Hazardous Waste Management: Toxicology and Public Health Protection

William Lambert, PhD

Oregon Health & Science University

CROET – Center for Research on Occupational and Environmental Toxicology

www.ohsu.edu/croet/

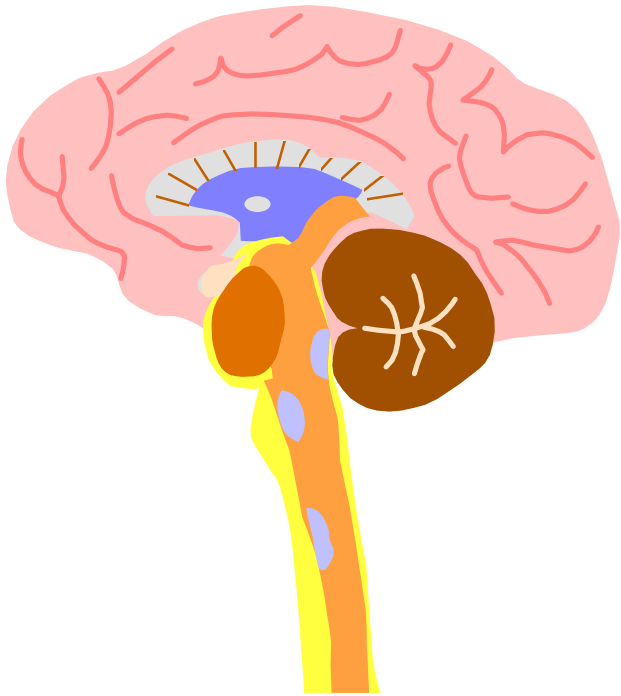
Current Issues

- Developmental neurotoxicants
- Pharmaceutical wastes
- Paint and solvent disposal
- Pesticide application and disposal
- Electronics product stewardship
- Polybrominated flame retardants
- Mercury product stewardship
- Endocrine disruptors

Why bother with these controls?

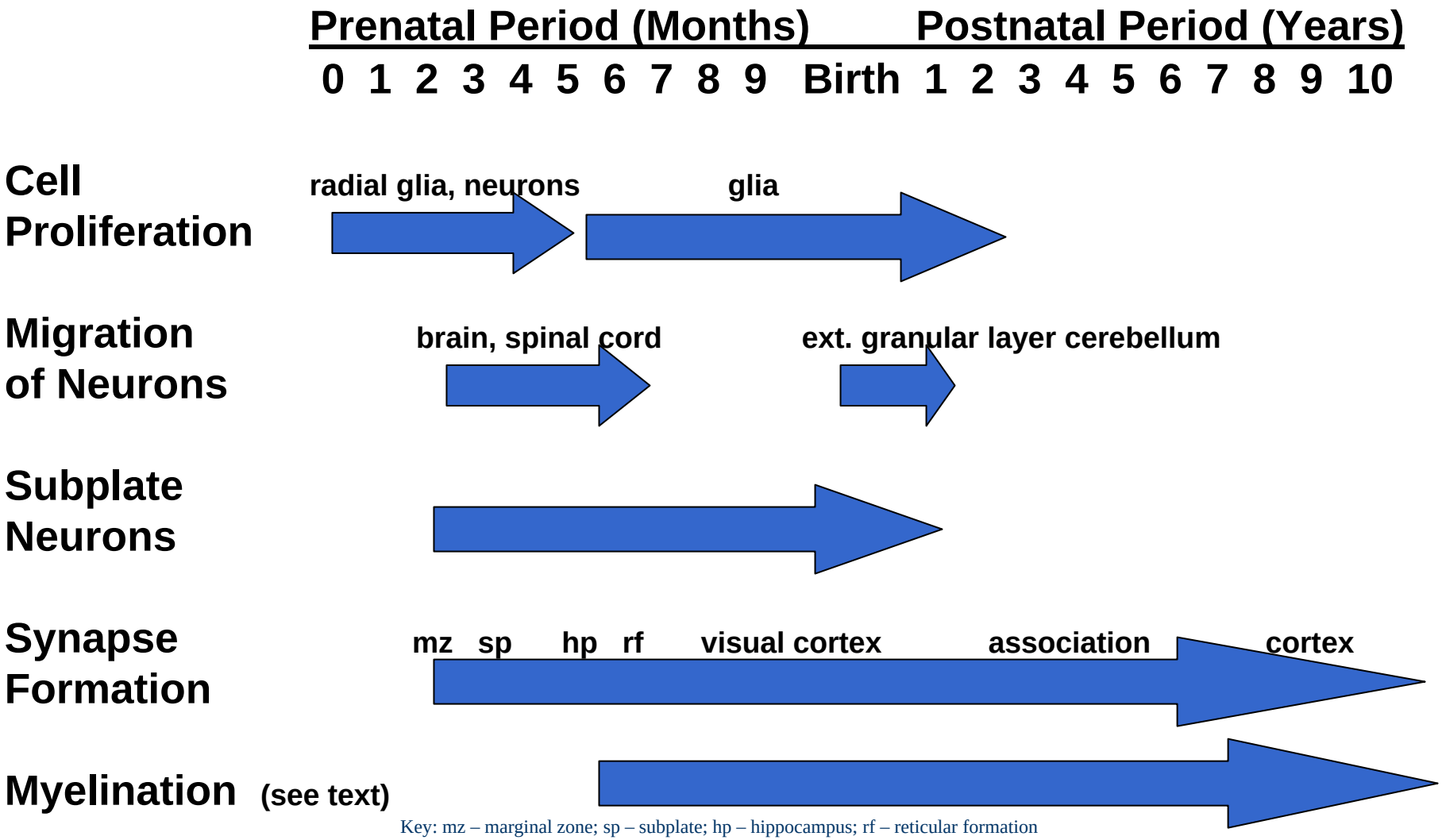
- Many chemical hazards are persistent
- Remediation costs are staggering
- Natural resources are limited
- Mounting evidence for health effects at low levels
- Disparities in exposure and health consequences exist

Events in Brain Development



- Critical sequence
- Vulnerable to disruption
- Size, timing, duration influence impact
- Downstream effects
- Susceptible throughout adolescence

Brain Development in Humans



Key: mz – marginal zone; sp – subplate; hp – hippocampus; rf – reticular formation

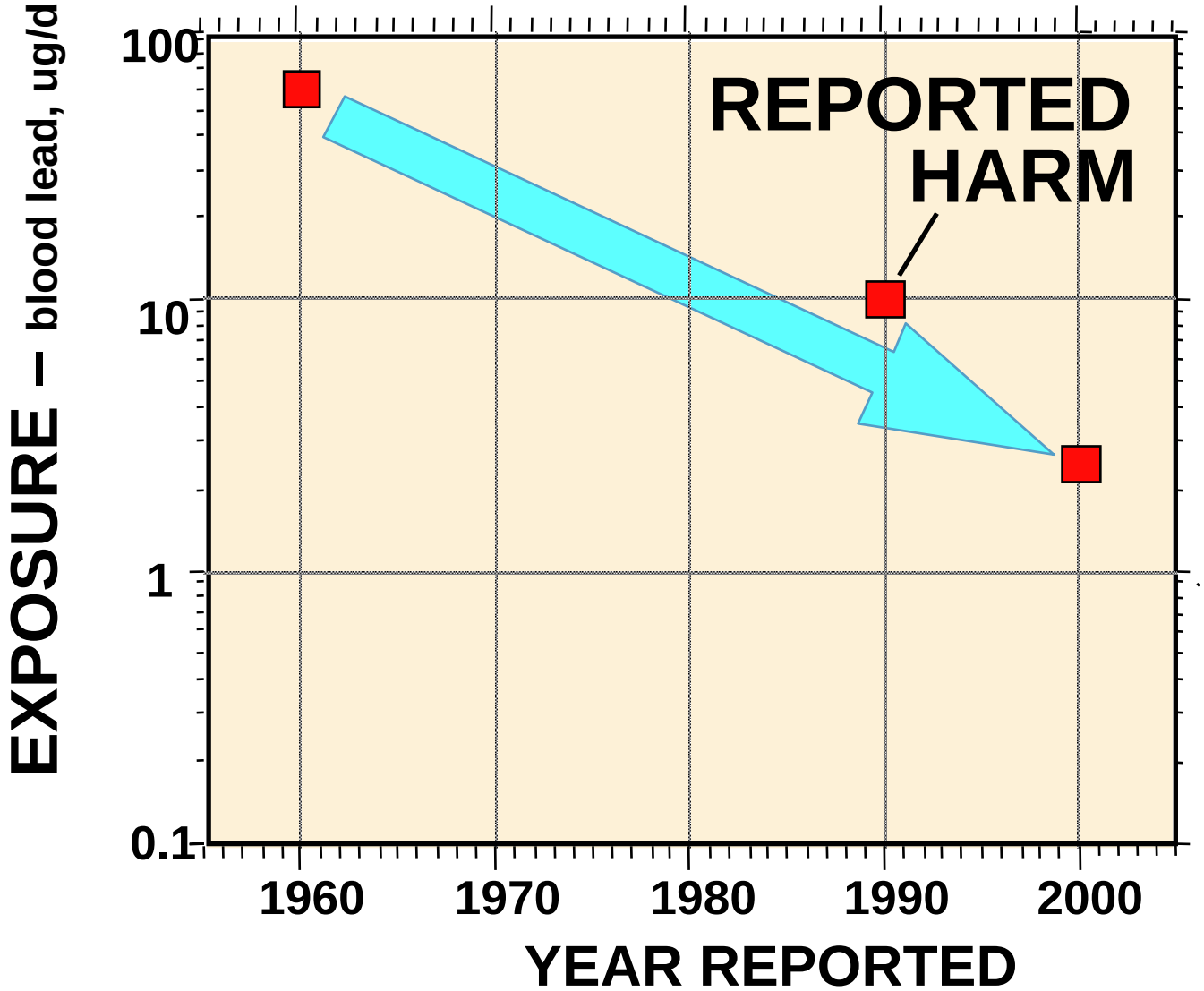
Actions of neurodevelopmental toxicants

proliferation	radiation, ethanol, mercury, cholinesterase inhibitors
migration	radiation, mercury, ethanol
differentiation	ethanol, nicotine, mercury, lead
synaptogenesis	radiation, ethanol, lead, triethyl tin, parathion, PCBs
gliogenesis & myelinization	decreased thyroid, ethanol, lead
apoptosis	ethanol, lead, mercury
signaling	ethanol, cholinesterase inhibitors, mercury, lead, PCBs

