external" actors

What Is Total Exposure Health

- Total Exposure Health (TEH) provides today's industrial hygienists a framework to more effectively respond to the changing nature of the industrial work environment, the increased availability of technology to obtain exposure monitoring, and the ability of the human body to respond to internal and external exposures at the genetic and molecular biological response levels.
- TEH can be thought of as the way for the exposure scientist to respond in a more effective way to society's desire for healthier life choices.
- TEH considers the exposome from four primary areas: Occupational, Environmental, Lifestyle & Clinical

Aims of TEH

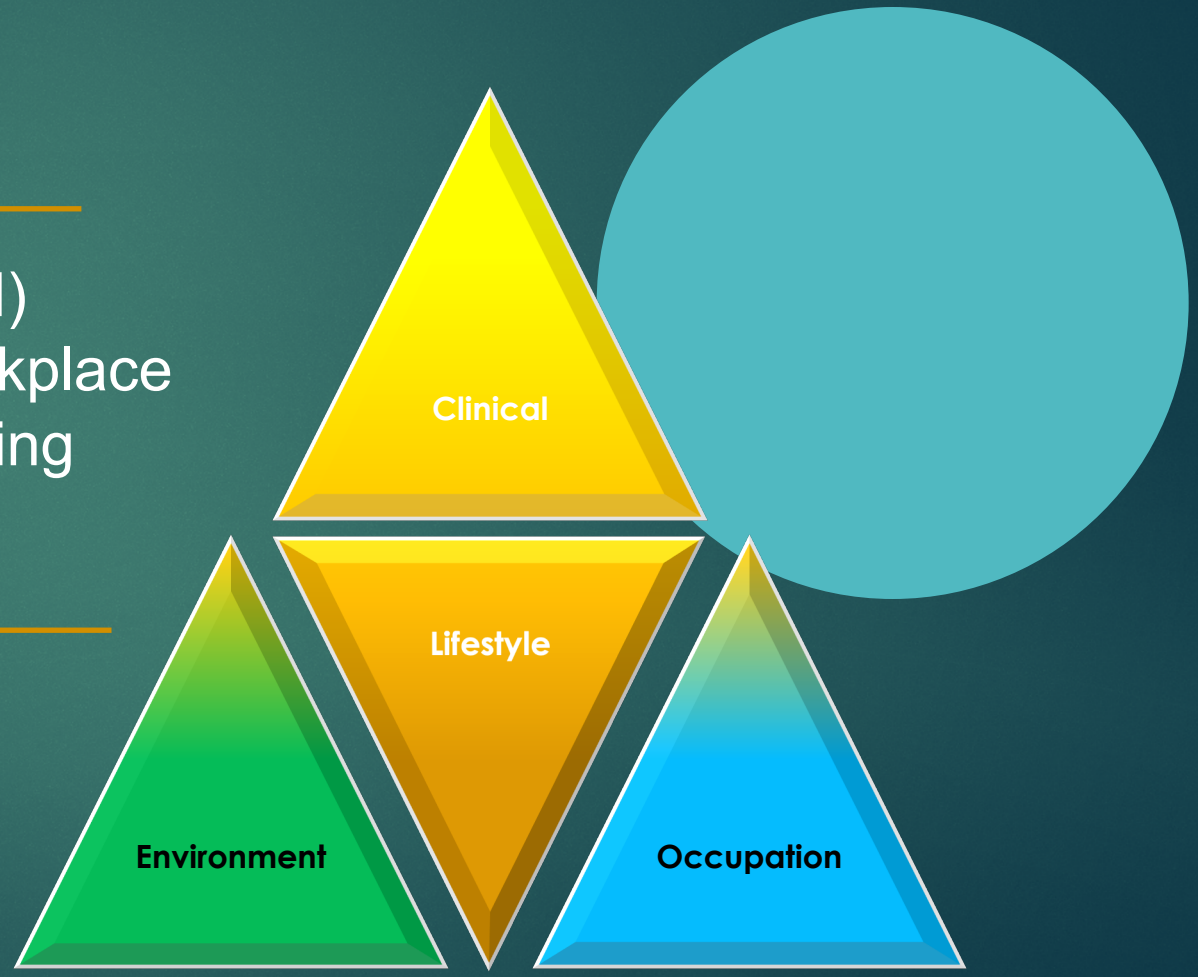
- New Framework for IH to Take advantage of the 4th and 5th Ind Rev
- Achieve true prevention for exposure-based illness and injury
- Enhance and expand the value of Industrial Hygiene to society
- Capitalize on advances in Precision Medicine
- Overcome the looming risk to relevancy
  - Fewer "industrial" workers and fewer are exposed above OELs
  - Provide exposure-based disease prevention:
    - Baseline + Increased sensitivity populations

What Is Total Exposure Health

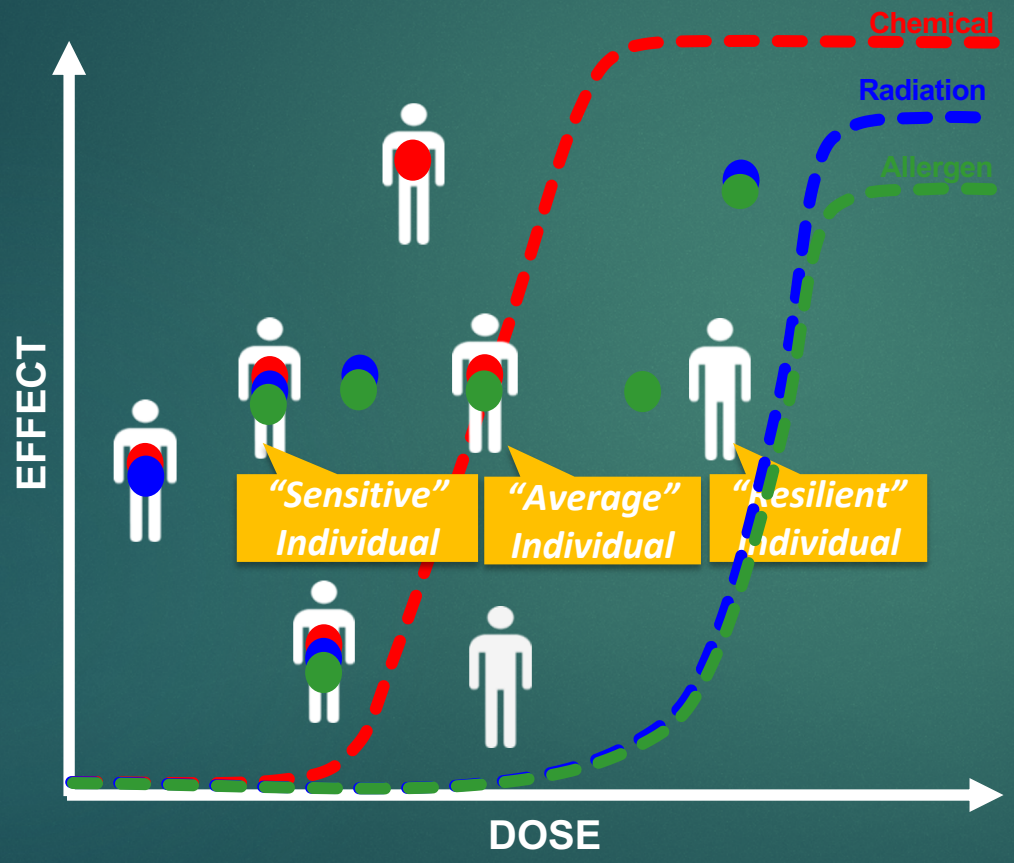
Workplace Only?

Total Exposure Health (TEH)
Incorporates Environmental, Workplace & Lifestyle Exposures Improving

“Health and Well Being”



Teh - Visualized



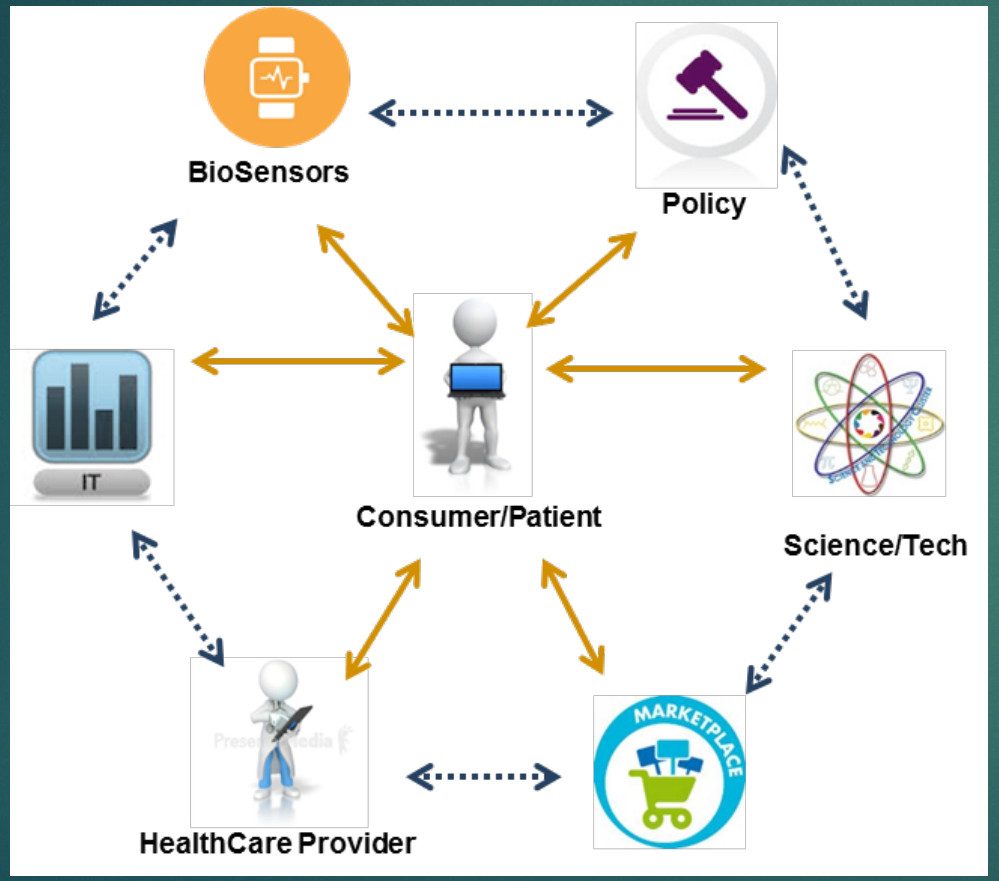
When we account for genetic variance we find we are all unique!

But we can also use this information to protect health and enhance performance

Reimagining Healthcare w/TEH

Total Exposure Health Framework

Healthcare is Changing – Focus on the Individual



Policy, technology, marketplace & consumer expectations are disrupting healthcare & we can position ourselves to better support

"Personalized Healthcare"

Novel Approaches to Prevention

- Disease is understood from changes in genetic expression
  - Combines computational toxicology, molecular biology, genetics
- Treatments are developed to reverse the impacts
  - Treatment to turn off the expressed gene
  - Treatment to break the "chemical cascade"
  - Treatments to neutralize the damaging chemical product

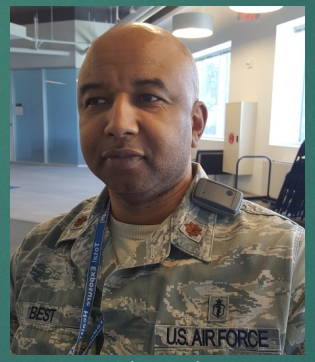
What exposures do humans encounter?

