Lead poisoning and impact on school readiness

How to overcome the toxic effects

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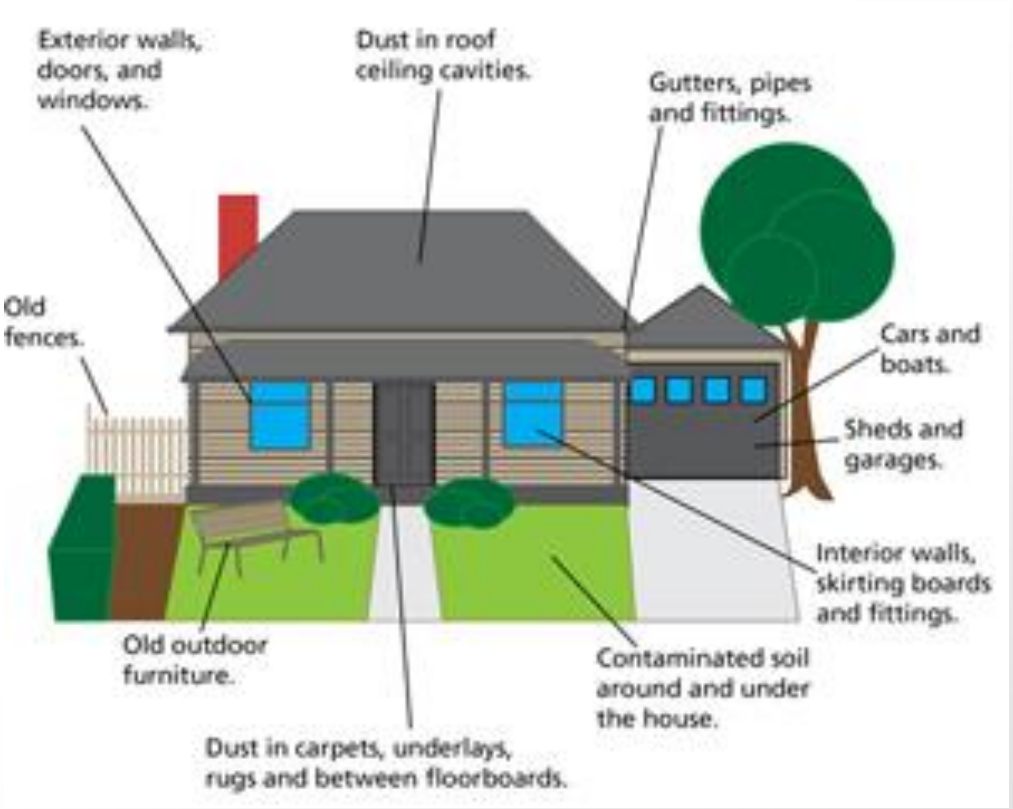
Objectives

At the end of the session, participants will be able to:

- describe multiple sources that may result in elevated lead levels in children
- understand the adverse health effects that can occur from lead exposure
- provide opportunities to children with lead exposures to optimize school readiness and ability to learn

How Do Children Get Lead Poisoned Today?

- Old paint
- Lead on the ground
  - From paint
  - From past use of leaded gasoline
  - Industrial sources – smelters
  - Solder



Other Sources

- As lead paint becomes less common, “Other” becomes proportionately more important

Other Potential Sources Of Lead In The Environment

- Lead glazed pottery
- Jewelry and cosmetics
- Toys
- Lead water pipes
- Spices
- Firing ranges
- Casting ammunition, fishing weights or sinkers
- Renovating (e.g., ceramic tile, torching walls)

TABLE 2. Deficiencies contributing to elevated blood lead levels identified during the investigation of an indoor firing range — CDC's National Institute for Occupational Safety and Health, California, 2013