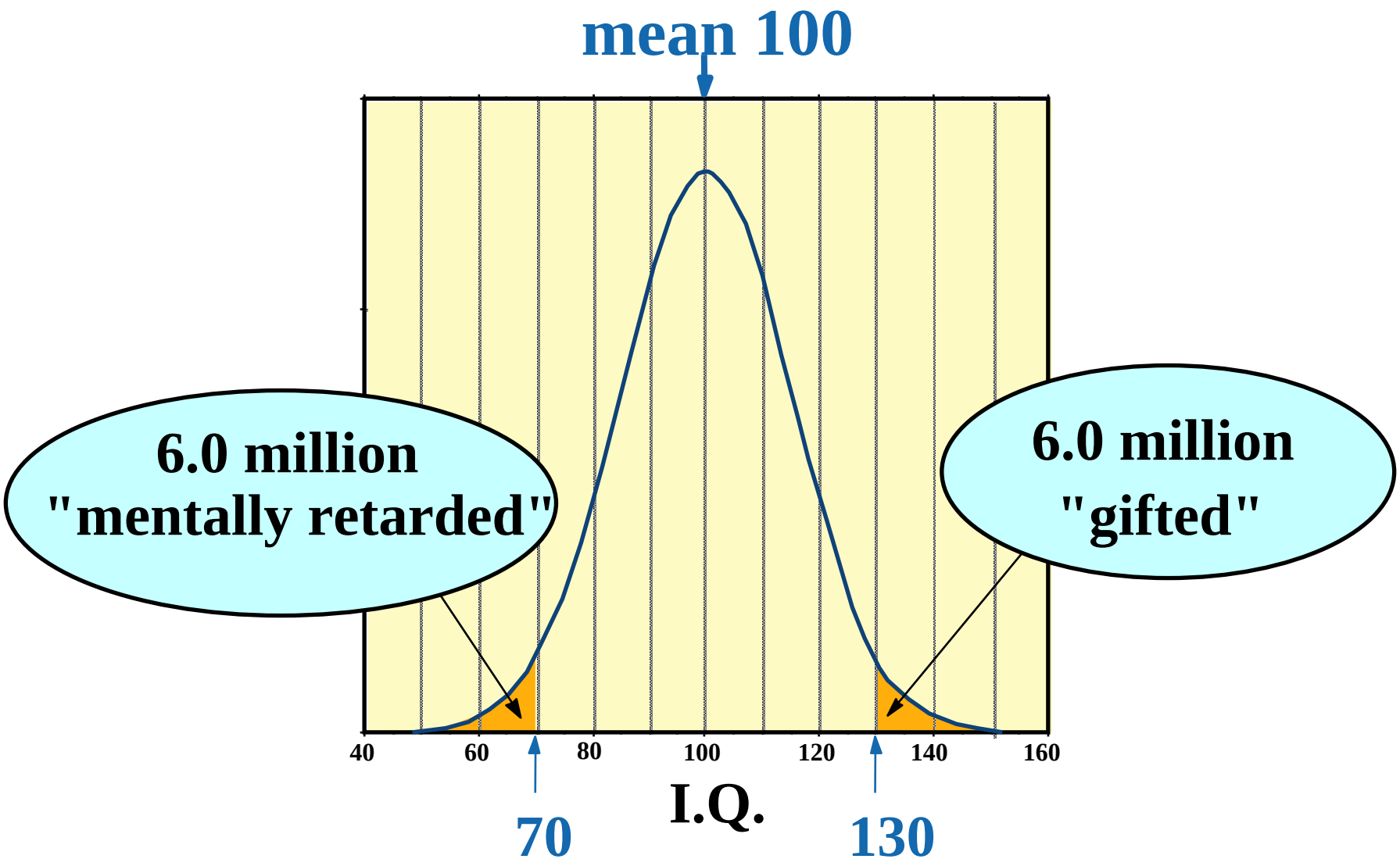
State of Knowledge

- Only 12 chemicals tested for neurodevelopmental toxicity according to current EPA guidelines
- Extensive data on effects of lead, mercury, polychlorinated biphenyls (PCBs), alcohol, nicotine
- Less extensive but substantial data on pesticides and solvents other than alcohol
- Still fewer data on other compounds including manganese, fluoride

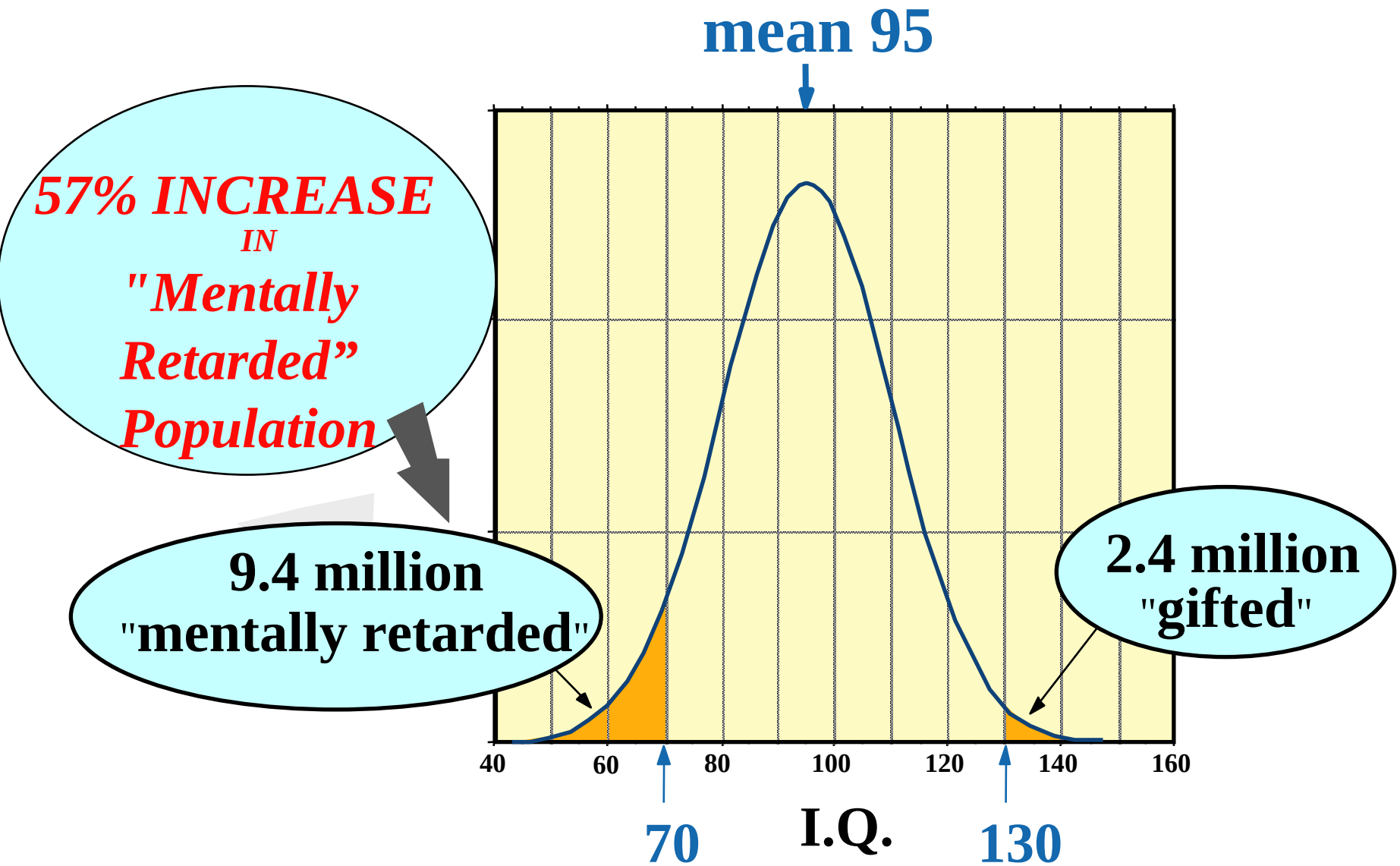
DECLINING THRESHOLD OF HARM - LEAD



Significance of a small shift in IQ for a population of 260 million



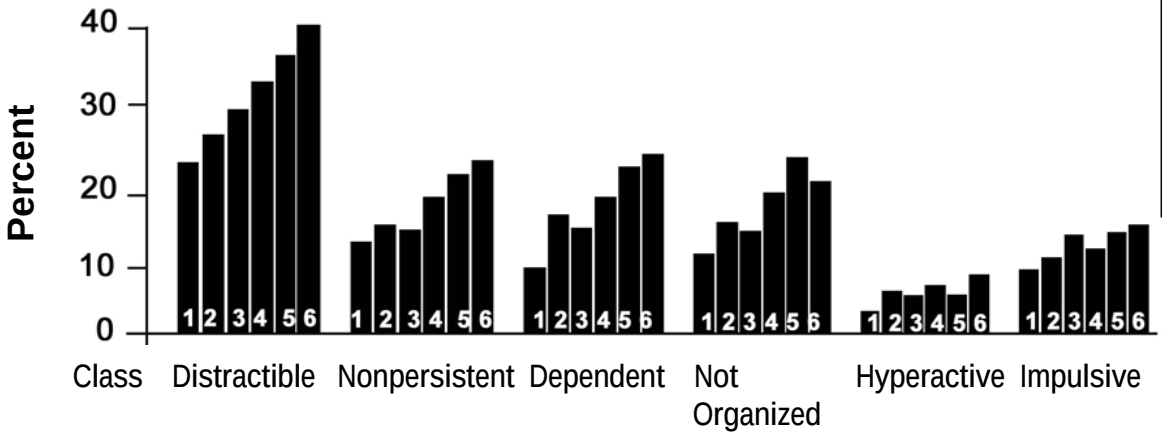
5 Point Decrease in Mean IQ



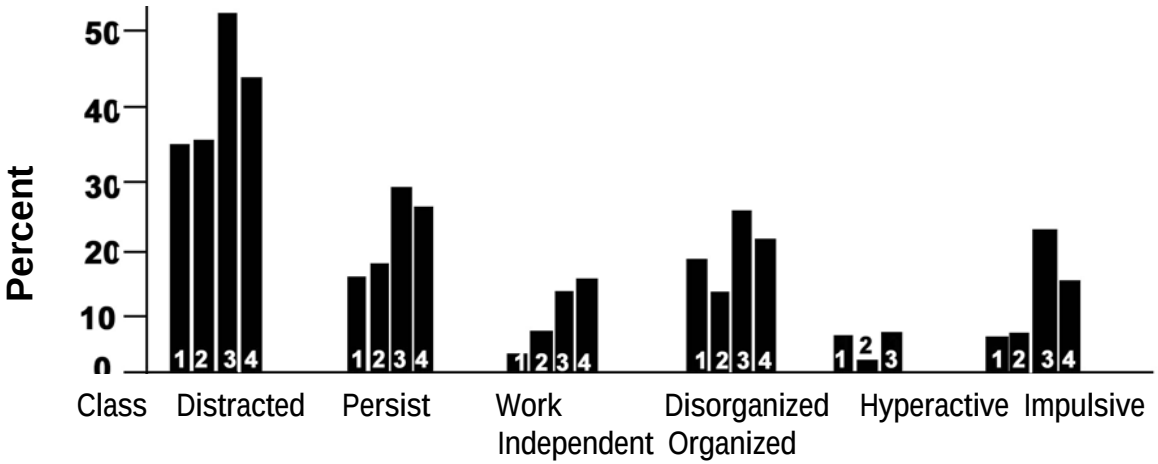
Effects of Lead on Cognitive and Behavioral Traits

ADHD	LD	OTHER
↑ hyperactivity	↓ reading, math	↓ fine motor
↑ impulsivity	↓ spelling	↓ visual motor
↑ distractibility	↓ pattern recognition	↑ aggressive
↑ dif. w. instructs	↓ word recognition	↑ antisocial
↑ conduct problems		↑ off-task
↓ executive function		
↓ attention/vigilance		
↓ social skills		

Association of Teacher Ratings With Student Lead Burden

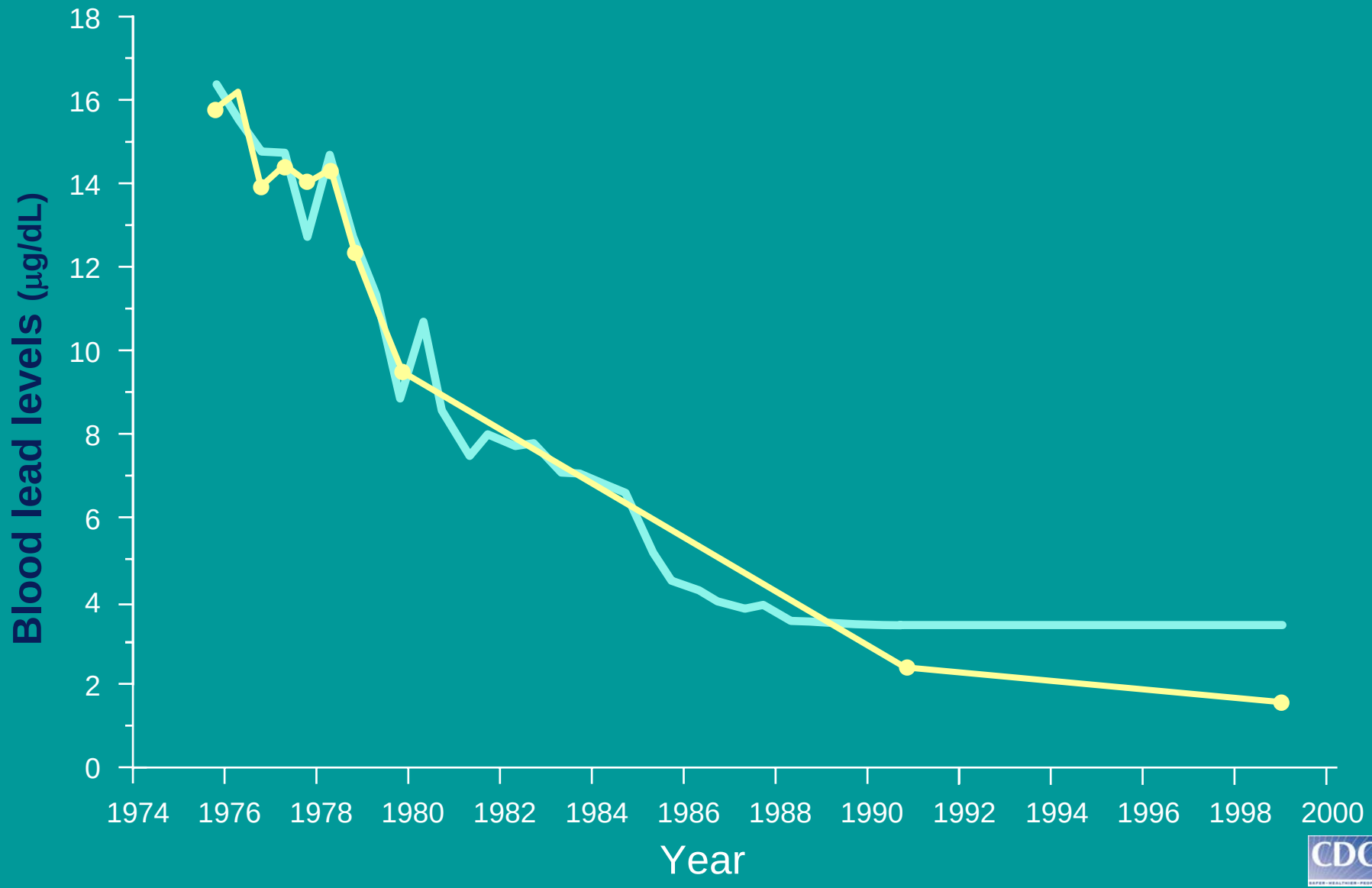


Class	Dentine Lead (ppm)
1	<5.1
2	5.1-8.1
3	8.2-11.8
4	11.9-17.1
5	17.2-27.0
6	>27