- Use/Develop State-of-the-Art Bioanalytical Instrumentation and Sensors
- Use IoT to obtain exposure data
- Historical understanding of exposures
- Use of Unbiased Exposomics and Metabolomics

Personnel Exposure Monitor (PEM)

- Initial NEDP device senses noise exposure but is actually a ***general wearable sensor platform***
  - Air (VOCs, CO, T, RH)
  - Toxins
  - Radiation
- Micro GC/MS
- Anything an individual is exposed to: work, home or recreation
- Transmits data to cloud

  (via phone or sensor node)



At work

Off work

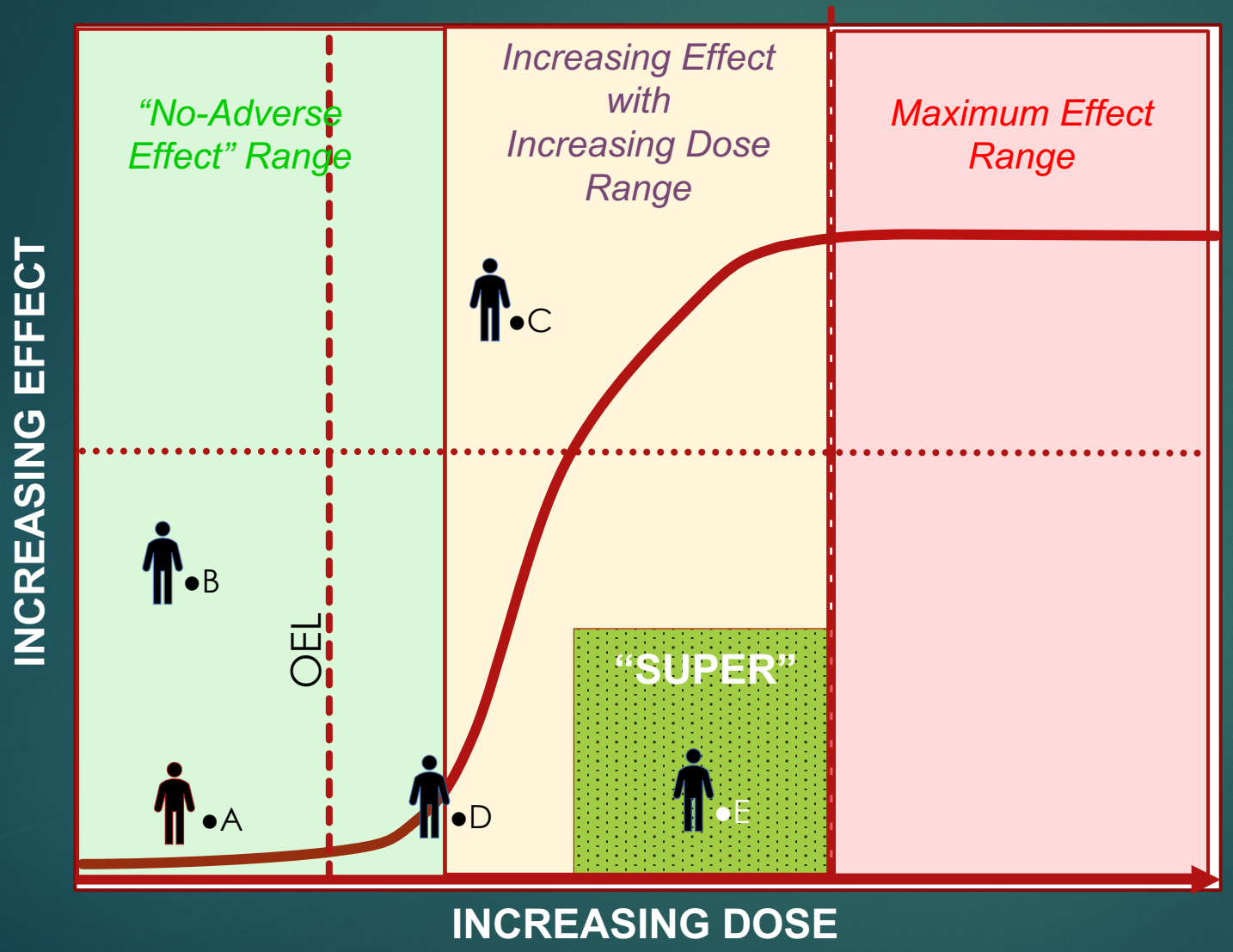
Enabled Instruments/Detectors

- Area monitoring/ident using instruments:
  - SAM (radiation)
  - Hapsite (GC/MS)
  - NGCD (chem detector)
  - Biomeme (bio)
  - …
- All devices plug into same sensor node for secure mesh-enabled communications infrastructure

5

TOTAL EXPOSURE HEALTH

Dose-Response Curve (Std Pop)

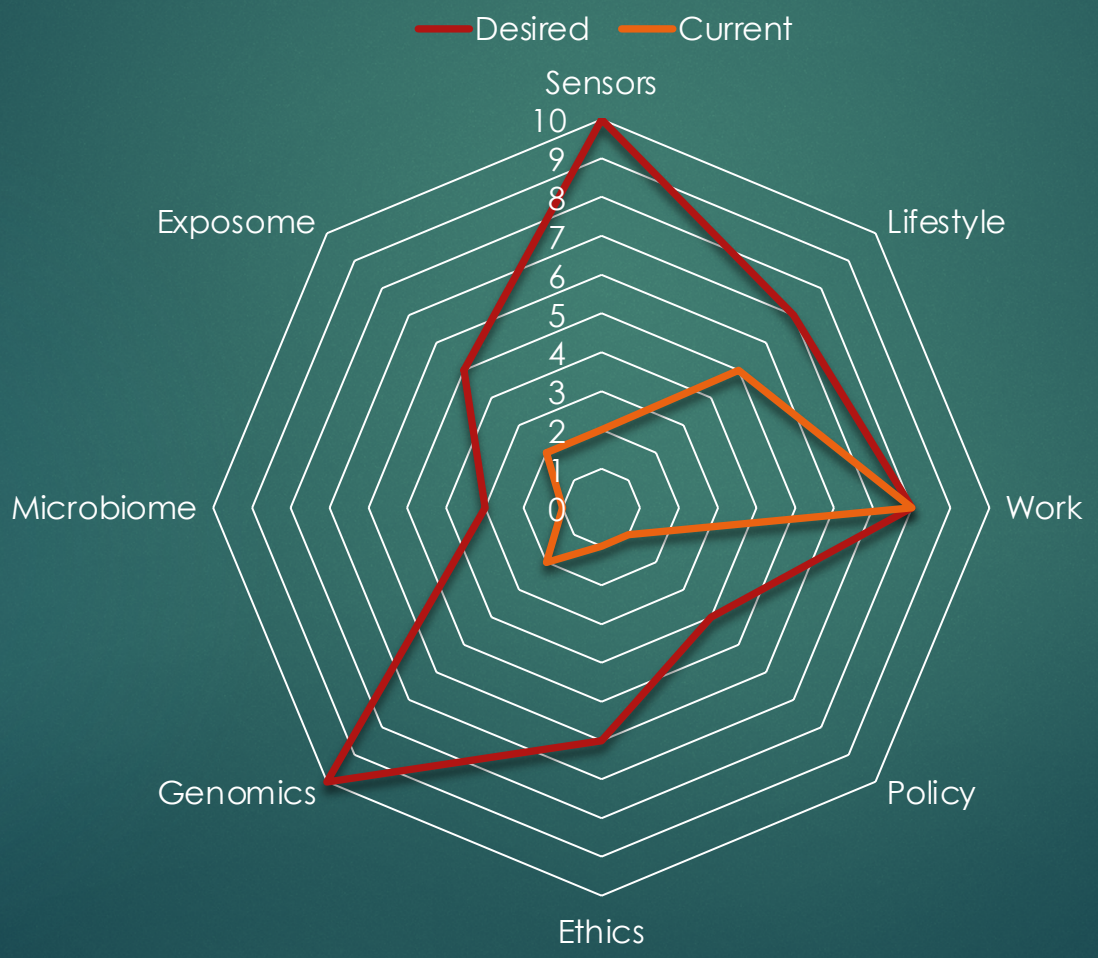


Exposure limits Pop Based

Protects based on Economic Feasibility

We all Respond Differently

TEH – Desired and Current State – outlines areas of opportunity



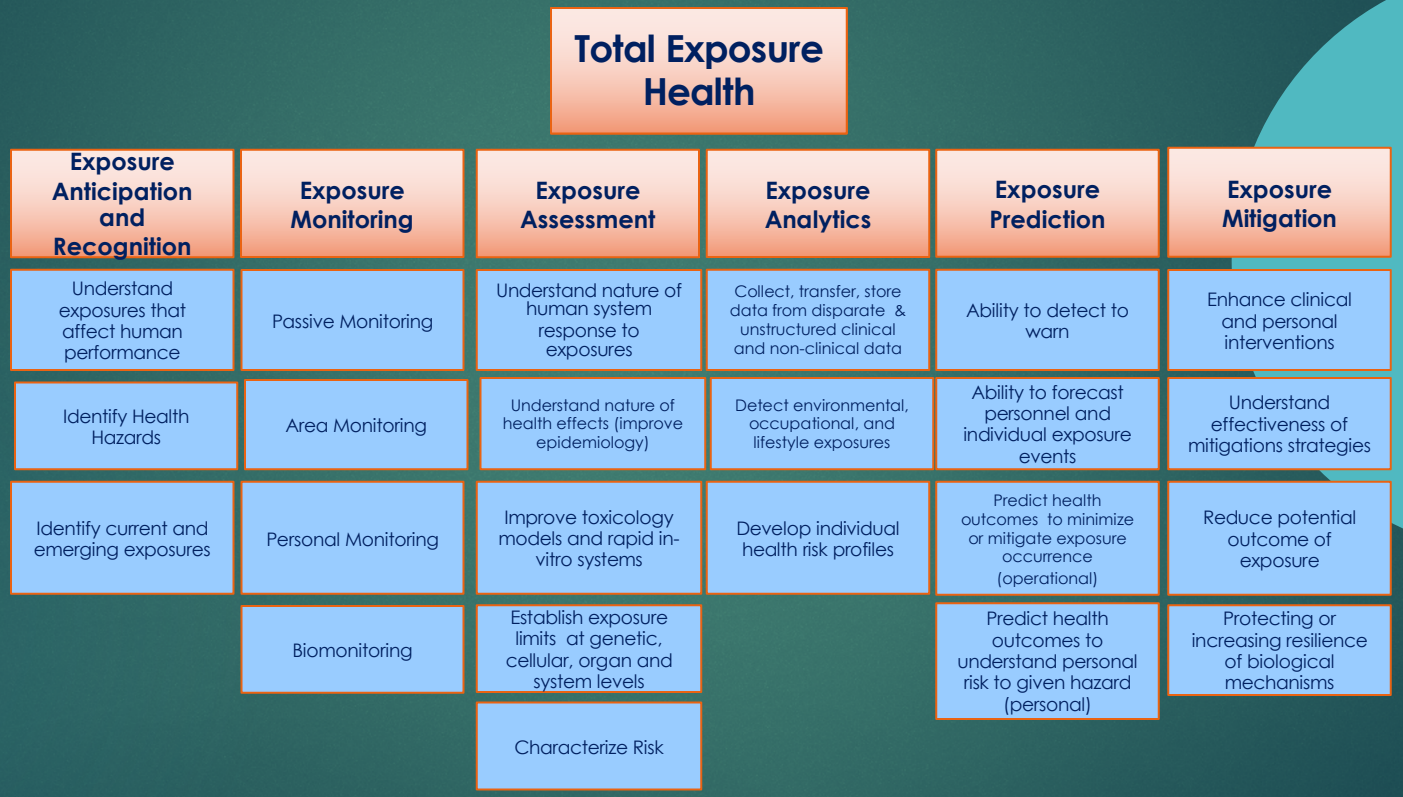
Benefits as Exposure Scientists…

- We are positioned to:
  - Effectively contribute to this fundamental change in our health care system as "exposure scientists"
  - Link our expertise not only to the health of individuals but also to their overall well-being
- Collectively We Can:
  - Improve the delivery of care and health outcomes providing patient centric exposure monitoring
  - Advance science and technology through the development of biosensors and area Sensors
  - Increase the knowledge/research base through "Omics"
  - Become a critical touch point to the worker/human/patient and provider