Deficiency type	Problem observed
Engineering control deficiencies	
Range ventilation system	Airflow at the firing line contained regions of backflow, causing lead to be carried back into the shooter's breathing zone instead of downrange.
	The range air supply diffusers produced turbulent jets of air, creating uneven air distribution at the firing line.
	The downrange airflow was not evenly distributed and did not have the minimum recommended airflow of 30 ft/min (15 cm/sec).
	The range filters did not have a minimum efficiency reporting value of 18 or 19, so contaminated air was released outside.
	The range filters did not have side and face gaskets to prevent air from bypassing the filter; this allowed lead-contaminated air to be distributed to other areas served by the ventilation system.
Building ventilation system	Openings in the wall between the firing range and the rest of the building allowed lead to be circulated throughout the building.
Housekeeping deficiencies	
Range housekeeping	Carpet and porous materials were present inside the shooting range.
	Uniforms worn by employees who cleaned the range were reused, laundered infrequently, and stored in an open storage room.
Building housekeeping	Lead was detected on carpets, desks, tables, counters, eating surfaces, and ventilation supply and return air ducts outside the range. It was also detected inside the clean clothing bins and on towels that had been laundered by a commercial launderer.
	Lead was detected on employees' shoes as they prepared to leave work.
	No showering facilities were available for employees.
	Employees' hands and street clothes were contaminated with lead.
Medical surveillance deficiencies	
Employees	No employees had undergone the required medical surveillance.
	The physician who evaluated employees to determine their fitness to wear a respirator did not complete the required forms properly.

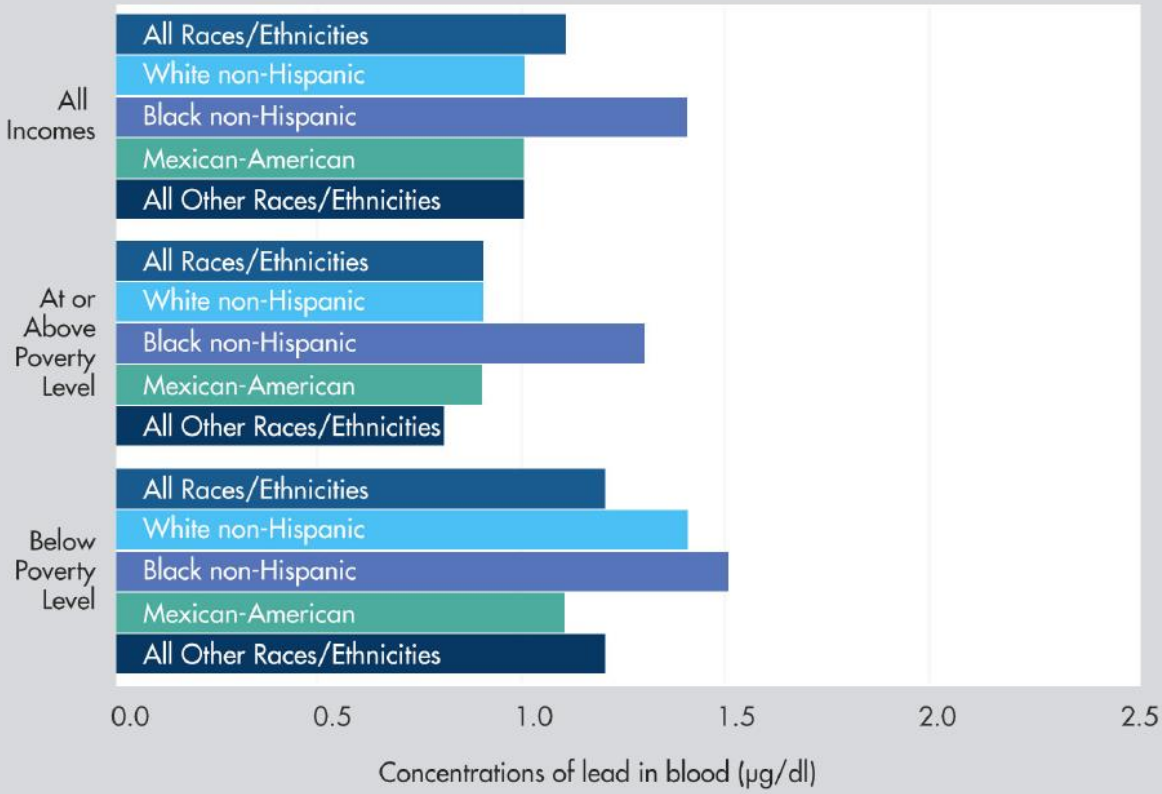
MMWR, April 25, 2014, Volume 63, No. 16

Who is at greatest risk?