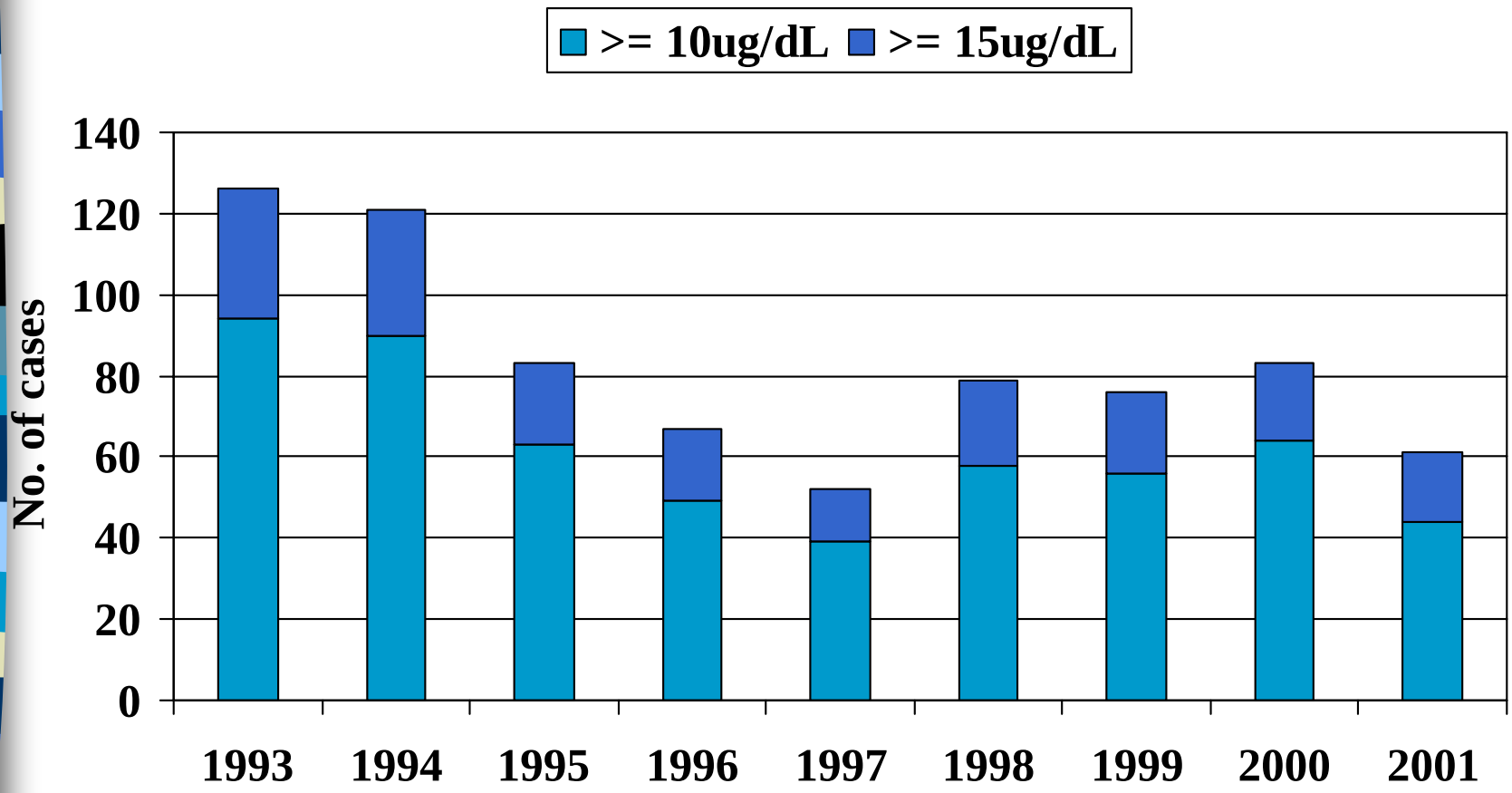


Class	Blood Lead, (micrograms/dl)
1	7-10
2	11-12
3	13-16
4	17-32

Blood lead levels in the U.S. population 1976 -1999
NHANES II, III, 99+

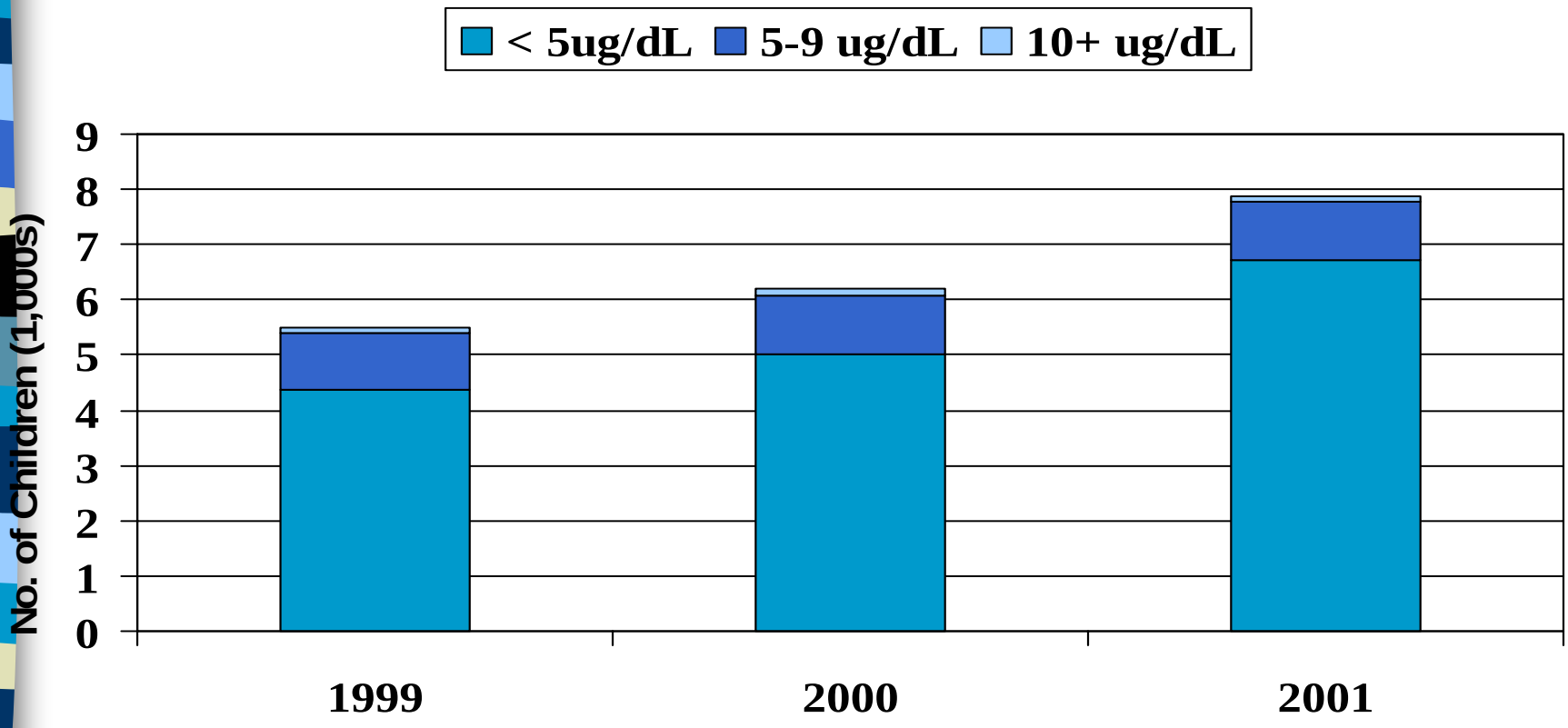


Confirmed Lead Poisoning Cases, Multnomah County



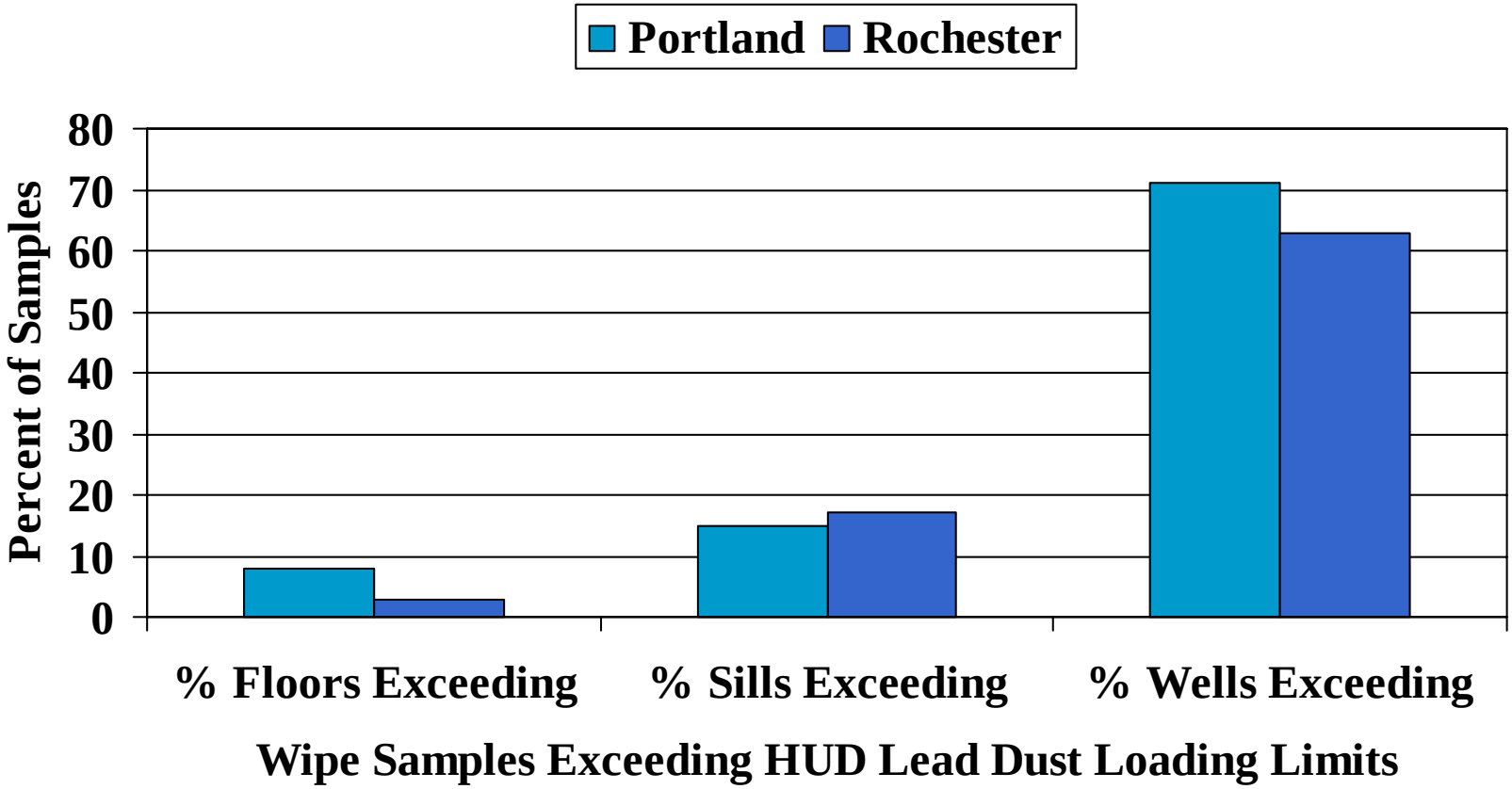
Multnomah County Health Department, 2003, *The Environmental Health of Multnomah County*)