Total Exposure Health: Where it takes US

Current State - Exp Science	Future State – Exp Science
Work exposure only	Work, environment, lifestyle, clinical, exposures
Animal models of exposures are applied to populations and (SEGs)* with safety factors for workers protection and clinical intervention	Individual exposure applied to each person's genome with tailored interventions to include prevention, protection and clinical care
Limited sensors (time, sensitivity, analytes)	Individual and area sensors with a full analyte complement, real time/all-the-time, sensitive to low level exposure levels
Clinical intervention based on organ function disruption/damage	Clinical intervention based on molecular biology changes brought by exposure
Paper-based exposure summary somewhere in the clinical record	Expert system matching billions of bits of information (DNA, sensor, etc.) relevant to exposure with clinical prevention
Prevention concerns applied post-occupational/lifestyle choice	Opt-in to prevention of key health outcomes part of the care decision for career/life from birth to death and from hiring to retirement

Advancing Health through Exposure R&D



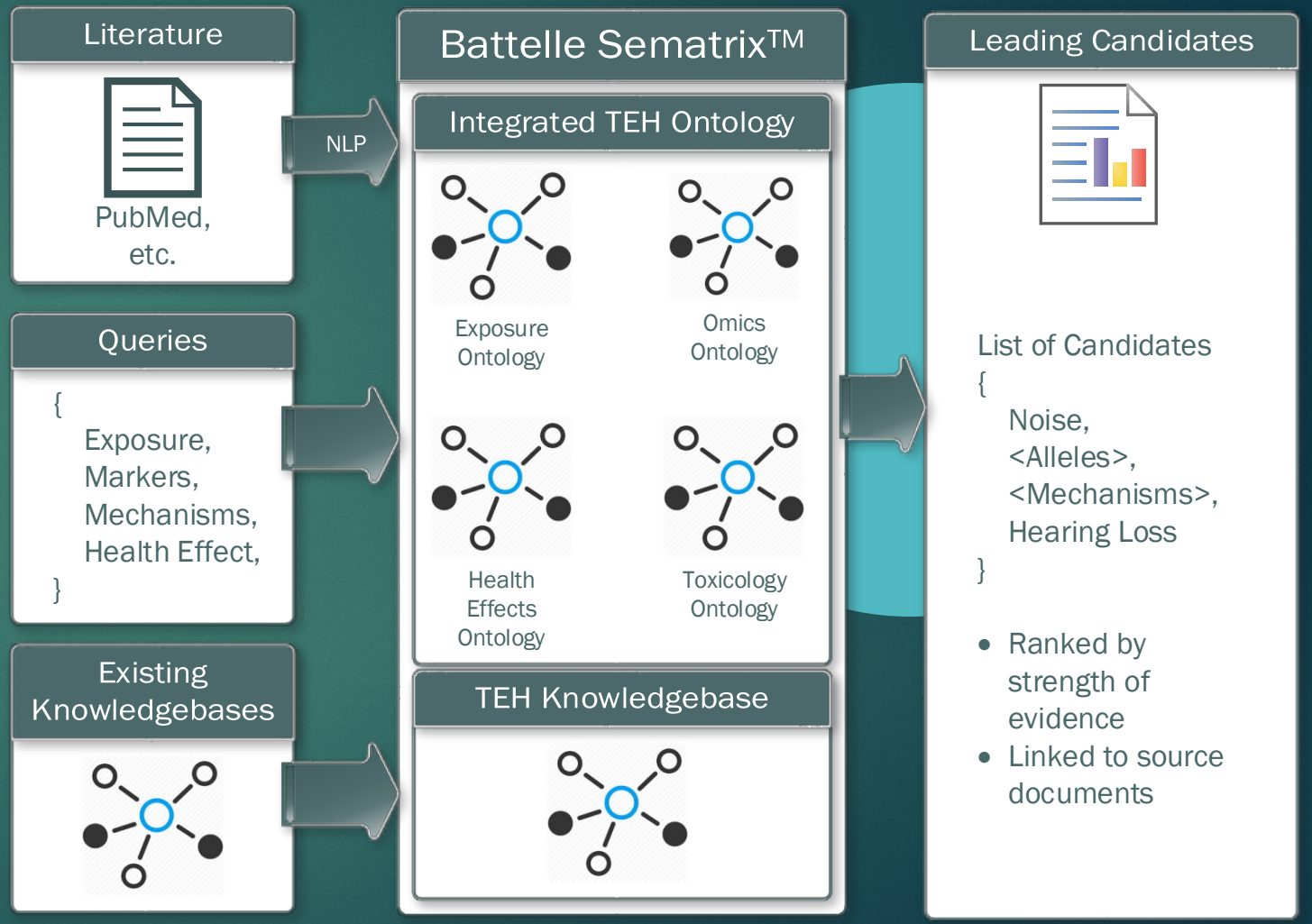
Aligning Health with TEH Thinking

- Break stovepipes
- 4 "What" questions
  - What exposures do humans encounter, (significant, interesting, large seg of pop, etc)?
  - What genetic effects (expression or suppression) from exposures?
  - What mechanism to disease from the changes?
  - What interventions are possible, (interrupt, reverse, neutralize, modify) mechanism?

Recent Articles/Papers

- Your Childhood Environment Can Have Long-Term Effects on Your Genes—Here's Why
  - https://www.wellandgood.com/how-environment-affects-genes/
- This coronavirus vaccine would be two breakthroughs in one
  - https://www.wired.co.uk/article/coronavirus-vaccine-mrna
- Epigenetics Explains Why Your DNA Doesn't Predict Your Destiny
  - https://science.howstuffworks.com/life/genetic/epigenetics-definition.htm
- DNA damage linked to plastic additive
  - https://news.harvard.edu/gazette/story/2020/01/plastic-additive-linked-to-excessive-reproductive-abnormalities/
- A massive study of 200,000 veterans identifies genetic links to anxiety
  - https://www.cnn.com/2020/01/09/health/anxiety-genetic-association-wellness-trnd/
- Elucidating Gene-by-Environment Interactions Associated with Differential Susceptibility to Chemical Exposure
  - https://ehp.niehs.nih.gov/doi/10.1289/ehp2662
- NIOSH: Medication Could Prevent Hearing Loss
  - https://ehsdailyadvisor.blr.com/2019/12/niosh-medication-could-prevent-hearing-loss/
- The plan to mine the world's research papers
  - https://www.nature.com/articles/d41586-019-02142-1
- Do Hand Dryers Hurt Kids' Hearing? This 13-Year-Old Studied It
  - https://www.nytimes.com/2019/07/01/us/hand-dryers-children.html
- British woman is first in the world to undergo gene therapy for most common form of blindness
  - https://www.telegraph.co.uk/science/2019/02/18/british-woman-first-world-undergo-gene-therapy-common-form-blindness/
- Clues to Your Health Are Hidden at 6.6 Million Spots in Your DNA
  - https://www.nytimes.com/2018/08/13/health/genetic-test-heart-disease.html

Identification of Connections in Literature & Genome-Wide Association Study (GWAS)



What interventions are possible?

- Modified controls from the Heirarchy
- Pre-exposure prophylaxis (e.g. for noise induced hearing loss)
- Predict the efficacy of pharmaceuticals
- Pharmacogenomics
- Increased medical screening
- Gene activation/inavtivation
- Gene editing (future)

TEH/TWH Examples

Employee/Patient Genetic Proclivity Awareness

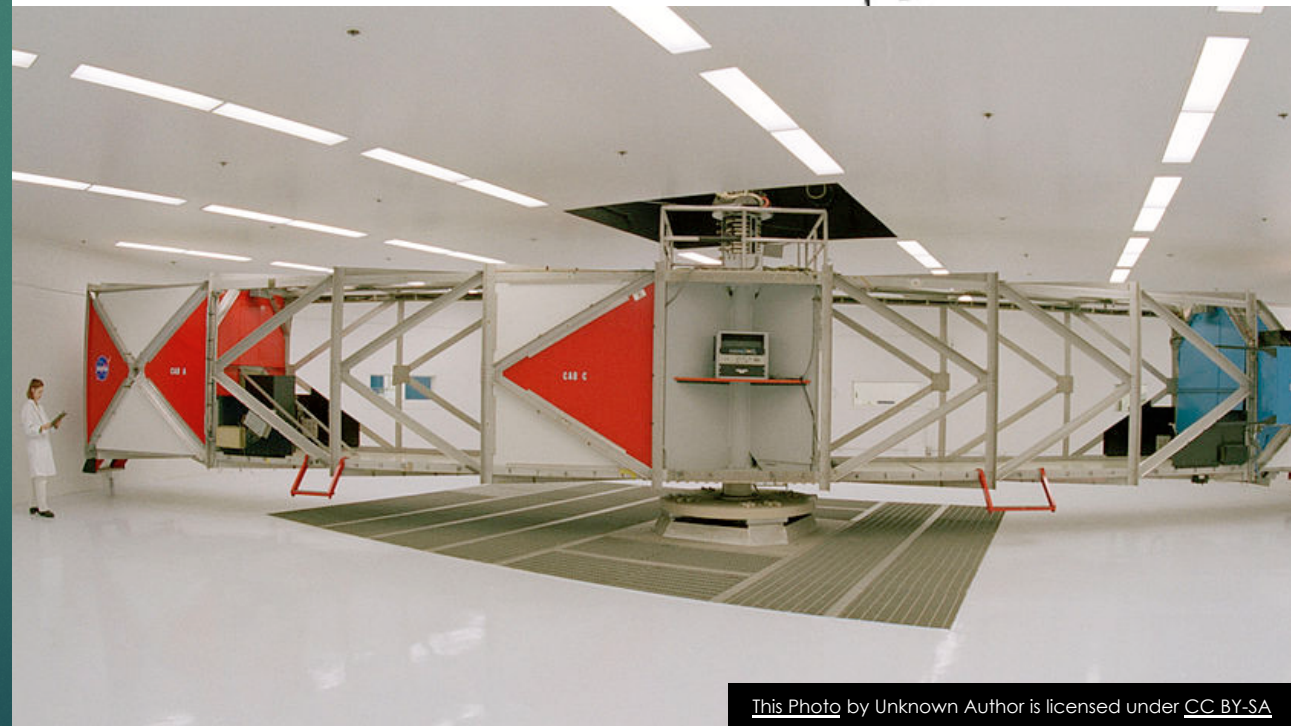
- Xcode Life® ads currently on (facebook, google, etc.)
  - 77+ traits for $99
  - Disclaimer to "Talk to YOUR medical professional"
  - MEGA PACK
    - Nutrition
    - Fitness
    - Health
    - Allergy
    - Skin
    - Precision Med
    - Methylation
    - Carrier Status
    - Traits and Personality