- Children < 3 years
- Immigrant, refugees and internationally adopted
- Children who live or attend daycare in a home built before 1960 (includes foster homes)
- Pregnant women

http://www.weekendcollective.com/

Lead in U.S. children ages 1 to 5 years: Median concentrations in blood, by race/ethnicity and family income, 2009-2012



Data: Centers for Disease Control and Prevention, National Center for Health Statistics and National Center for Environmental Health, National Health and Nutrition Examination Survey

EPA. America's Children and the Environment, Third Edition, Updated February 2016
https://www.epa.gov/ace/biomonitoring-lead

Key Federal Programs to Reduce Childhood Lead Exposures and Eliminate Health Impacts. National Center for Environmental Health. Nov 2016

Blood Lead Level	Sufficient Evidence or Causal Determination of Children's Health Effects
Below 5 µg/dL	Nervous System Effects: - Cognitive function: Decreases in IQ, academic achievement, specific cognitive measures - Externalizing behaviors: Increased incidence of attention-related and problem behaviors
Below 10 µg/dL	Effects listed above PLUS Nervous System Effects: - Auditory function: decreased hearing Reproductive and Developmental Effects: - Reduced postnatal growth - Delayed puberty for girls and boys
10-40 µg/dL	Effects listed above PLUS Nervous System Effects: - Nerve function: slower nerve conduction Blood Effects: - Decreased hemoglobin, anemia
40-80 µg/dL	Effects listed above PLUS Gastrointestinal Effects: - Abdominal pain, constipation, colic, anorexia and vomiting
Above 80 µg/dL	Effects listed above PLUS Nervous System Effects: - Severe neural effects: convulsions, coma, loss of voluntary muscle control and death

Neurodevelopment

The Impact of Elevated Blood Lead Levels

Prevention is key

- Children cannot avoid negative impacts on neurodevelopment
- Many children continue to be exposed through unsafe housing and under-identification of unsafe environments and children with past exposures

Table 1. Studies on Lead and Educational Outcomes

Blood Lead Levels	Educational Impact	Size of Study	Location of Study
≤ 3 µg/dL	Decreased end of grade test scores	More than 57,000 children	North Carolina (Miranda et al. 2009)[1]
4 µg/dL at 3 years of age	Increased likelihood learning disabled classification in elementary school	More than 57,000 children	North Carolina (Miranda et al. 2009)[1]
	Poorer performance on tests	35,000 children	Connecticut (Miranda et al. 2011)
5 µg/dL	30% more likely to fail third grade reading and math tests	More than 48,000 children	Chicago (Evens et al. unpublished data)
	More likely to be non-proficient in math, science, and reading	21,000 children	Detroit (Zhang et al. 2013)
5-9 µg/dL	Scored 4.5 points lower on reading readiness tests	3,406 children	Rhode Island (McLaine et al. 2013)
≥10 µg/dL	Scored 10.1 points lower on reading readiness tests	3,406 children	Rhode Island (McLaine et al. 2013)
10 and 19 µg/dL	Significantly lower academic performance test scores in 4th grade	More than 3,000 children	Milwaukee (Amato et al. 2012)
≥ 25 µg/dL	$0.5 million in excess annual special education and juvenile justice costs	279 children	Mahoning County, Ohio (Stefanak et al. 2005)

CDC. 2015. Educational Interventions for Children Affected by Lead

Threshold of effects

- Epidemiologic studies suggest that there is no discernible threshold for lead effects on IQ
- Deficits are measurable at least down to 5 mcg/dL
- Some evidence to suggest that impact may be greater at lower levels

Mechanisms of Neurotoxicity

- Impact on sites and processes in the brain involved in impulse control (e.g., frontal and prefrontal lobes, dopaminergic systems)
- Cortical gray matter loss in prefrontal cortex with higher lead levels
- Altered myelination and axonal integrity with early exposures
- Pattern of “general dampening” of intellectual functioning that can be ascribed to a number of environmental causes.

Irreversible?

- Effects of early exposure to lead on IQ and other measures of cognitive attainment and behavior are not reversible through pharmacologic or nutritional interventions
- Deficits related to early exposure are not reversible in the absence of educational interventions or other deficit related services

Institute of Medicine (2000)

- Compelling evidence that children benefit from childrearing in an environment that has varied and age-appropriate educational opportunities and early intervention services.
- “The course of development can be altered in the early childhood by effective interventions that change the balance between risk and protection, thereby shifting the odds in favor of more adaptive outcomes”

Who is at risk?