Oregon Child Blood Lead Surveillance: 1999-2001



(Oregon Lead Poisoning Prevention Program, Oregon Department of Human Services, 2003)

Portland, OR Lead Dust vs. Rochester, NY



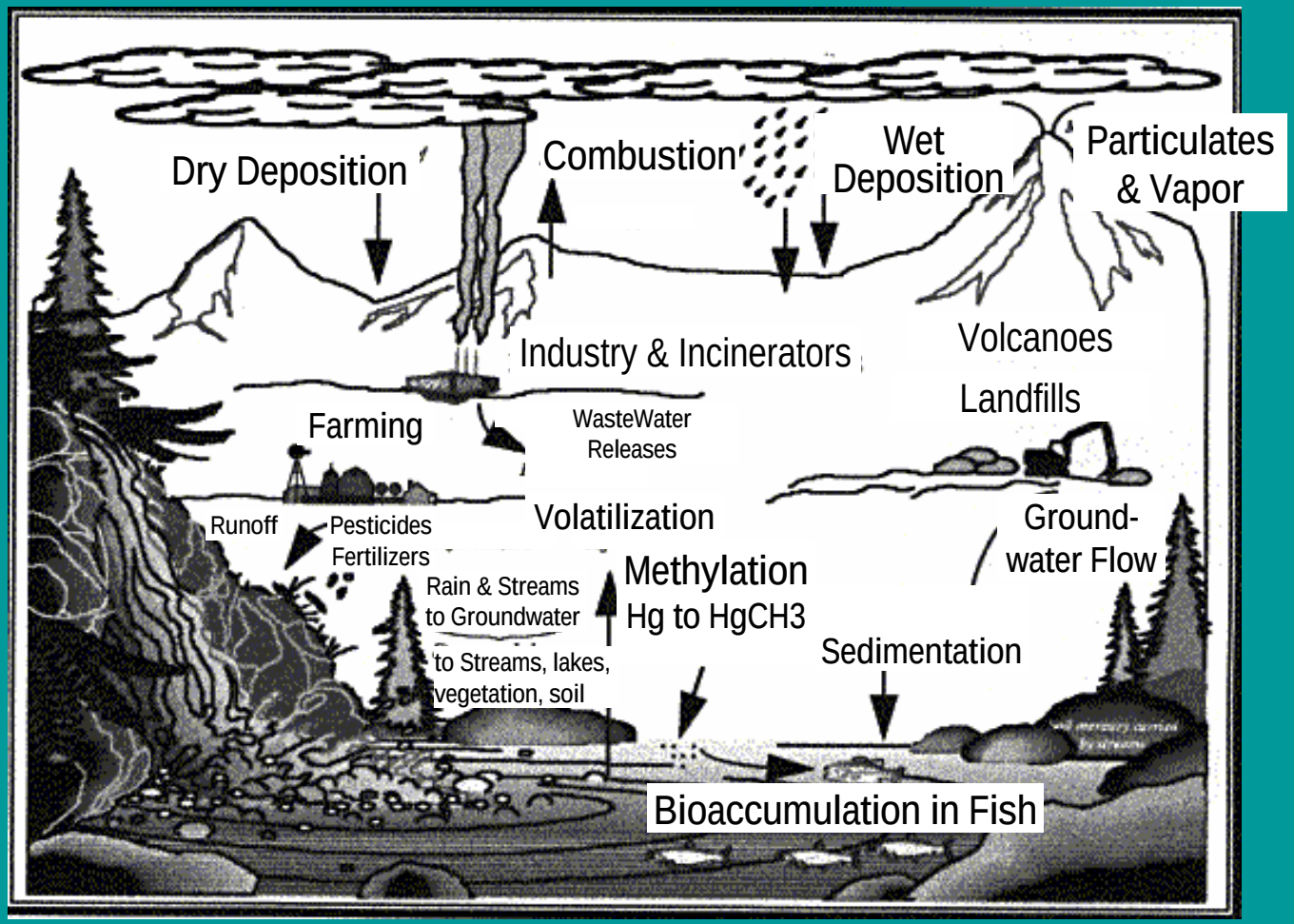
(Multnomah County Health Department, 2001, *Prevalence of Lead Dust Hazards Study*)

Other Sources of Lead Exposure

Ceramics

Toy Necklaces

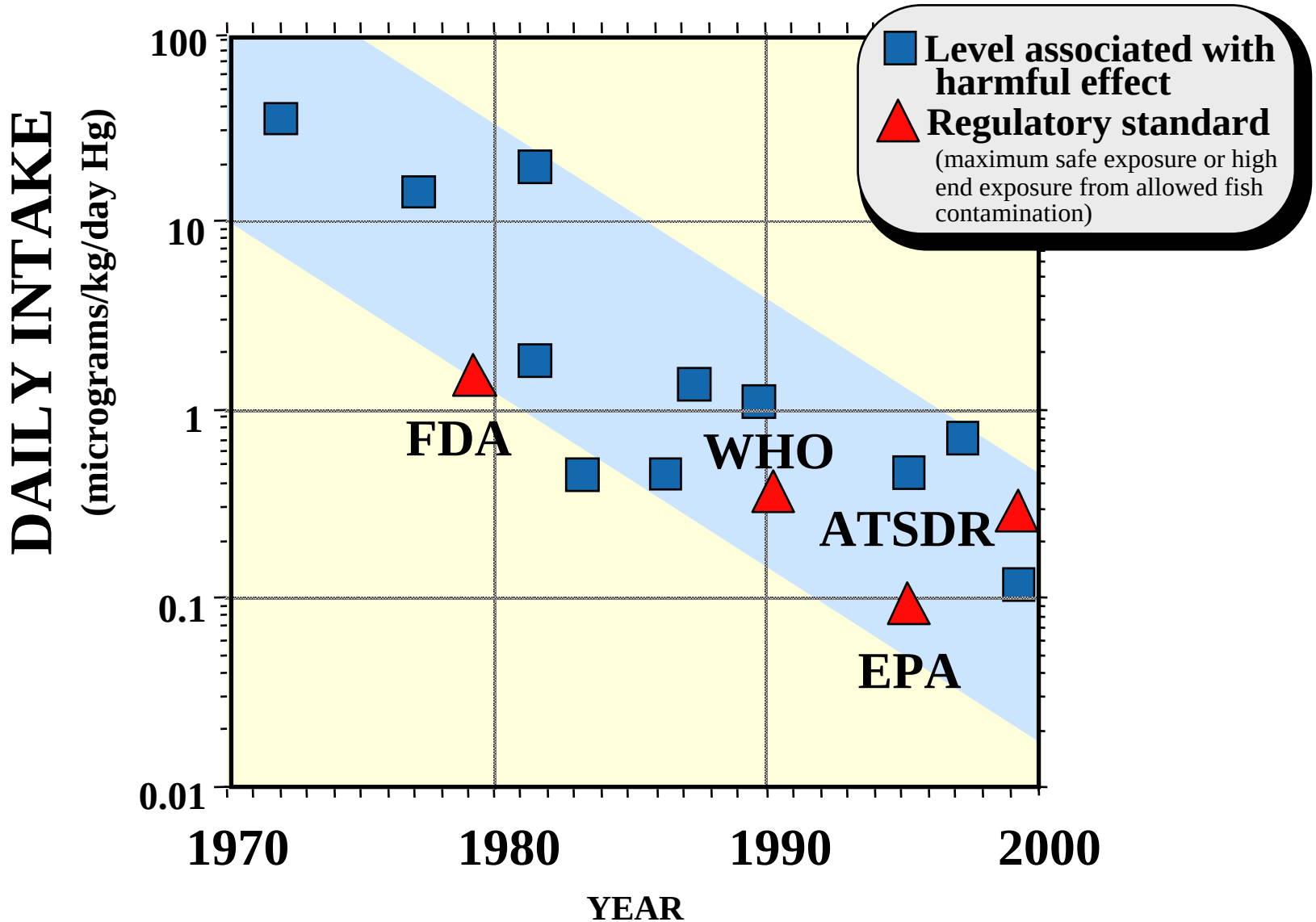
An Overview of Mercury



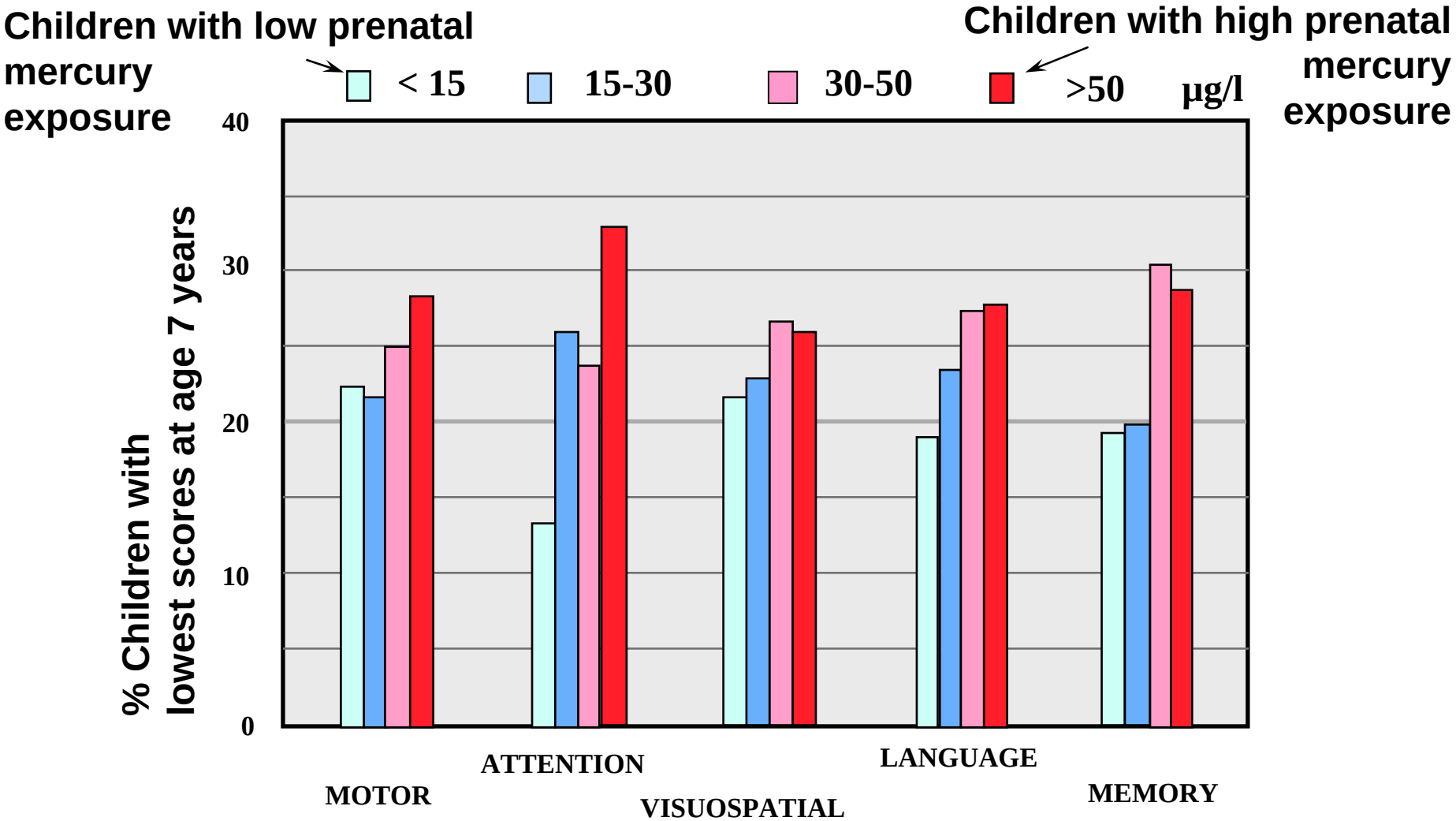
Mercury:
Effects of Higher Dose Prenatal Exposure

- Mental retardation
- Seizures
- Cerebral palsy
- Disturbances of vision, hearing, sensation
- Abnormal gait
- Abnormal speech
- Disturbances of swallowing and sucking
- Abnormal reflexes

Mercury:
Declining Threshold of Harm



Mercury:
Effects of Low Dose Prenatal Exposure



Source: Grandjean, et. al., "Cognitive Deficit in 7-year-Old Children with Prenatal Exposure to Methylmercury", Neurotoxicology and Teratology, Vol. 19, No. 6, 1997

Figure shows prenatal mercury exposure levels of Faroese children with scores in the lowest quartile after adjustment for cofounders. For each of the five major cognitive functions, one neuropsychological test with a high psychometric validity was selected.