Physical Conditioning/Optimal Performance

- Who
  - Rated employees (pilots, aircrew, atronauts) need moment of optimal physical conditioning
  - Critical Skill Employees with operations affected when ill/absent
  - Illness and Injury Rates – Sedentary to Active or Exercise Maven
- ID more susceptible to Musculoskeletal Injuries (bone density, tendon or ligament damage)
- Benefits
  - Optimum health at day or time of greatest need
  - Exercise plan that prevents injury setbacks
  - Maintaining critical workers for critical task/time

Bone Density / Ergonomic Considerations

- Who
  - Employees where strength is important: (construction, shipping, oil and gas, pilots, aircrew, astronauts experiencing G-forces
  - Aging workforce
  - Job tasks with high strength forces
- ID more susceptible to Musculoskeletal Injuries (bone density)
- Benefits
  - Prevent Injury
  - Early Intervention
  - Maintaining critical workers for critical task/time



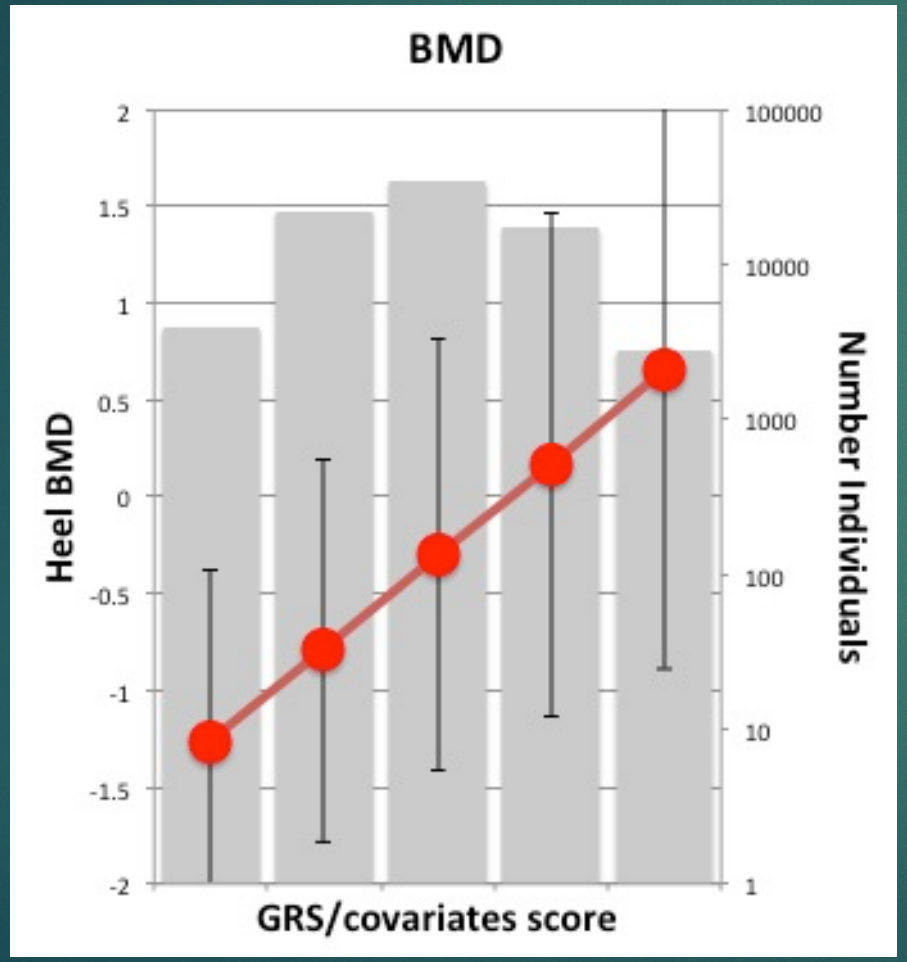
A genetic algorithm for heel Bone Mineral Density and Fracture Risk

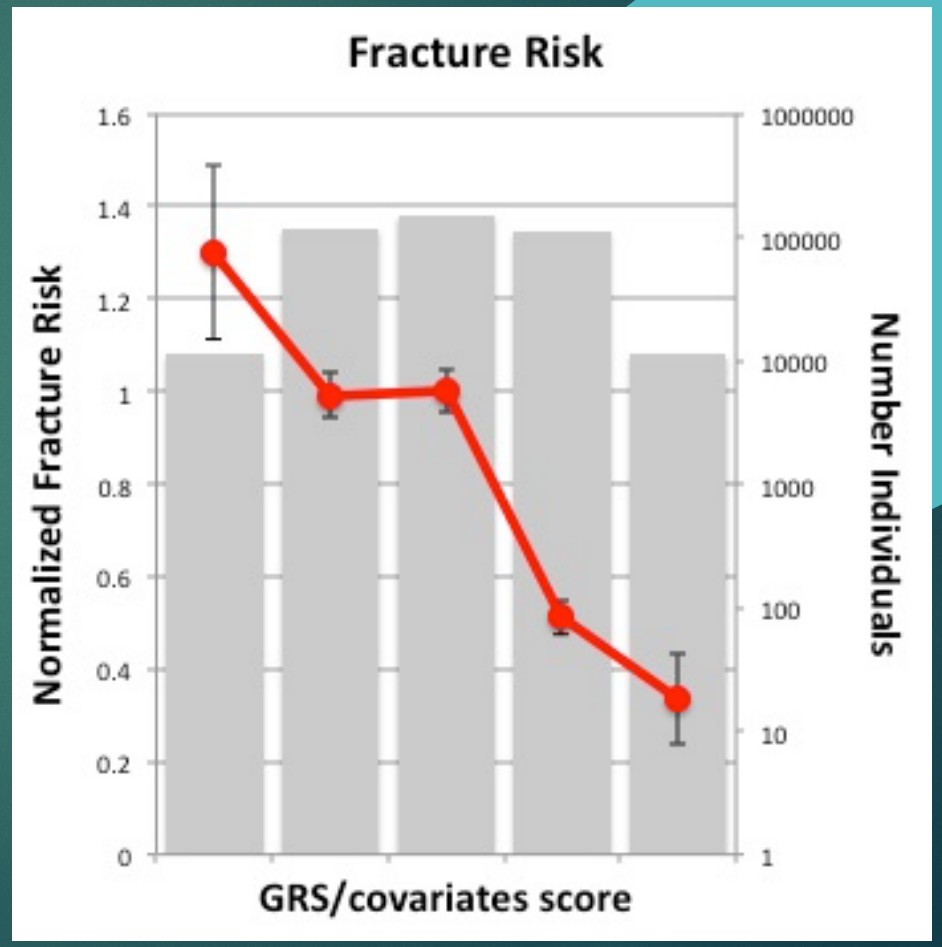
- - Algorithm trained on ~90K individuals from UK Biobank
- - 531 DNA variants, height, weight, age and sex
  - Tested on second set of ~90K individuals
- - Correlation of GRS/covariates score with BMD = 0.38

Stuart Kim,
Professor Emeritus,
Stanford University

A genetic algorithm for heel BMD and Fracture Risk

531 DNA variants (plus height, weight, age and sex)
Correlation of GRS/covariates score with BMD = 0.38



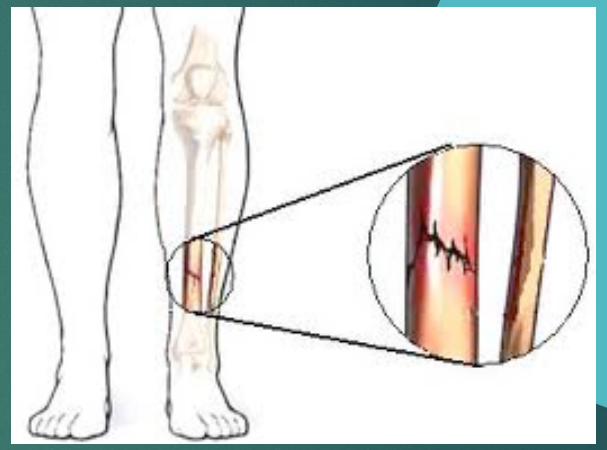


Interventions to decrease stress fracture risk

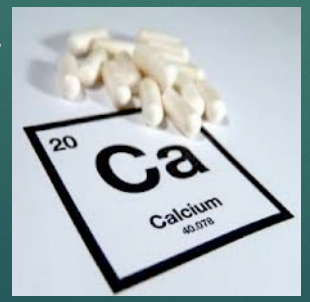
Stress Fracture	Increased risk for low Bone Mineral Density and Stress Fracture	strong

Stress Fracture - Interventions

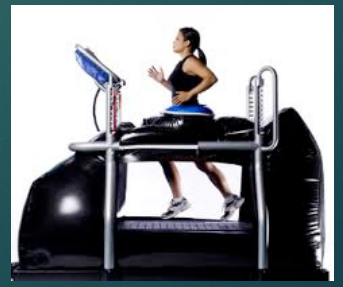
1. DEXA Scan
2. Vitamin & Mineral Supplements
3. Strength & Flexibility
4. Low Impact Training
5. Cross Training
6. Biomechanical Movement Evaluation
7. Optimize Footwear