- Lead is “an equal opportunity neurotoxicant”
  - Differs as a function of the child’s economic and social environment
  - Some children may be at greater risk for poor academic performance compared to other children with similar blood lead levels

Kindergarten readiness

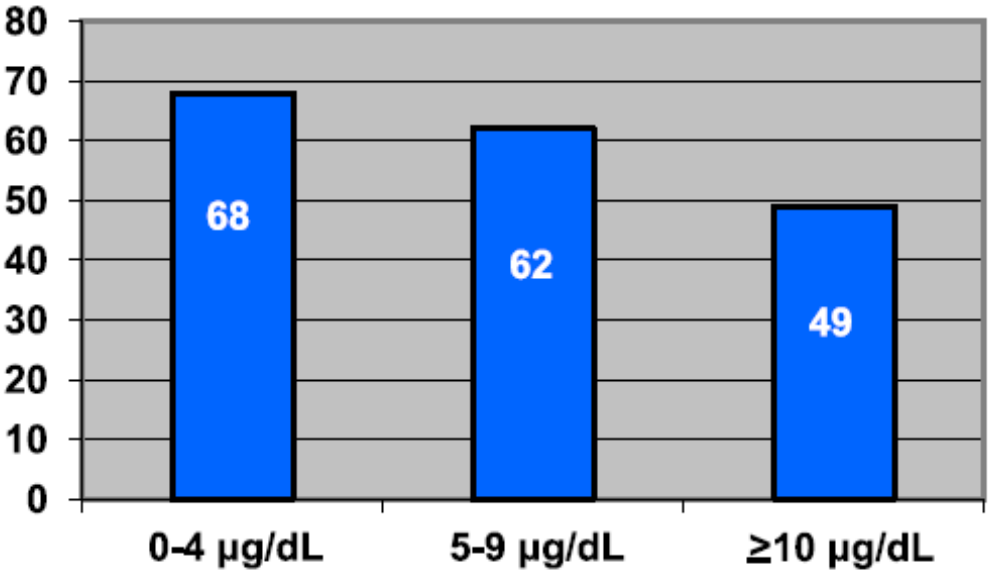


FIGURE 2
Proportion of children scoring above the fall PALS-K benchmark, by BLL.

McLaine et al. Pediatrics 2013

School Readiness

- Association between moderate lead poisoning with elementary school end-of-grade exams
  - 1133 families responded to survey
  - 43% had blood lead levels between 10 and 20 mcg/dL
  - Lead exposure was associated with significantly lower scores in all sections of end-of-grade exams
  - Children who were black, had a parent with less than a high school education, and were classified as having “less than excellent health” had significantly lower performance on all components

Magzamen et al. Annals of Epidemiology 2013

TABLE 3—Odds Ratios of Scoring "Less Than Proficient" on Michigan Educational Assessment Program (MEAP) Tests: Detroit Public Schools, MI, 2008–2010

Variable	Mathematics, OR (95% CI)	Science, OR (95% CI)	Reading, OR (95% CI)
Blood lead level, μg/dL (Ref = ≤ 1)			
1–5	1.42* (1.24, 1.63)	1.33* (1.10, 1.62)	1.45* (1.27, 1.67)
6–10	2.00* (1.74, 2.30)	2.22* (1.82, 2.72)	2.21* (1.92, 2.55)
> 10	2.40* (2.07, 2.77)	2.26* (1.84, 2.78)	2.69* (2.31, 3.12)
Grade level (Ref = 5)			
3	0.36* (0.34, 0.38)	. . .	0.56* (0.53, 0.60)
8	1.62* (1.52, 1.74)	1.71* (1.59, 1.83)	0.99 (0.92, 1.06)
Gender: male (Ref = female)	1.11* (1.06, 1.17)	1.22* (1.14, 1.30)	1.38* (1.31, 1.46)
Race: Black (Ref = non-Black)	1.99 (0.98, 1.21)	1.11 (0.96, 1.28)	0.76* (0.68, 0.84)
Language: other (Ref = English)	1.16* (1.07, 1.26)	1.34* (1.22, 1.52)	1.29* (1.19, 1.40)
School lunch: free (Ref = paid)	1.56* (1.46, 1.66)	1.64* (1.51, 1.79)	1.45* (1.35, 1.54)
Maternal education: ≤ high school (Ref = > high school)	1.25* (1.18, 1.33)	1.32* (1.20, 1.41)	1.37* (1.28, 1.45)

Note. CI = confidence interval; OR = odds ratio. Science MEAP scores were restricted to grades 5 and 8.
*$P < .05$.