New Tuna Guidance from FDA

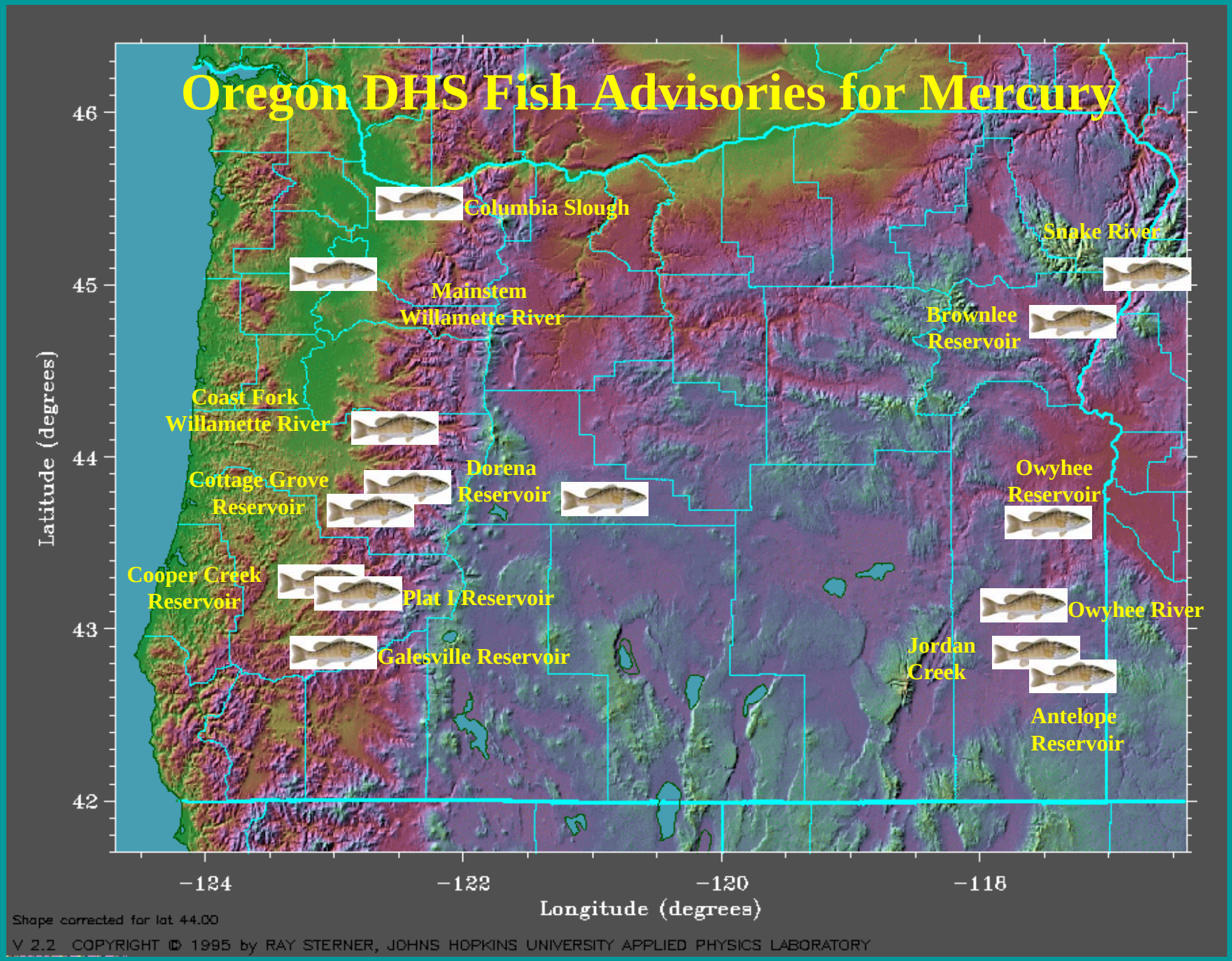
Advised Exposure Limit

- **EPA Reference Dose ("safe" upper limit) – 0.1 microgram/kilogram/day**
- **New FDA guidelines for women of CBA**
  - **< 6 oz. tuna/week or 2 fish meals**
  - **Avoid swordfish, shark, mackerel, tilefish**

Mercury Exposures

Current exposures

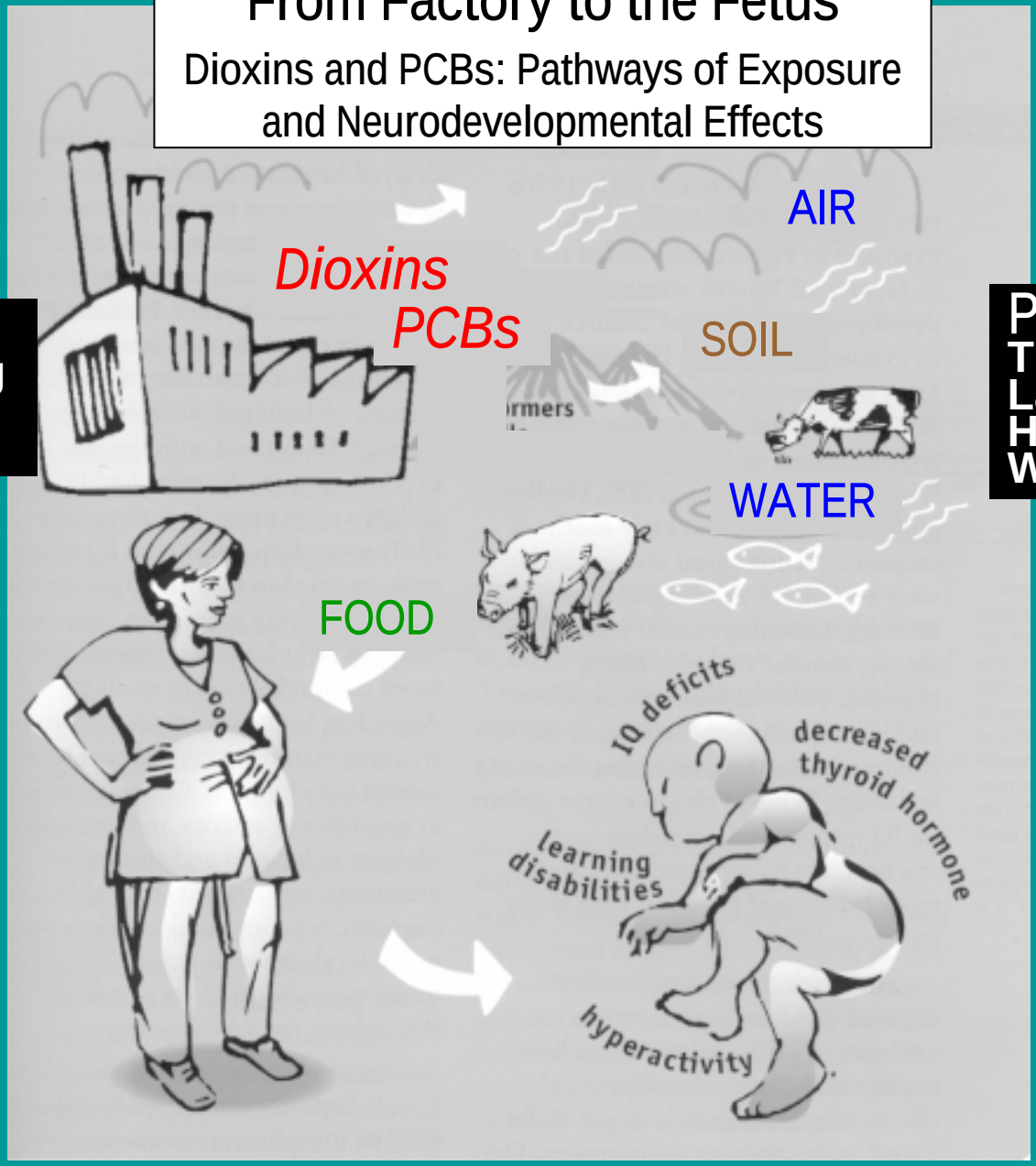
- **>10% of women of reproductive age exceed Reference Dose (RfD)**
- **50% of women who eat fish exceed RfD on any given day**
- **Higher risk: Subsistence fishers, immigrants, Native Americans**


Oregon DHS Fish Advisories for Mercury
Columbia Slough
Snake River
Mainstem
Willamette River
Brownlee
Reservoir
Coast Fork
Willamette River
Dorena
Reservoir
Cottage Grove
Reservoir
Owyhee
Reservoir
Cooper Creek
Reservoir
Plat I Reservoir
Owyhee River
Galesville Reservoir
Jordan
Creek
Antelope
Reservoir
46
45
44
43
42
Latitude (degrees)
−124
−122
−120
−118
Longitude (degrees)
Shape corrected for lat 44.00
V 2.2 COPYRIGHT © 1995 by RAY STERNER, JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