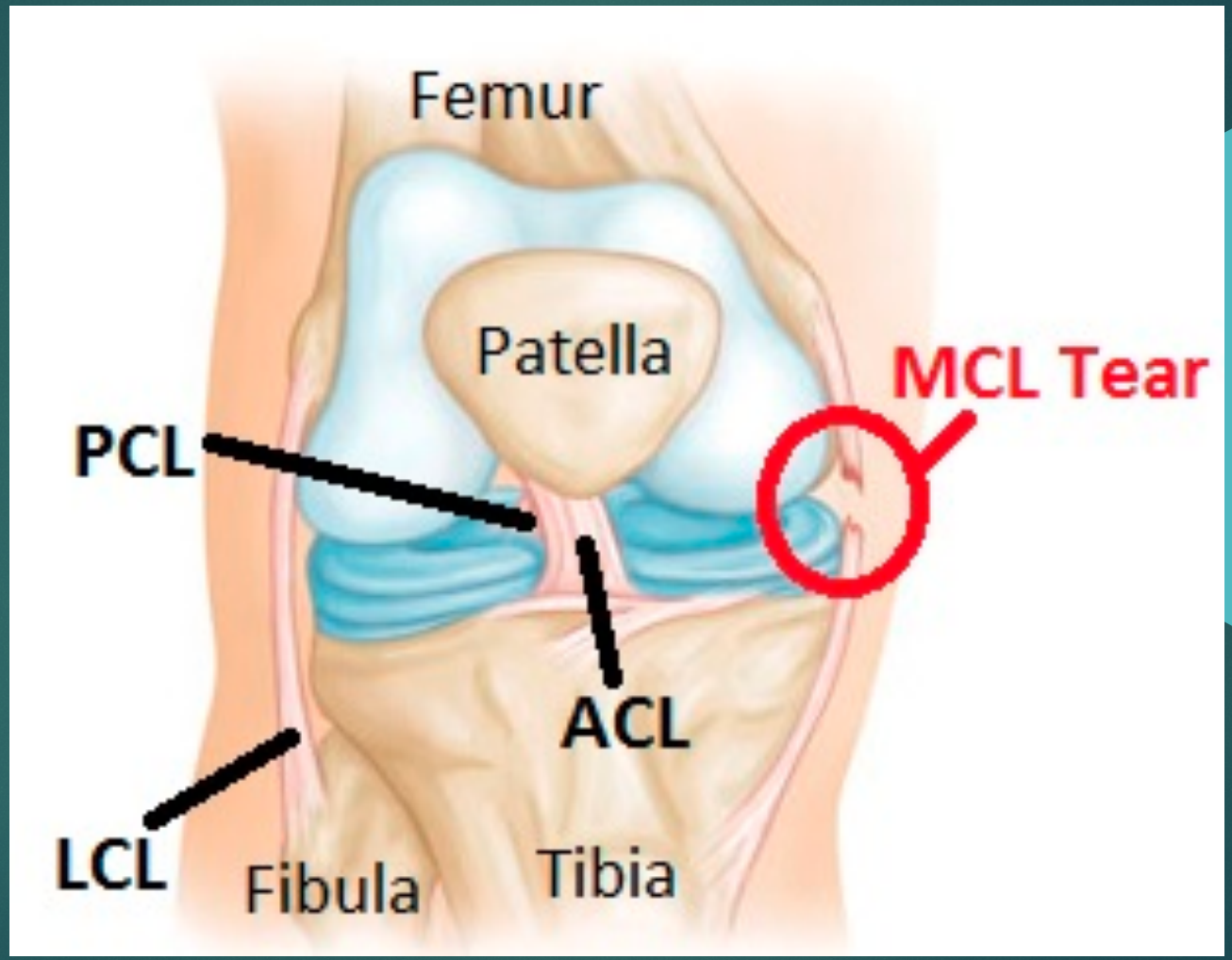
1. 

2. 

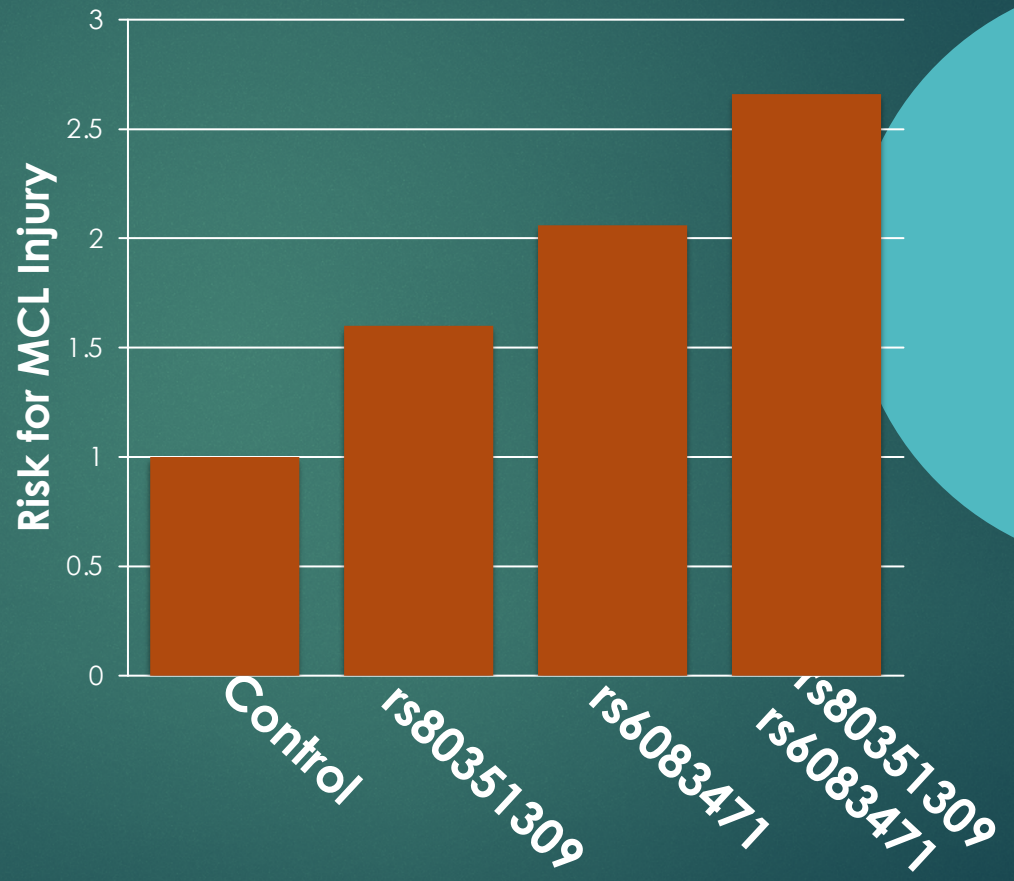
3. 

4. 

Medial Collateral Ligament (MCL) Injury

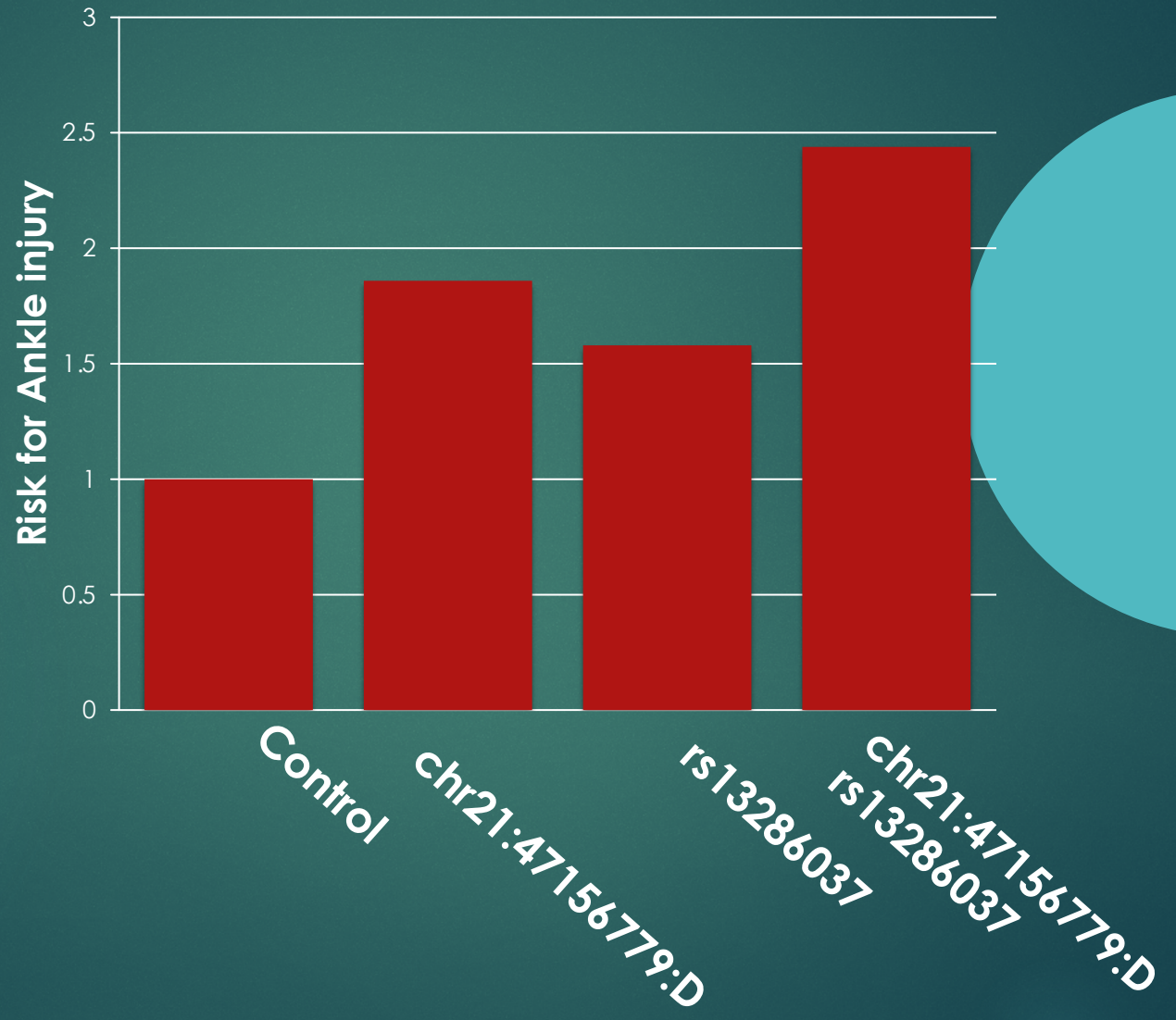


Two Genetic Markers for MCL Injury



Ankle Sprain GWAS

Ankle Injury



New genetic markers for sports injuries

genome-wide significant ($p<5x10^{-8}$)

Injury	Study	SNP	Risk
BMD/Fracture	274,000 participants	GRS with 531 SNPs	↑30% fracture ↓299% fracture
MCL rupture	1,572 cases 100,931 controls	rs80351309 rs6083471	↑106% ↑60%
Ankle sprain	1,694 cases 97,646 controls	chr21:47156779:D rs13286037	↑86% ↑58%
Rotator Cuff Injury	8,348 cases 94,622 controls	rs71404070	↑28%
Shoulder dislocation	662 cases 82,602 controls	rs12913965	↑69%
Plantar fasciitis	21,624 cases 80,879 controls	chr5:118704153:D rs62051384	↓5% ↑4%

Genetic Testing For Injury Risk

- **Bone Mineral Density/Stress Fracture**
- **MCL rupture**
- **Shoulder dislocation**
- **Rotator Cuff injury**
- **Ankle sprain**
- **De Quervain Tenosynovitis**
- **Plantar fasciitis**

- Caffeine Use
- Sickle Cell Trait
- **Osteoarthritis**
- **Disc Degeneration**
- Mineral/Vitamin Deficiencies

NOISE EXPOSURE

TEH – Helping to Solve Hearing Loss

- Common exposure
  - We all experience noise exposure in workplace, lifestyle and environment
  - Untreatable hearing loss can negatively affect one's quality of life
  - 2nd Grade 2X worse and by 8th Grade 4X worse than 10 yrs ago
  - Between 2000-2015 Americans w/NIHL doubled nearing 50M
- Costly Exposure
  - $1.5-3B DoD/VA annual bill (Benefits and Medical)
  - Hearing loss and tinnitus are among the top medical complaints, and most widespread injuries,
  - Linked to chronic disease, dementia, depression, and anxiety.
- Affects business
  - Effectiveness directly proportional good communication
  - Good hearing is prerequisite for peak performance

Exposure Monitoring

- All exposure is important; for some, “non hazardous” noise measurement is important
  - Ambient Noise
  - Personal Choice Exposure (headphones, concerts, hobbies)
  - Occupational Noise
- Miniaturization and low cost detectors making personal exposure of all possible

Back Environmental Sound Levels

Highlights

Show All

Environmental Sound Levels

Your average environmental sound levels were OK over the last seven days.