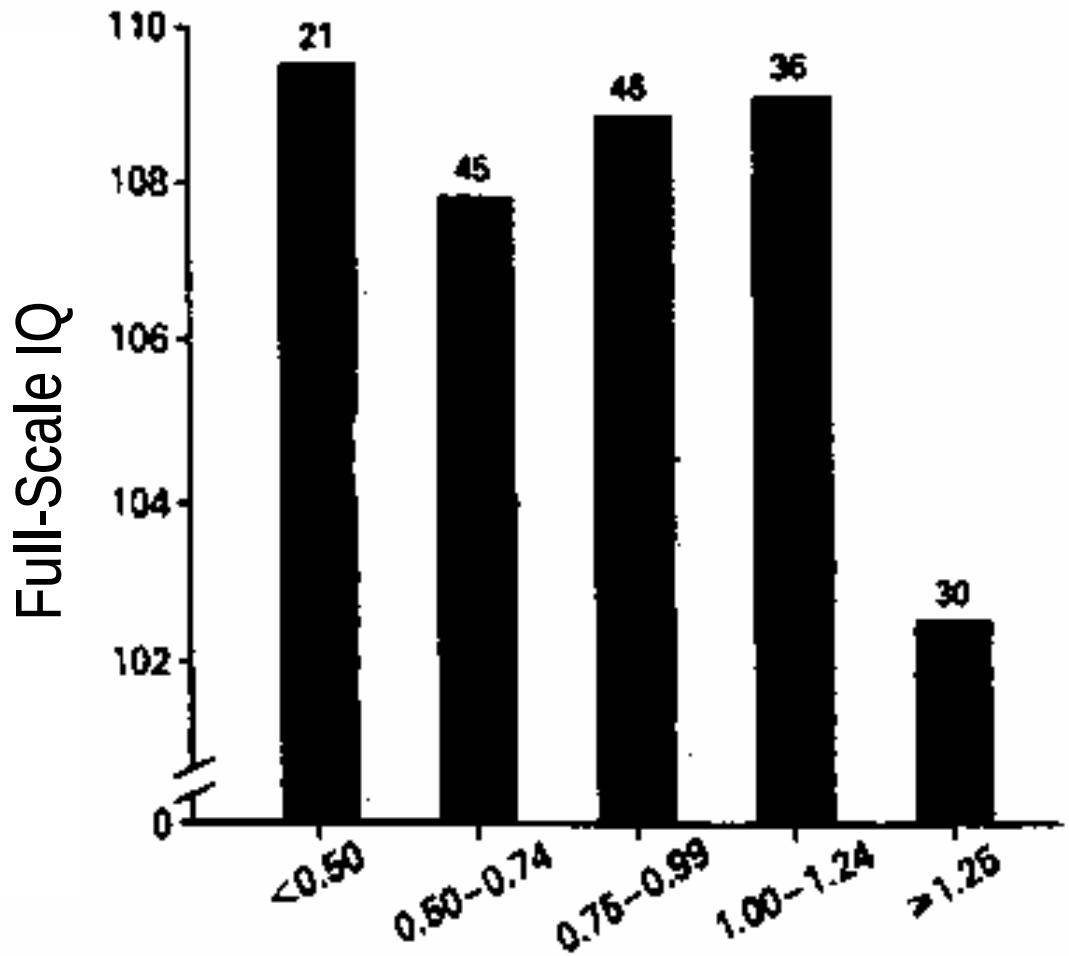
From Factory to the Fetus

Dioxins and PCBs: Pathways of Exposure and Neurodevelopmental Effects

Dioxins:
PVC Manufacturing
Medical/Municipal Incinerators

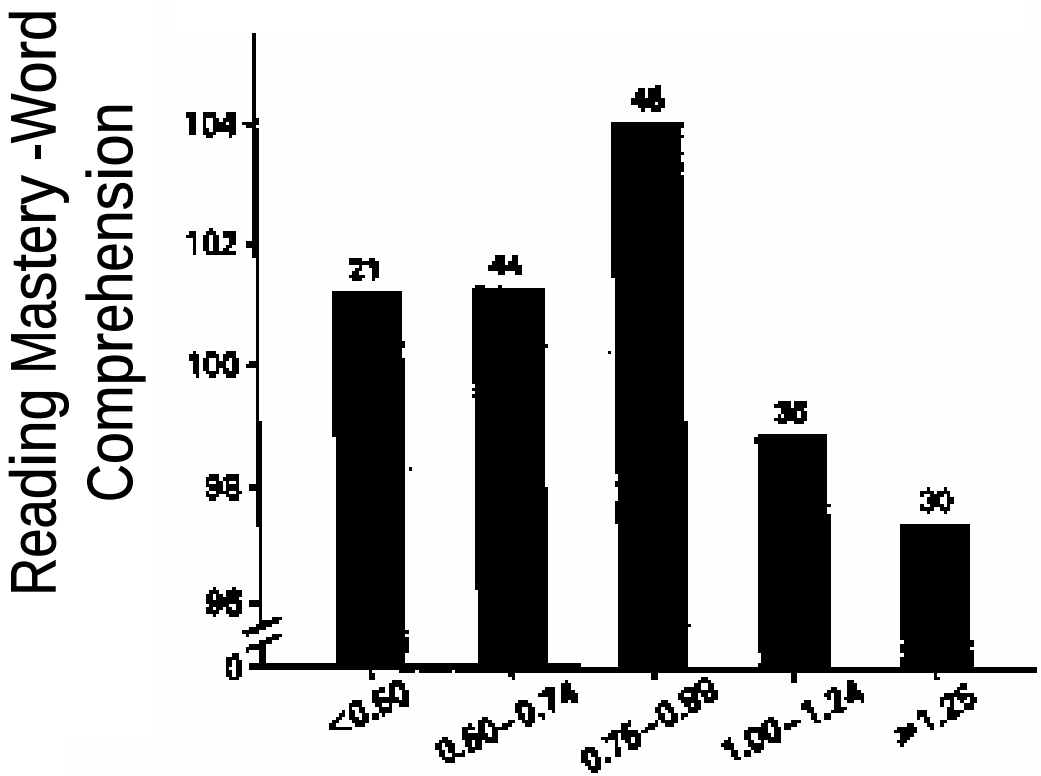


PCBs:
Transformers
Landfills
Hazardous Waste Sites



Prenatal Exposure to Polychlorinated Biphenyls (PCBs) ug/g of fat

PCBs



Prenatal Exposure to Polychlorinated Biphenyls (PCBs) ug/g of fat

PCBs: Pervasive developmental effects

Infant

- **Birth weight**
- **Head circumference**
- **Gestational age**
- **Performance on Brazelton Neonatal Behavioral Assessment (BNBA) - motor immaturity, poor lability, startle**

PCBs: Pervasive developmental effects

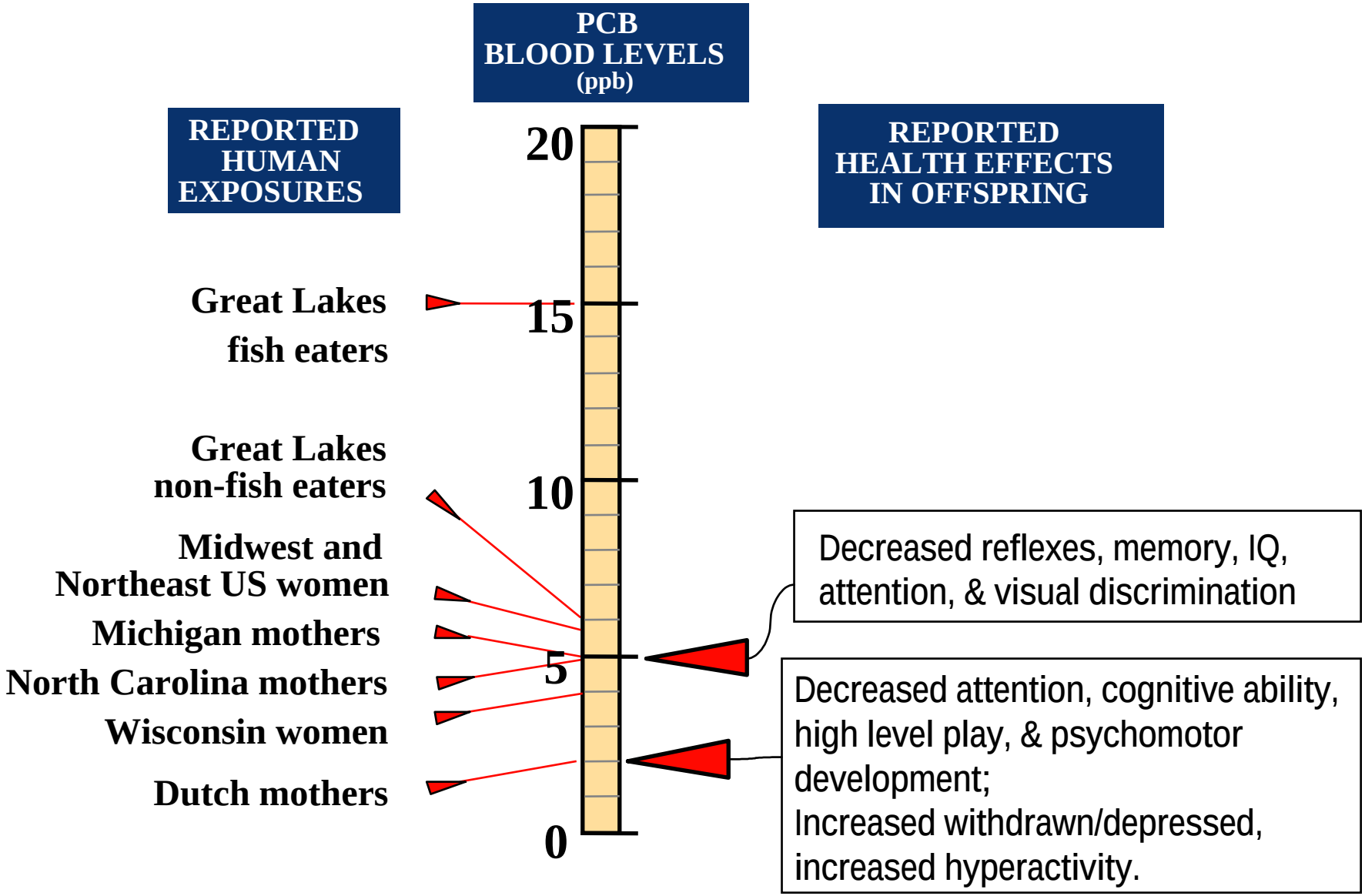
Early Childhood

- **Memory, attention, verbal ability, information processing**
- **Psychomotor development**
- **Sustained activity, high level play**
- **Withdrawn, depressed behavior**
- **Hyperactivity**

Preteen

- **Word and reading comprehension**
- **Full scale and verbal IQ**
- **Memory and attention**

PCBs: Exposures exceed known effect levels



PCBs:
Effects on thyroid metabolism

- **Altered thyroid hormone**

  Mothers: ↓ Thyroid Hormone, ↑ Thyroid Stimulating Hormone (TSH)

  Infants: ↓ Thyroid Hormone, ↑ TSH

- **Developmental Implications**

  Elevated maternal TSH during pregnancy, with or without reductions of thyroid hormone, associated with reduced IQ at age 7-9 yrs.

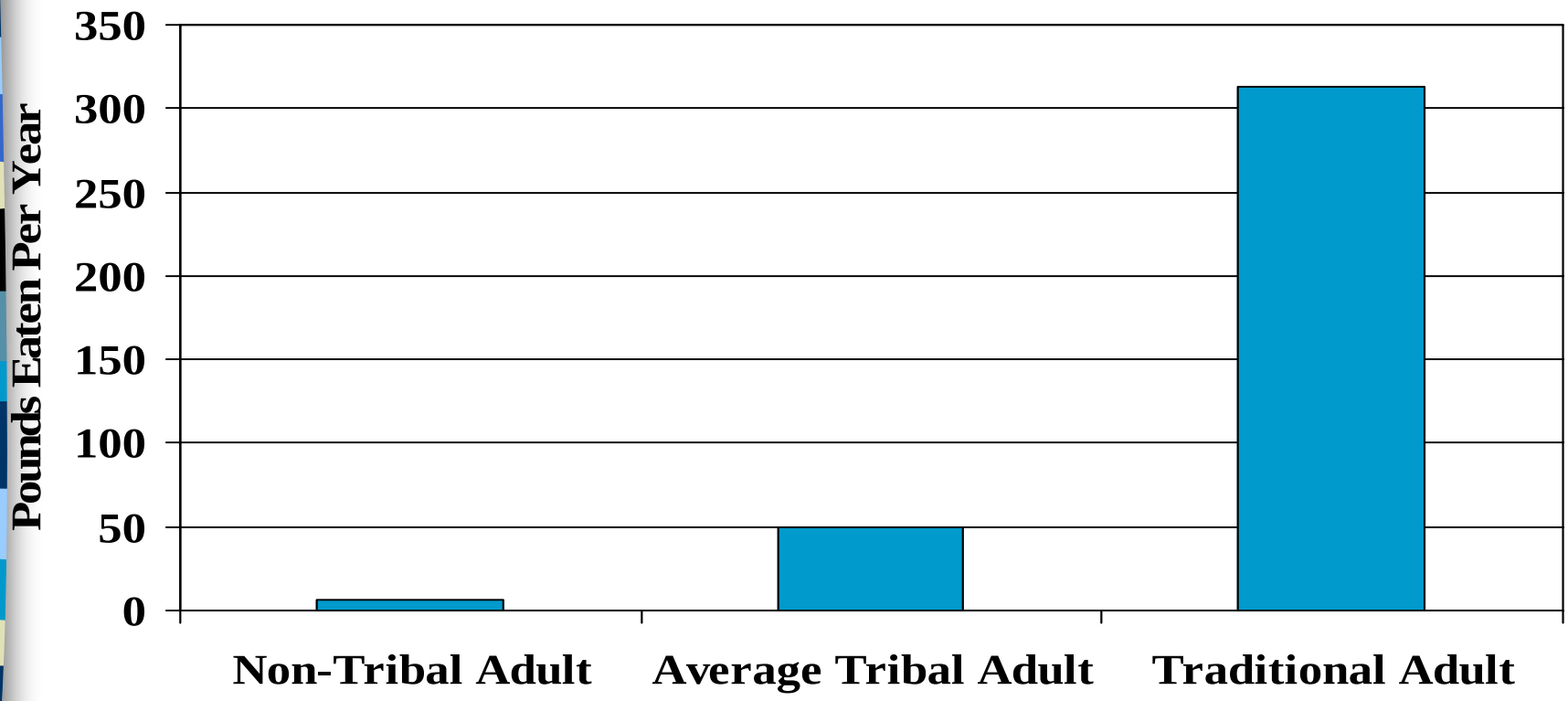
Possible Mechanisms

- Altered neurotransmitter levels
- Ah receptor mediated effects (dioxin-like PCBs)

  Disruption of production of growth factors and hormones including enzyme induction, modulation of growth factors, hormones
- Interference with thyroid hormone
  - metabolism through enzyme induction
  - interference with thyroid-hormone-mediated gene transcription
  - displacement of thyroxin from carrier protein

Many Native Americans Continue to Follow a Traditional Diet that Includes Fish

Fish Consumption of Salmon Treaty Tribes Far Exceeds Non-Tribal Populations

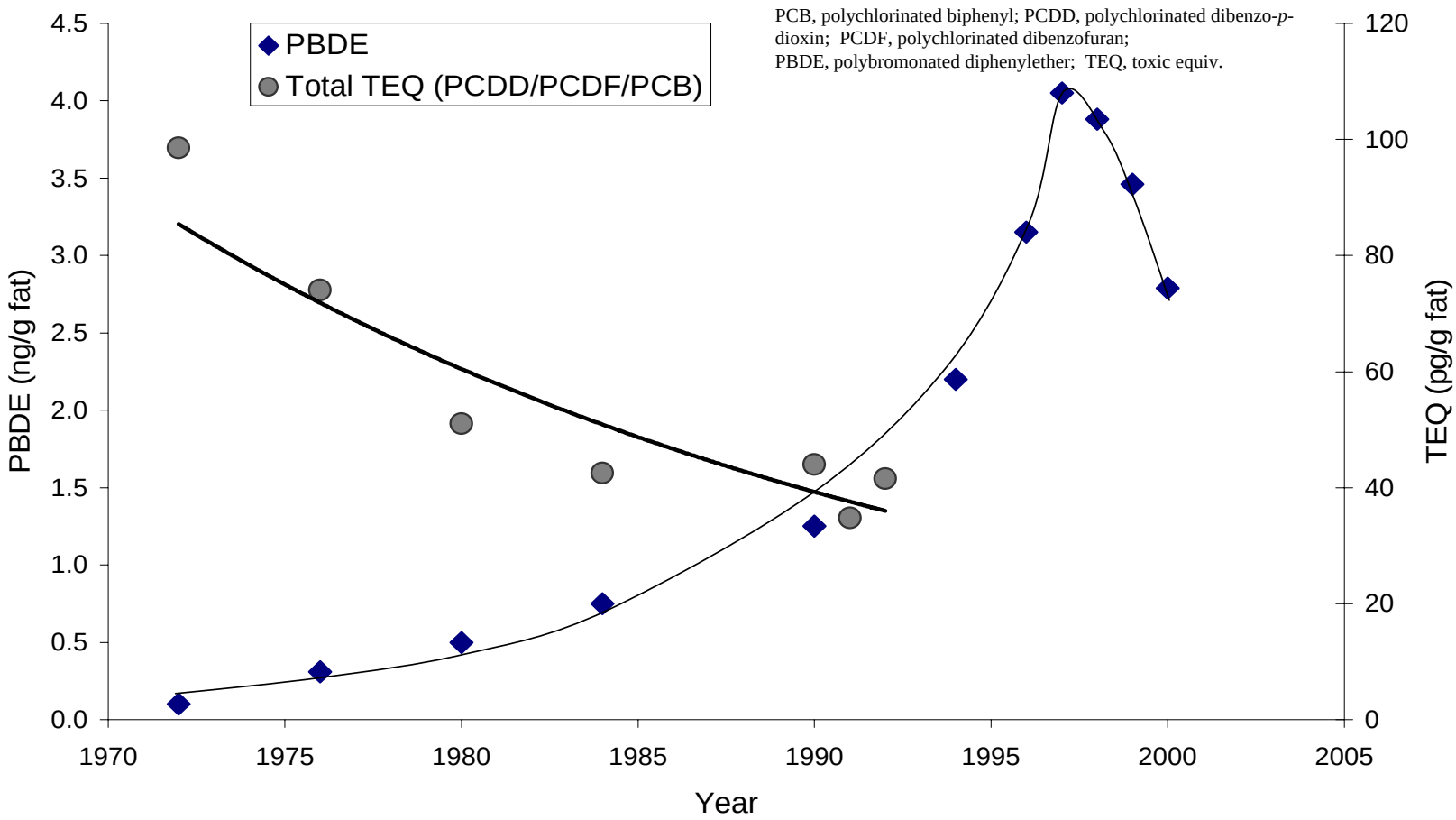


Estimated Health Risks from Contaminated Subsistence Fish

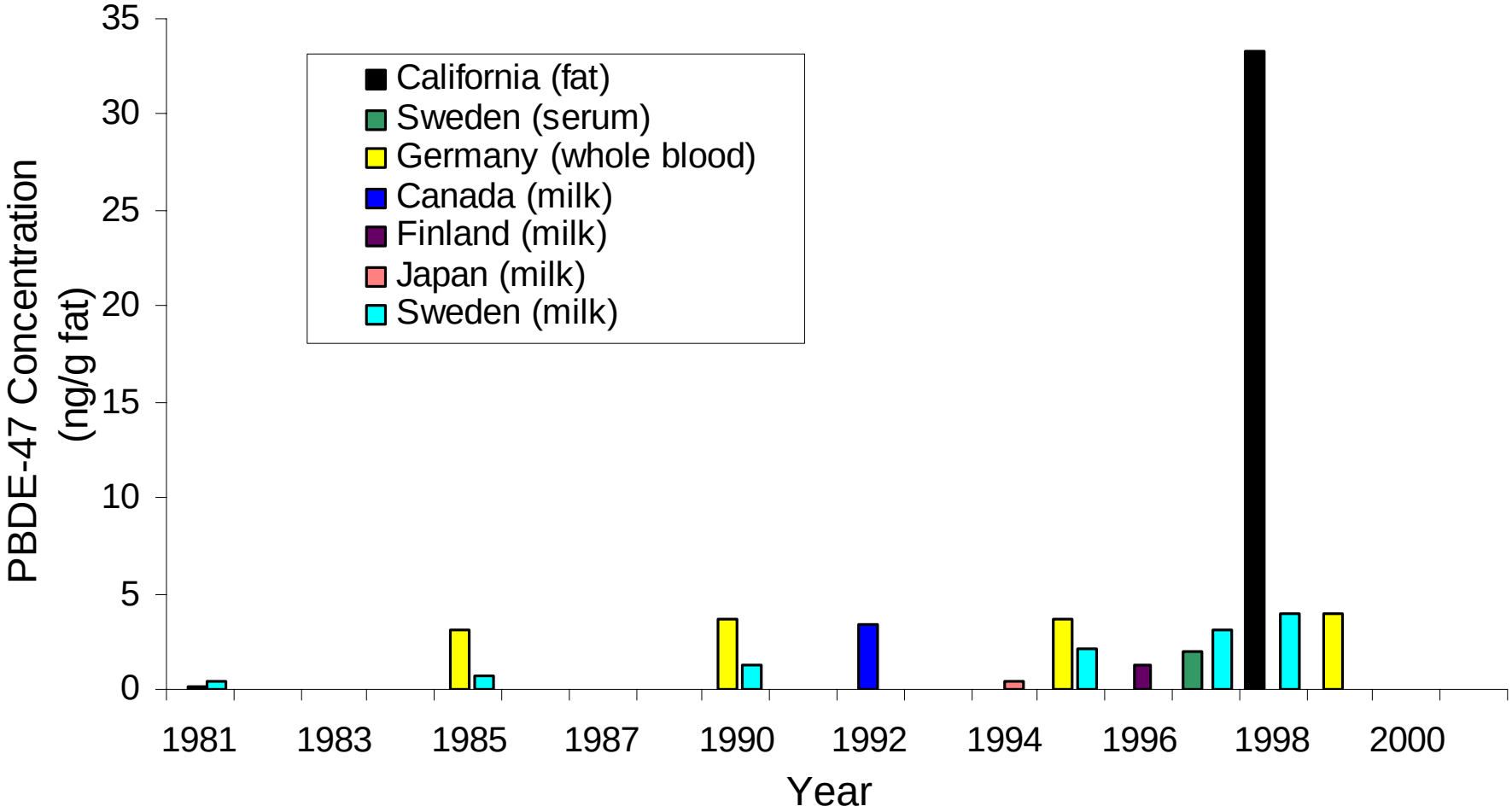
- **PCB and mercury exposures to children pose risks for CNS, reproductive, and immune systems**
- **Life time risks for cancer elevated to 10^{-4} to 10^{-3}.**

(U.S. EPA Region 10, 2002, *Columbia River Basin Fish Contaminant Survey)*

Organohalogen Compounds in Breast Milk in Sweden



PBDE Levels in Humans



PBDE, polybrominated diphenylethers. (She et al., 2001)

Some PBDEs to be phased out

Firm to stop making risky chemicals
State ordered flame retardants banned by 2008
Jane Kay, *San Francisco Chronicle*
Tuesday, November 4, 2003

“An Indiana chemical company promised Monday to stop manufacturing two industrial mixtures of flame retardants that California officials say are harmful to women and wildlife. Great Lakes Chemical Corp. in West Lafayette, Ind., said it would phase out the two mixtures of PBDEs -- polybrominated diphenyl ether -- by 2005 instead of the 2008 final ban date passed earlier this year by the state Legislature. The mixtures are called "penta" and "octa." Penta is used to prevent burning of polyurethane foam in furniture and mattresses. Octa is added to plastic in printers, keyboards and casings.”

Pesticides

- **Most are synthetic agents new to humans and the environment - insecticides, fungicides, herbicides**
  - **Developed since 1940's**
  - **891 pesticidal "active ingredients"***
  - **523 used on food or feed**
  - **140 currently considered neurotoxic**
- **Inherent toxicity**
- **Few human studies**

*** 1999 estimates**

Acute Poisonings

US Poison Control (2000)

- 11,000 unintentional organophosphate (OP) exposures; 3000 treated in health care facility
- includes 4000 children < 6 years old

World Health Organization

- 3 million acute, severe poisonings/yr
- 220,000 deaths/yr

Implications for protection of public health

Limits of acute poisoning data

- **Incomplete coverage of U.S. population**
- **Unreported incidents**
- **Long term impacts of acute/high level exposures**