Average Level

OK

68 dB for 2 d 20 hr

F S S M T W T

Environmental Sound Levels

On average, nearby sound levels were about the same this month and last month.

68 dB

January

68 dB

December

14:14

Summary Headphone Audio Levels

Highlights

Show All

Headphone Audio Levels

Your audio exposure is under the 7-day limit.

63 dB

This week

65 dB

Last week

Summary Browse

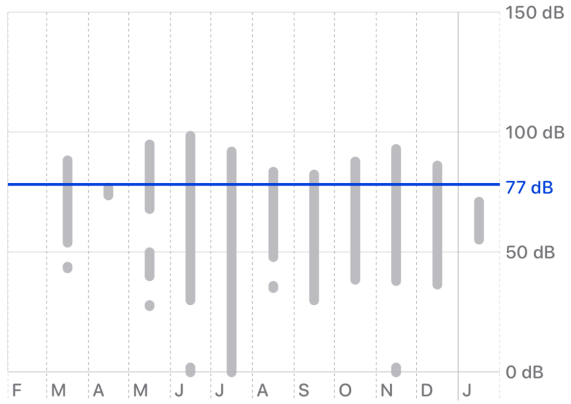
Headphone Audio Levels Done

H D W M Y

EXPOSURE

OK

Feb 2020–Feb 2021



Exposure	77 dB (1d 3h)
Headphone Notifications	--
Monthly Average	63–85 dB
Latest: Yesterday	59 dB
Range	0–99 dB

Filter by Headphone Type

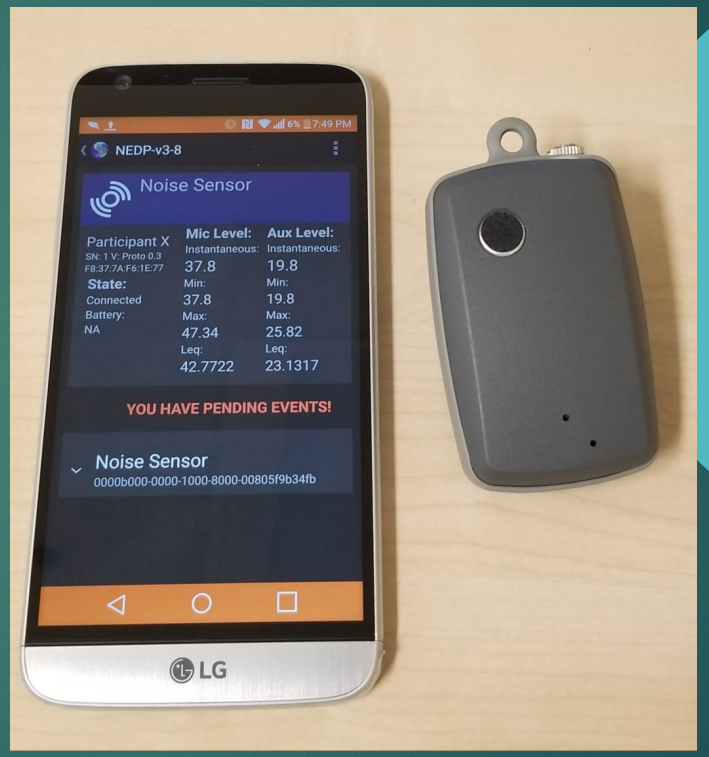
Novel Treatment to prevent NIHL

- Pre-exposure prophylaxis
  - Drug nearing market to counter act free radicals produced by some but not all people exposed to noise (genetic inclined)
  - Phone settings and Kiosks to set “delimiter” on noise generation of headphones based on music, hardware, listening preferences

Technology - Highlights

53

- Noise monitoring sensor measures
  - External (ambient/audio)
  - "Digital"
  - 24/7
- Bluetooth
- Agnostic app for individual's device
- Low- Profile low cost

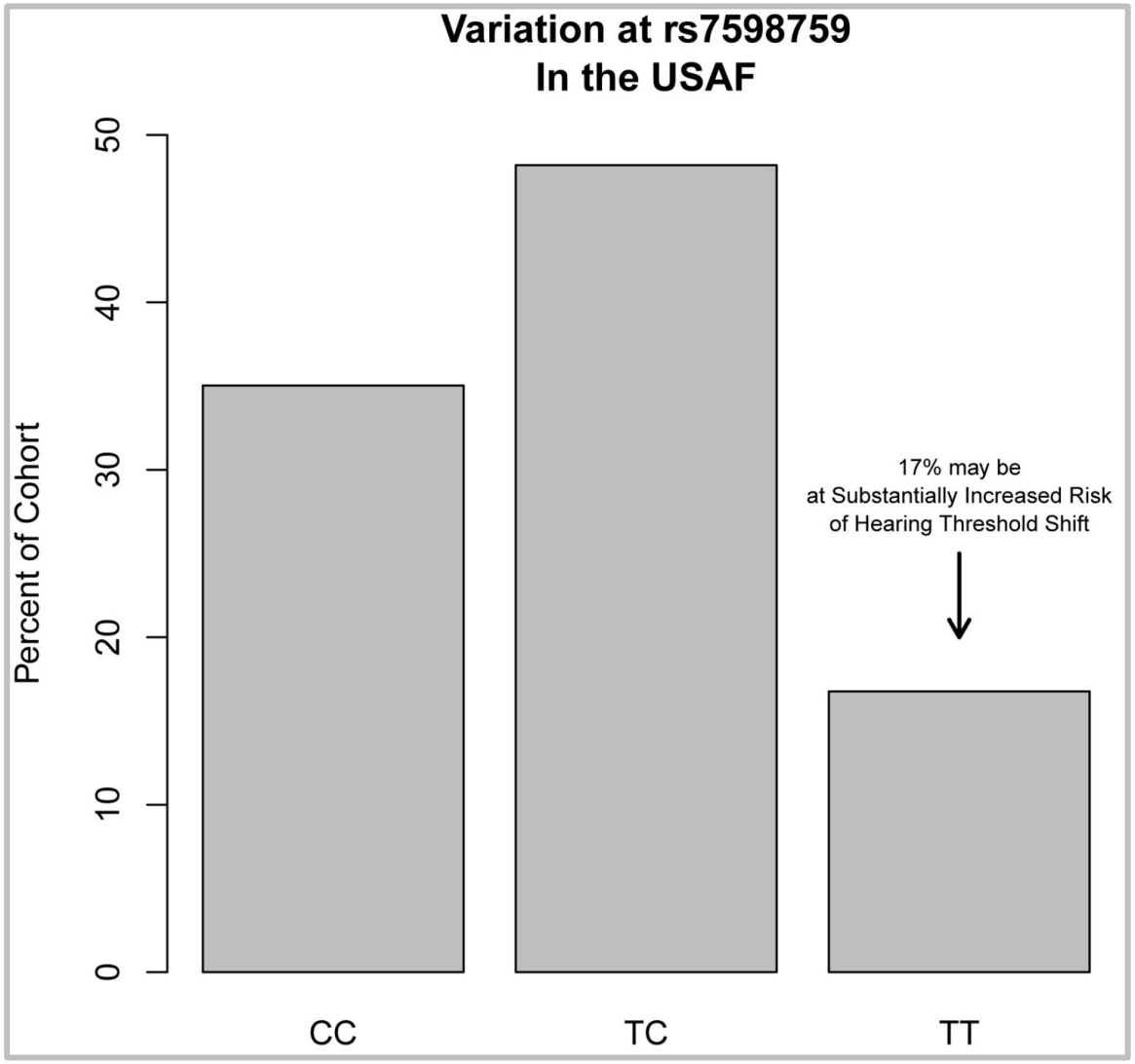


What genetic effects from exposures? Noise Induced Hearing Loss

- 10 published studies
  - Small to modest sample sizes
  - Multiple genetic variants in multiple genes associated with NIHL or related phenotypes
    - Grondin et al 2015. "Genetic Polymorphisms Associated with Hearing Threshold Shift in Subjects during First Encounter with Occupational Impulse Noise." PLoS ONE 10 (6): e0130827.
  - Effect sizes are surprisingly large
    - Odds Ratios range from 5.2 to 22.36
  - Several associated genotypes are already typed in the available genechips

Genetics - Noise Induced Hearing Loss

- 10 published studies
  - Small to modest sample sizes
  - Multiple genetic variants in multiple genes associated with NIHL or related phenotypes
    - Grondin et al 2015. "Genetic Polymorphisms Associated with Hearing Threshold Shift in Subjects during First Encounter with Occupational Impulse Noise." PLoS ONE 10 (6): e0130827.
  - Effect sizes are surprisingly large
    - Odds Ratios range from 5.2 to 22.36
  - Several associated genotypes are already typed in the available genechips

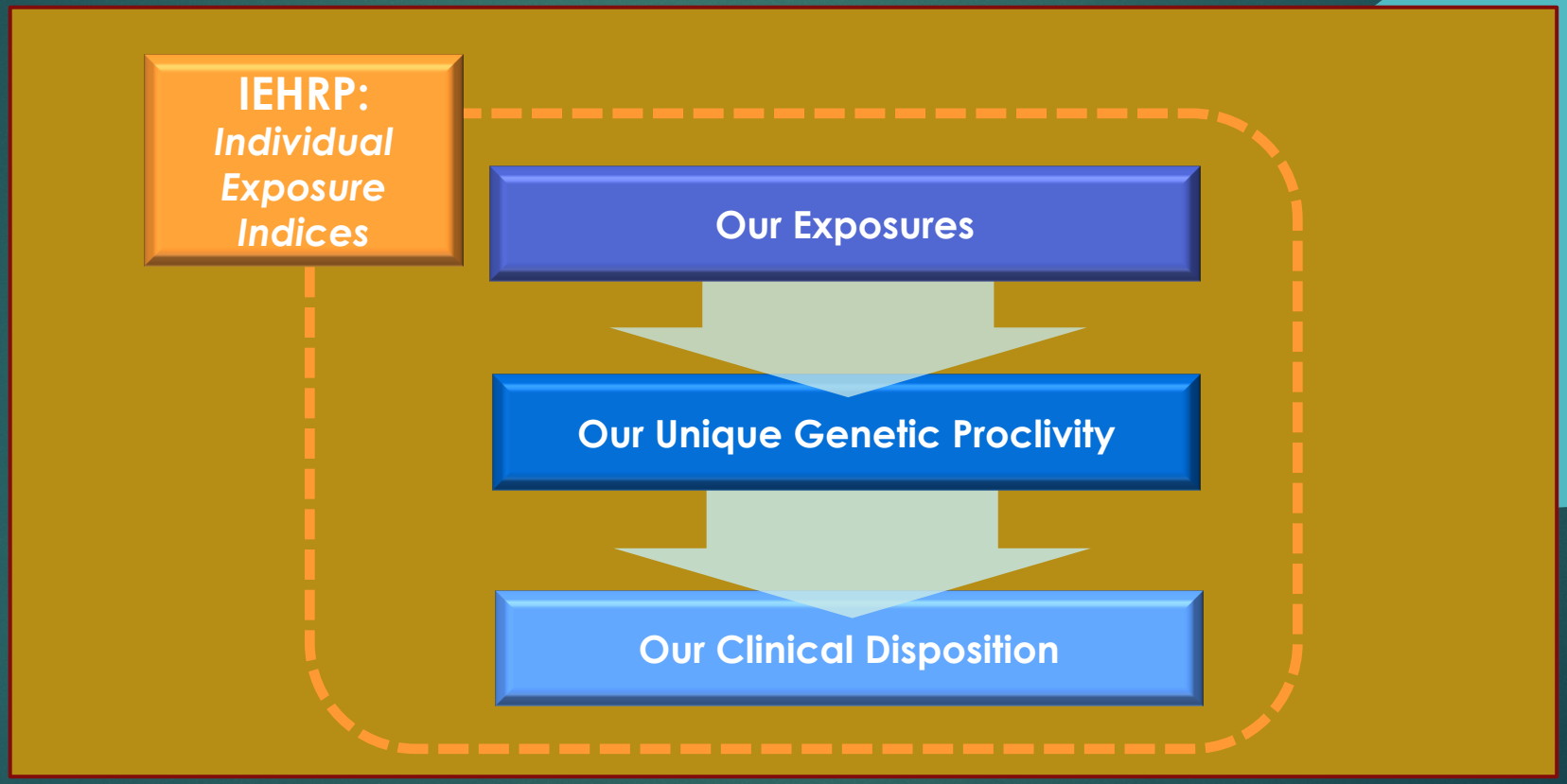


What mechanism to disease from the changes?