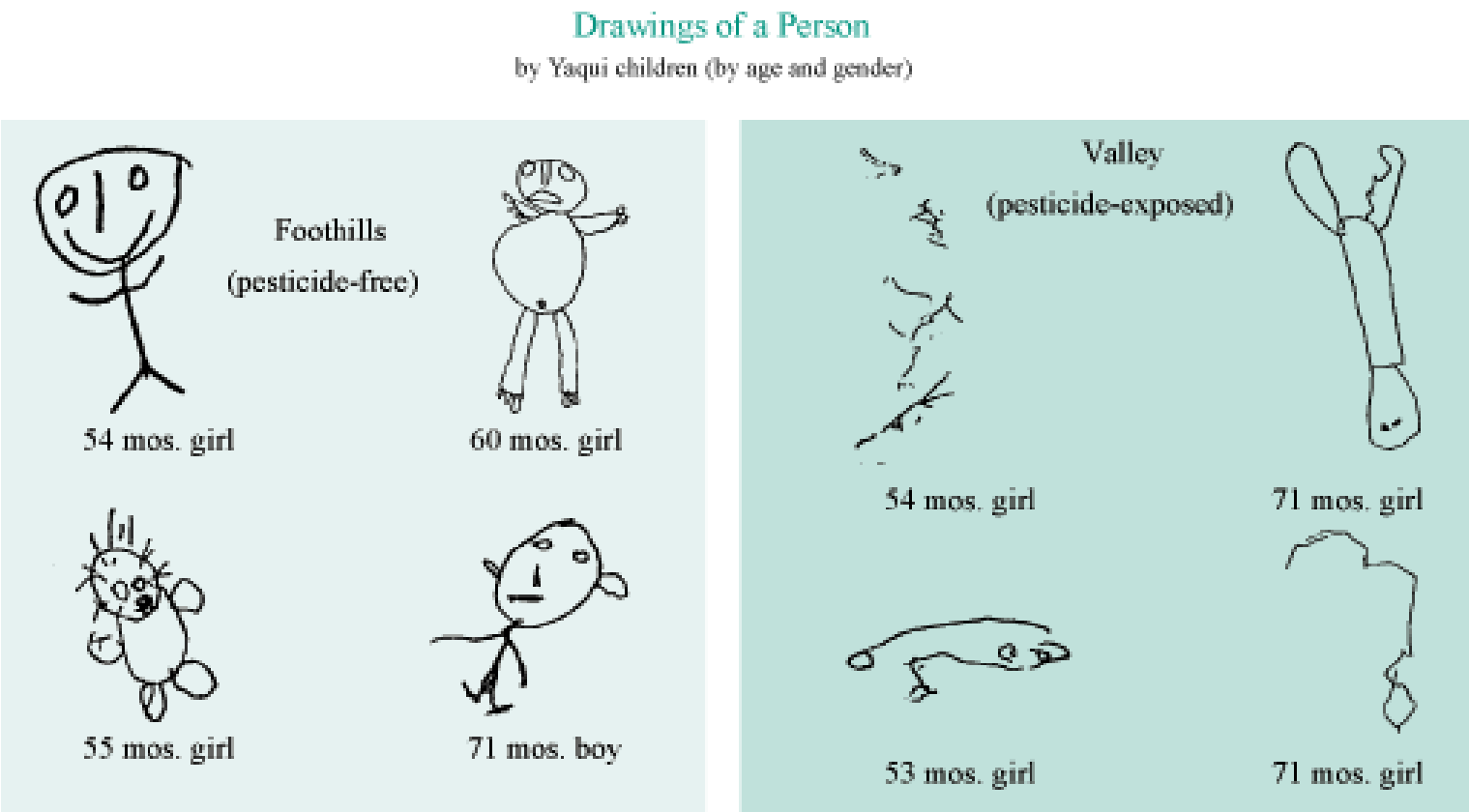
Limits of pesticide toxicity data

- **Few studies of impact of chronic/low-dose exposures**
- **Few developmental/neurodevelopment studies**

State of evidence: Perhaps analogous to what was known about lead toxicity decades ago.

Pesticides: the health effects

Yaqui Indian Pesticide - Anthropomorphic Study



Low Level Pesticide Exposure is Widespread

- **Reported use -** 98% of families, 80% during pregnancy
- **In Humans -** chlorpyrifos metabolites in 92% of children 82% adults urine samples
- **In Food -** detectable residues of at least one pesticide on 72% fruits/vegetables
- **In Homes -** 3 to 9 pesticide residues in typical home with 70% infant exposure from dust
- **In Air -** indoor air levels 10-100X higher than outdoor air
- **In Water -** >90% stream samples, 50% of wells

Farmers, Workers and Their Families Have High Opportunity for Pesticide Exposures

Rural Exposures: Agricultural Health Study

Exposures to farmers and families of farmer pesticide applicators:

- **27% of applicators store pesticides in their home**
- **94% of clothing worn for pesticide work is washed in the same machine as other laundry**
- **40% of wives of applicators also mixed or applied pesticides**
- **Over 50% of children aged 11 or more do farm chores**

Prenatal Exposures: The Urban Environment (NYC)

Meconium assays in 20 newborns (Whyatt 2001):

- **diethylphosphate (DEP); diethylthio-phosphate (DETP)**
- **Metabolites of chlorpyrifos, diazinon, parathion, organophosphate (OP) insecticides**

<u>Detections</u>:

- **DEP in 19/20 (95%) of samples (range 0.8-3.2 ug/g)**
- **DETP in 20/20 (range 2.0-5.6 ug/g)**

Early postnatal and gestational exposures to OPs (chlorpyrifos, diazinon) linked to adverse neuro-developmental effects in animal studies.

Preschooler Exposures (Seattle)

Two Seattle-area upper-middle and low to middle income communities:

- 110 children, ages 2-5
- Spot urine samples in Spring and Fall
- Examined for 6 dialkylphosphates (DAP)

Findings

- **99% had at least one DAP metabolite measured**
- **70-75% had 2 predominant metabolites (DMTP, DETP)**
- **Concentrations significantly higher in children of parents reporting pesticide use in the garden**

Children's OP Exposure Varying by Diet

Children ages 2-5, consuming 75% organic or "conventional" juices and produce

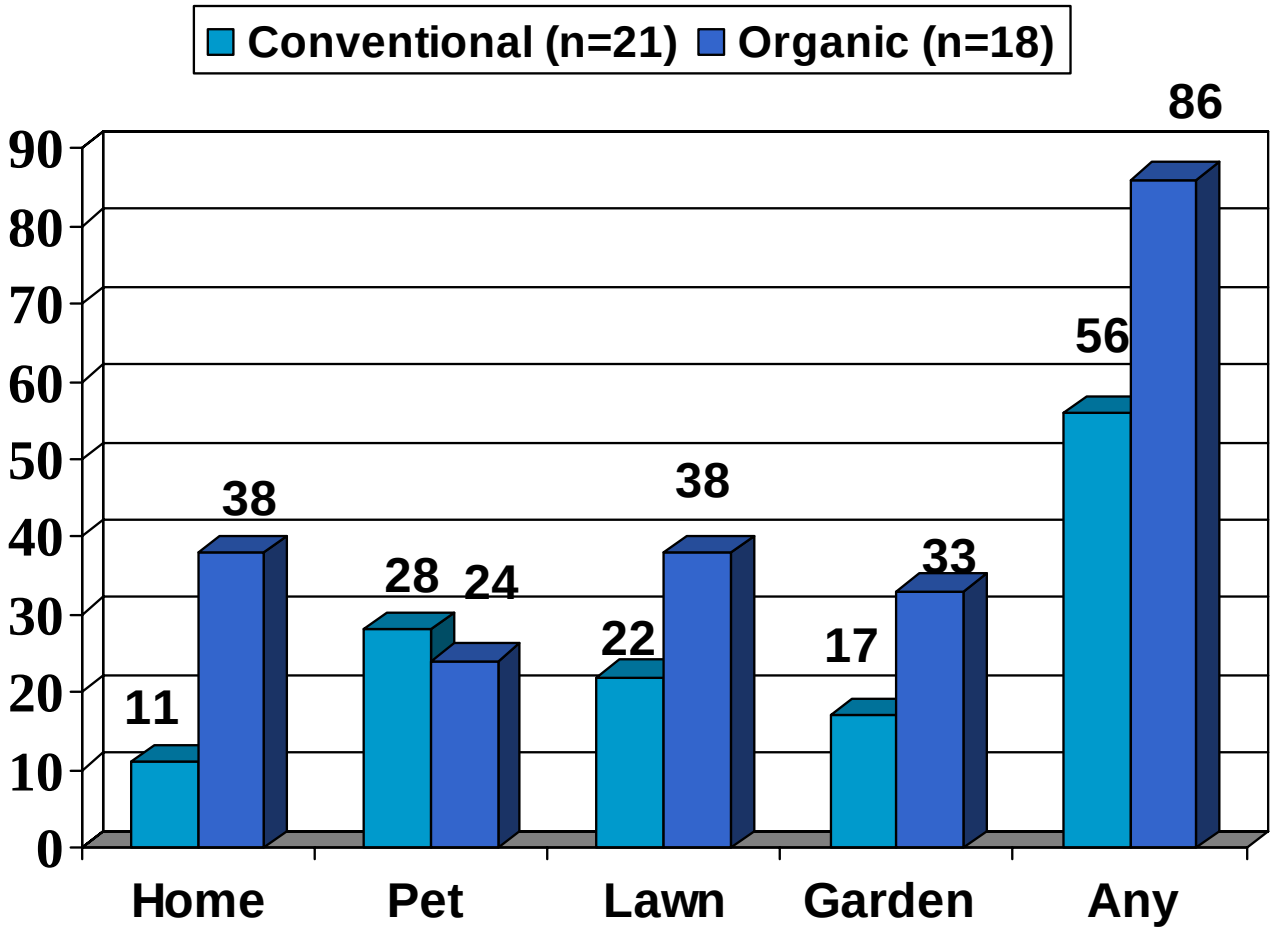
24-hr urine collection:

- **6-fold higher *median* total dimethyl OP metabolite concentrations in children on "conventional" diets**
- **9-fold higher *mean concentrations***

Dose estimates suggest eating organic fruits, vegetables and juice can lower a child's OP exposure level from above the EPA's reference dose (safe level) to below it.

Source: Curl et al. EHP, March 2003

Families (%) By Diet Reporting Ever Using Residential Pesticides



Source: Curl et al. EHP, March 2003

The roots of public health are in environmental health protection

Public Health Missions

- Prevent epidemics and the spread of disease
- Protect against environmental hazards
- Prevent injuries
- Promote and encourage healthy behaviors
- Respond to disasters and assist communities in recovery
- Assure the quality and accessibility of health services

Essential Public Health Services

- Monitor health status
- Investigate health problems and health hazards
- Mobilize communities to identify and solve health problems
- Develop policies and plans
- Enforce laws and regulations to protect health and ensure safety
- Evaluate effectiveness, accessibility, and quality of health services

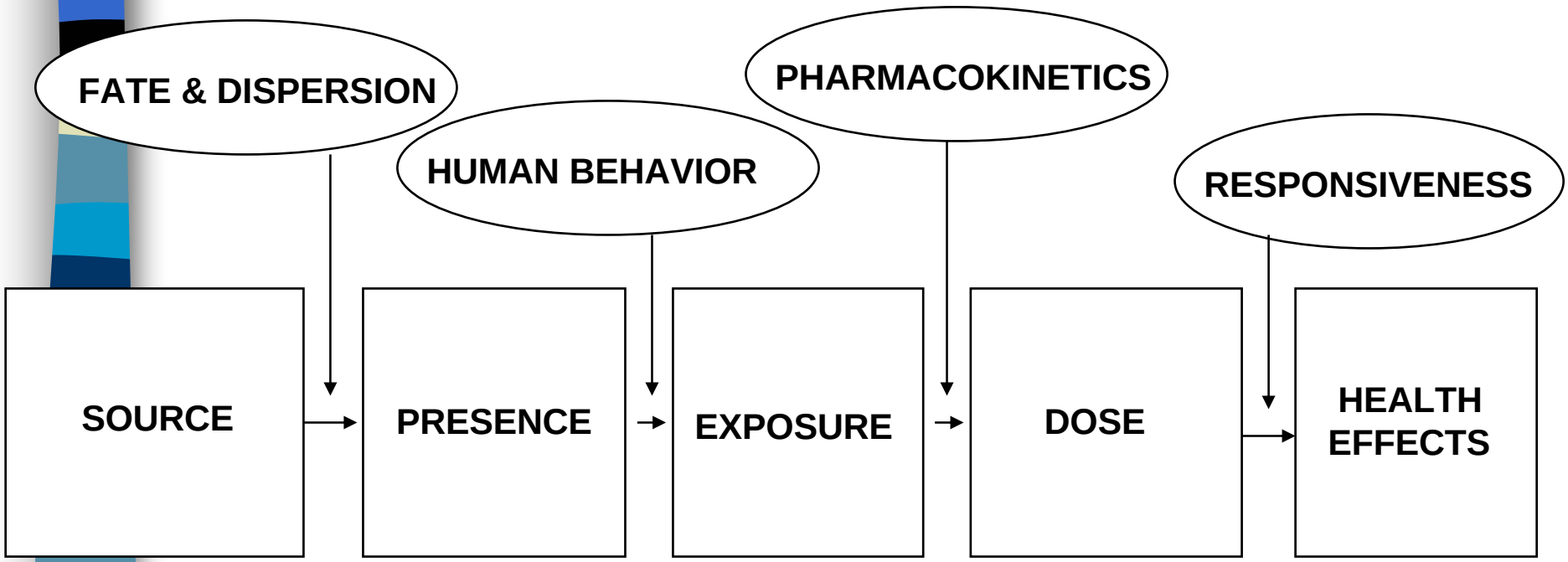
Core Functions of Public Health

Protection of public health is an iterative process – re-evaluating and striving to improve.

Preventing Illness

- PRIMARY PREVENTION - Eliminate or decrease exposure to the factor of concern before the onset of disease
- SECONDARY PREVENTION - Detect the presence of asymptomatic adverse effects
- TERTIARY PREVENTION - Manage symptomatic disease to reduce the occurrence of medical complications

Opportunities for Prevention



PRIMARY

SECONDARY

TERTIARY