IDENTIFIED GENE VARIANTS ASSOCIATED W/NIHL

IEHRP - Individual Exposure Health Risk Profile

Individual Exposure Health Risk Profile (IEHRP)



IEHRP Example – "Noise"

Basic linear equation for Noise:

Individual Exposure Risk Index (Noise Induced Hearing Loss) = (CF) Personal Monitored Exposure $_{(Noise)}$ + (CF) Medical/Clinical Disposition$_{(Noise)}$ + (CF) Genetic Proclivity$_{(Noise)}$ + n…+n

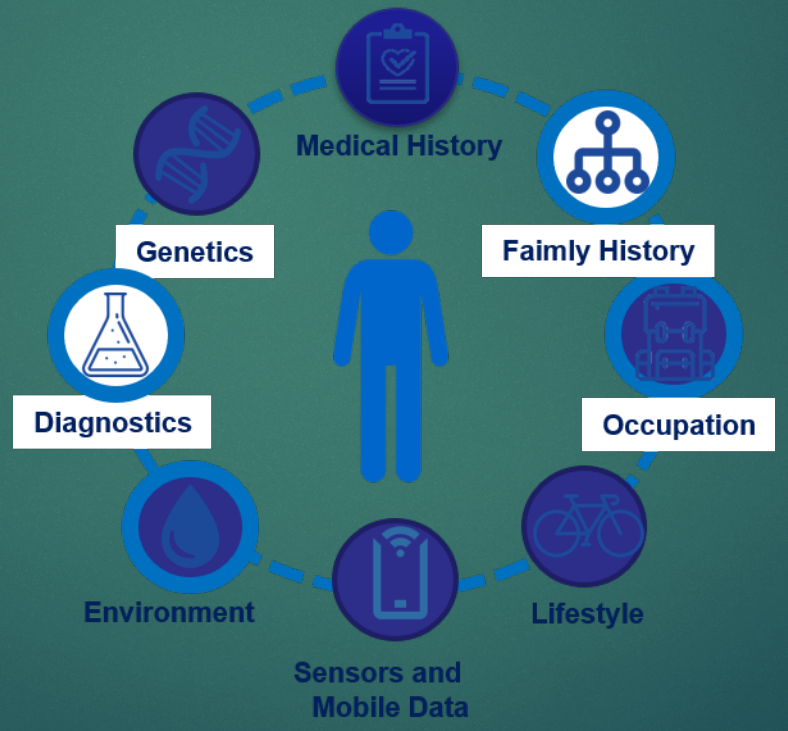
Adding Chemical Exposure the equation changes to:

Individual Exposure Risk Index (Noise Induced Hearing Loss) = (CF) Personal Monitored Exposure $_{(Noise)}$ + (CF) Medical/Clinical Disposition $_{(Noise)}$ + (CF) Genetic Proclivity $_{(Noise)}$ + (CF) Ototoxins + n…+n

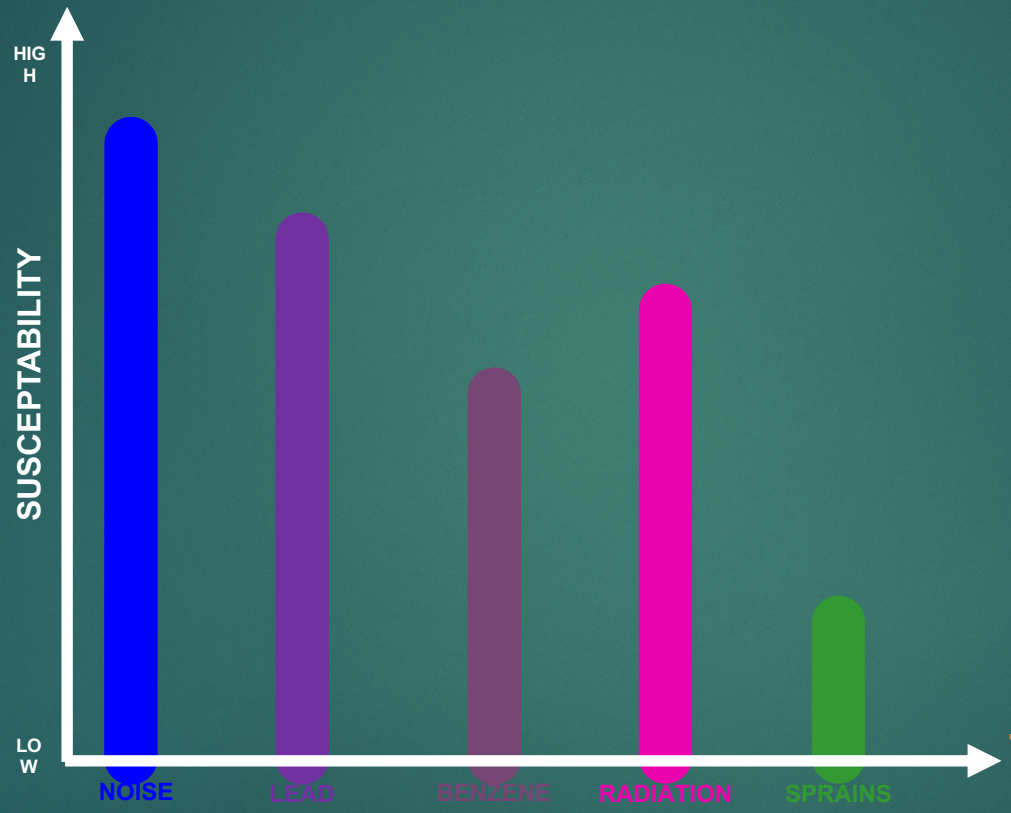
The Individual Exposure Risk Profile becomes more refined as we identify confounding factors that affect the risk of NIHL

Individual Exposure Risk Index (Noise Induced Hearing Loss) = (CF) Personal Monitored Exposure $_{(Noise)}$ + (CF) Medical/Clinical Disposition $_{(Noise)}$ + (CF) Genetic Proclivity $_{(Noise)}$ + (CF) Ototoxins + n…+n – Protective factors – Protective Interventions

Exposure Index can have many variables



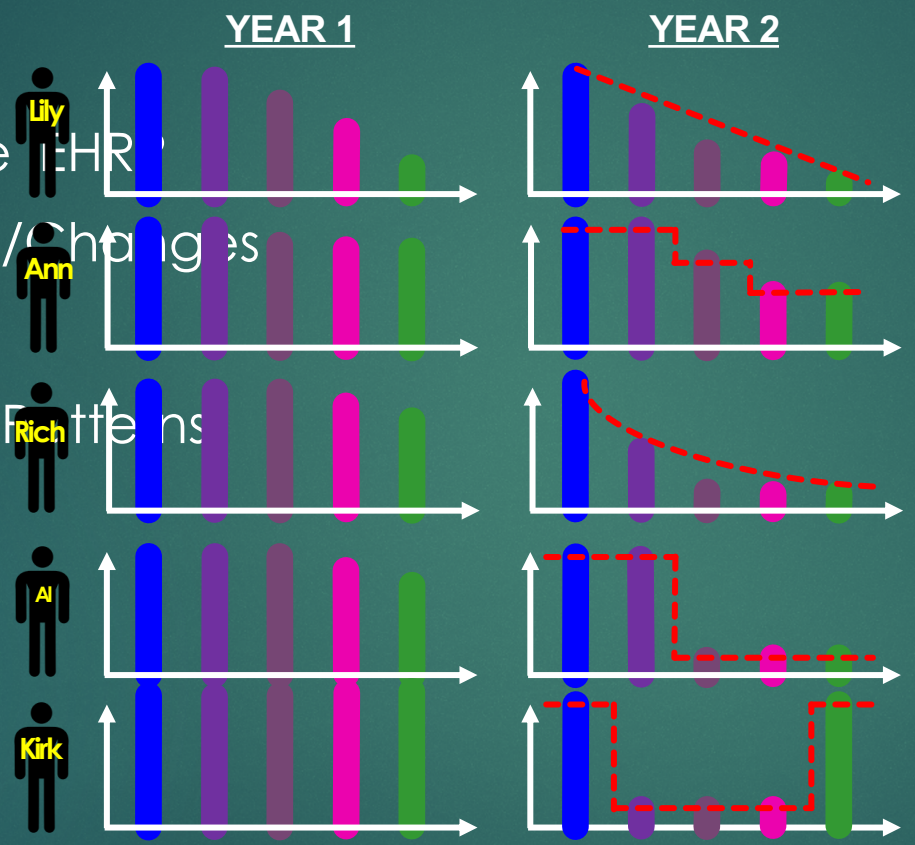
Visualizing the IEHRP – Individual

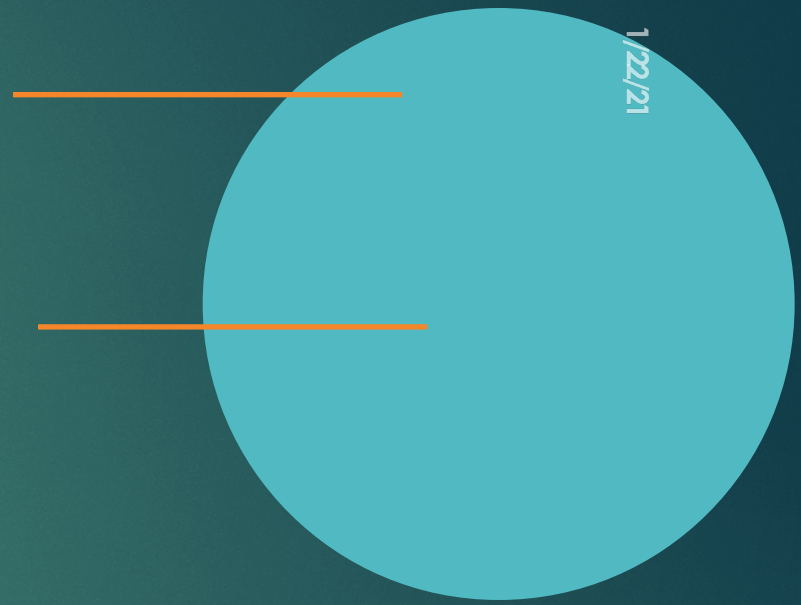


IEHRP will aid in visualizing an individual's unique exposure susceptibilities

Visualizing the IEHRP – Population

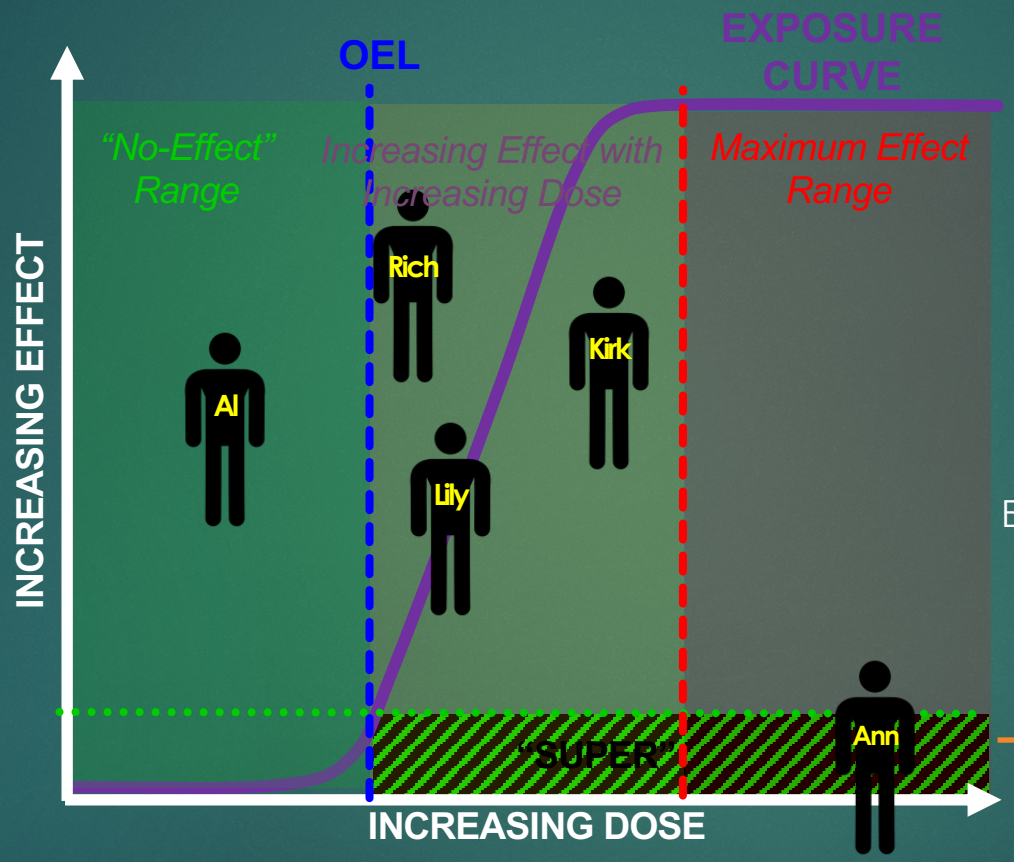
- Yr 1 Baseline IEHRP
- Intervention/Changes
- Y2 IEHRP
- See Unique Patterns





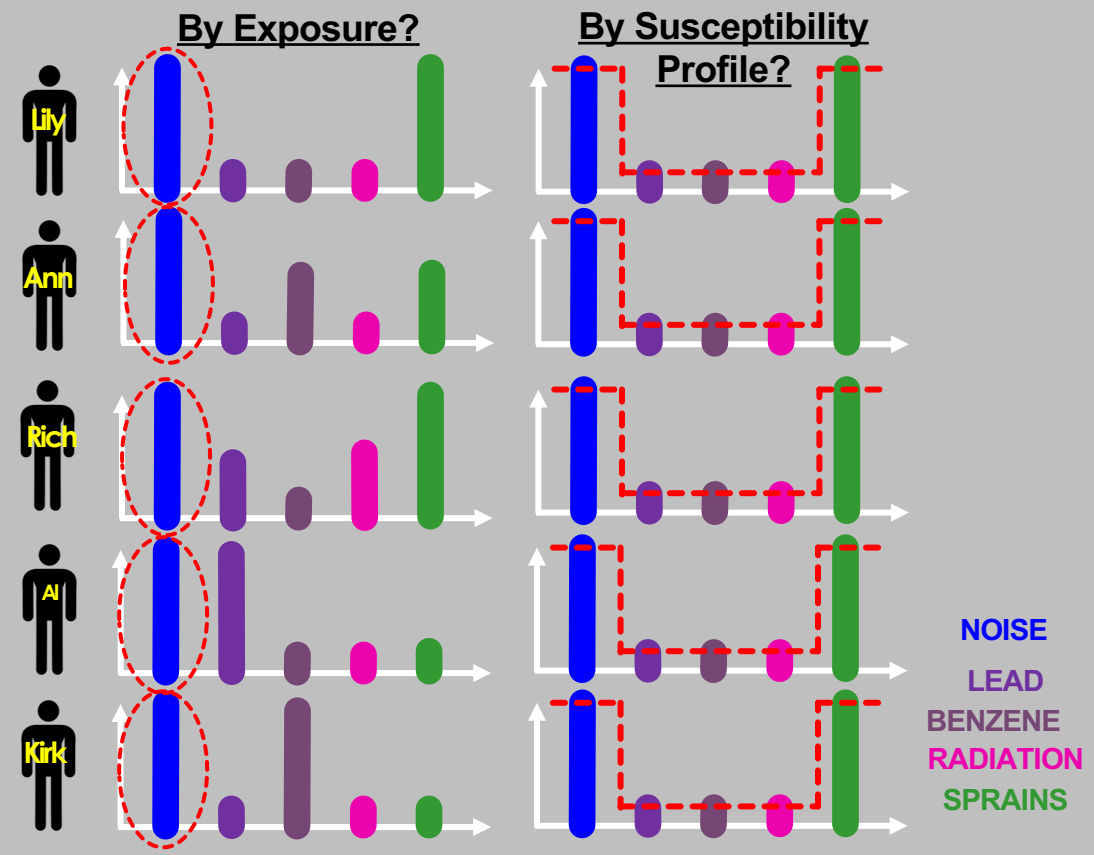
NOISE
LEAD
BENZENE
RADIATION
SPRAINS

Rethinking Exposure Limits



Exposure limits Pop Based
Protects based on Economic Feasibility
We all Respond Differently
Super humans?

Rethinking the Similar Exposure Group (SEG)

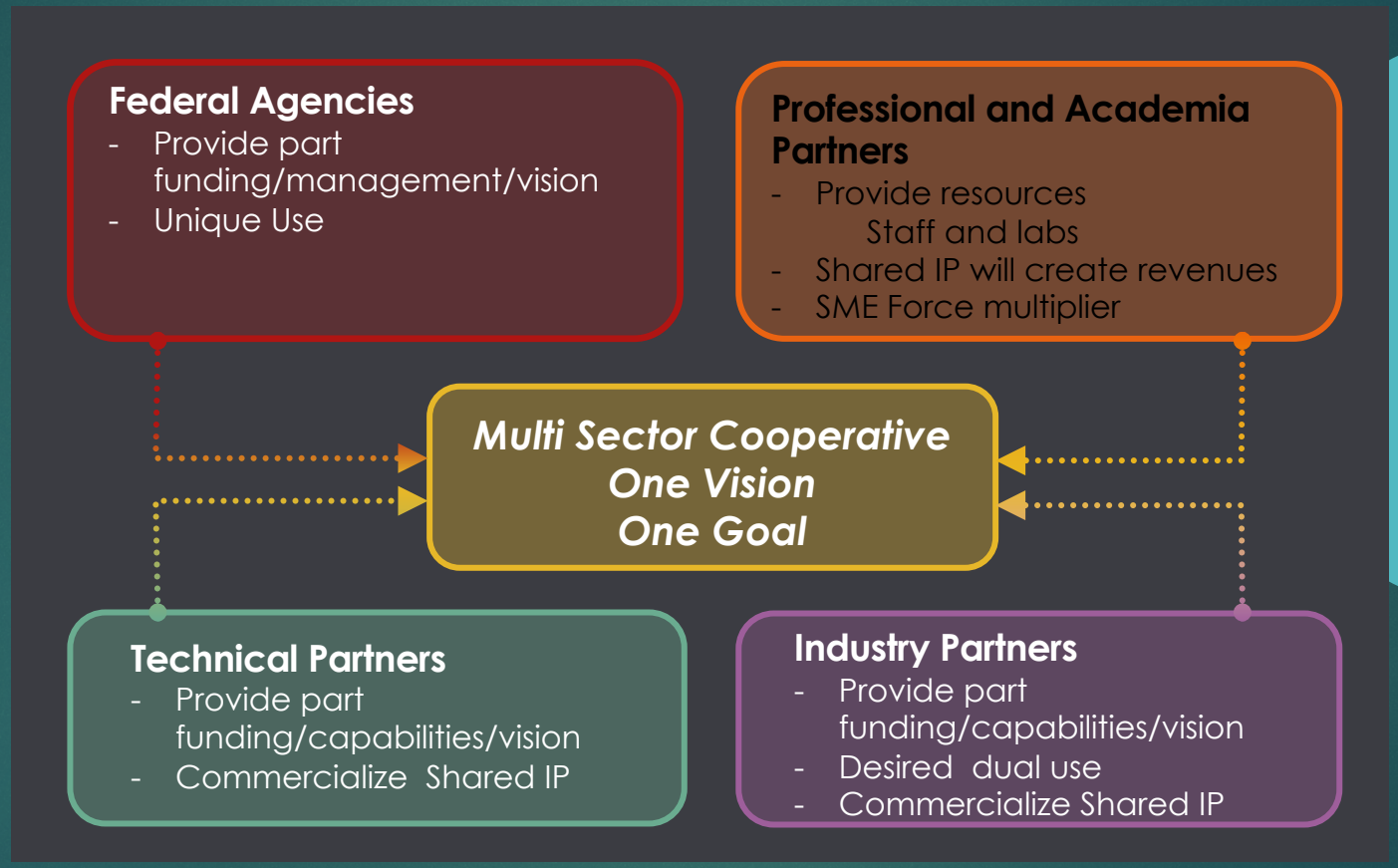


How will Similar Exposure Groups (SEGs) be determined?
By Exposure?
or
By Profile?

TEH Brings these things together:

- Area sensors, Personnel/Physiological Sensors, …
- Integrated with all genetics, previous exposures, DBs, …
- All information integrated about an individual
- Advanced analytics and decision support
- Situational awareness tools for real-time monitoring/use
- Predictive capability for exposure prevention/activity modification
- Open, integrated, advanced system for force health protection, improved care, and operational use
- Technologies are real, available, and ready for application/use

The Cooperative Opportunity



Can I do TEH?

…Yes!

It's a framework – fill your frame as needed

- Provide PPE for use away from work
- Educate workers on household exposures
- Consider exposure risk to home (Pb dust)
- Verify "quiet time" away from work
- Add in environmental data from others
- Use new sensors being sold
- Researchers
- Get IH needs into sensor development
- Use outlier populations with genome-wide association study to develop genetic proclivity

Questions?

Kirk Phillips, MS, IH
Chair TEH/TWH Advisory Group AIHA
Creator of TEH
Kirk.A.Phillips@gmail.com