Zhang et al. Am J Public Health 2013

School readiness

Characteristic	*n* (%)	BLL (μg/dL) Mean ± SD	Reading Score ISAT Mean ± SD	Math Score ISAT Mean ± SD	Reading Failure (%)	Math Failure (%)
Overall	12,319 (100)	4.16 ± 2.03	157.4 ± 13.8	160.5 ± 13.3	9.6	7.5
Gender						
Male	6215 (50)	4.24 ± 2.04 **	156.4 ± 14.1 **	161.1 ± 13.8 **	11.6 **	8.0 *
Female	6102 (50)	4.08 ± 2.01	158.4 ± 13.5	159.9 ± 12.8	7.6	6.9
Hispanic Subgroup [a]						
Mexican-American	8449 (69)	4.24 ± 2.03	157.6 ± 13.7	160.9 ± 13.3	9.2	6.9
Puerto Rican	2564 (21)	4.08 ± 2.02 **	156.0 ± 14.0 **	158.5 ± 13.2 **	11.9 **	9.7 **
Other Hispanic	1256 (10)	3.77 ± 2.00 **	159.3 ± 14.0 **	162.1 ± 13.5 **	7.6	6.9
Foreign Born Mother						
Yes	7103 (58)	4.17 ± 2.03	157.9 ± 13.7 **	161.6 ± 13.2 **	8.3 **	5.9 **
No	5216 (42)	4.14 ± 2.03	156.7 ± 14.0	159.0 ± 13.4	11.5	9.7
Mother's Education [b]						
Some high school	6609 (54)	4.31 ± 2.06 **	155.9 ± 13.6 **	159.2 ± 13.1 **	11.2 **	8.5 **
High School Graduate	3538 (29)	4.10 ± 2.04	158.0 ± 13.5	161.1 ± 13.1	8.3	6.6
Some College	1671 (14)	3.85 ± 1.90	160.6 ± 13.8	162.8 ± 13.4	7.2	6.0
College Graduate	375 (3)	3.78 ± 1.78	162.3 ± 15.5	165.6 ± 15.1	6.9	6.2
Post College	126 (1)	3.60 ± 1.67	166.7 ± 15.3	169.0 ± 15.4	2.4	2.4
Low-Income						
Yes	10,974 (89)	4.19 ± 2.04 **	156.8 ± 13.6 **	159.9 ± 13.0 **	10.0 **	7.8 **
No	1345 (11)	3.90 ± 1.95	162.4 ± 14.9	165.6 ± 14.6	6.5	4.9
SGA						
Yes	1368 (11)	4.19 ± 2.11	155.5 ± 14.0 **	158.4 ± 13.5	13.1 **	10.8 **
No	10,799 (89)	4.15 ± 2.02	157.7 ± 13.8	160.8 ± 13.3	9.2	7.0
Preterm Birth [a]						
Term	11,169 (92)	4.17 2.03	157.6 ± 13.8	160.7 ± 13.3	9.3	7.2
Late PTB	765 (6)	4.14 ± 2.07	156.2 ± 14.5 **	159.3 ± 13.1 **	12.8 **	8.4
Early PTB	234 (2)	3.82 ± 1.91 *	154.4 ± 14.3 **	156.2 ± 13.6 **	15.5 **	15.8 **

Blackowicz et al. Int J Env Res Public Health 2016

Socioeconomic Circumstances (SEC)

- Higher BLLs associated with greater magnitude and/or persistence among children from lower SEC.
- Lower SEC associated with exposures to other neurotoxicants, poorer nutrition, inequities in medical coverage, increased stress, and fewer opportunities for stimulation.

Inter-Child Variability

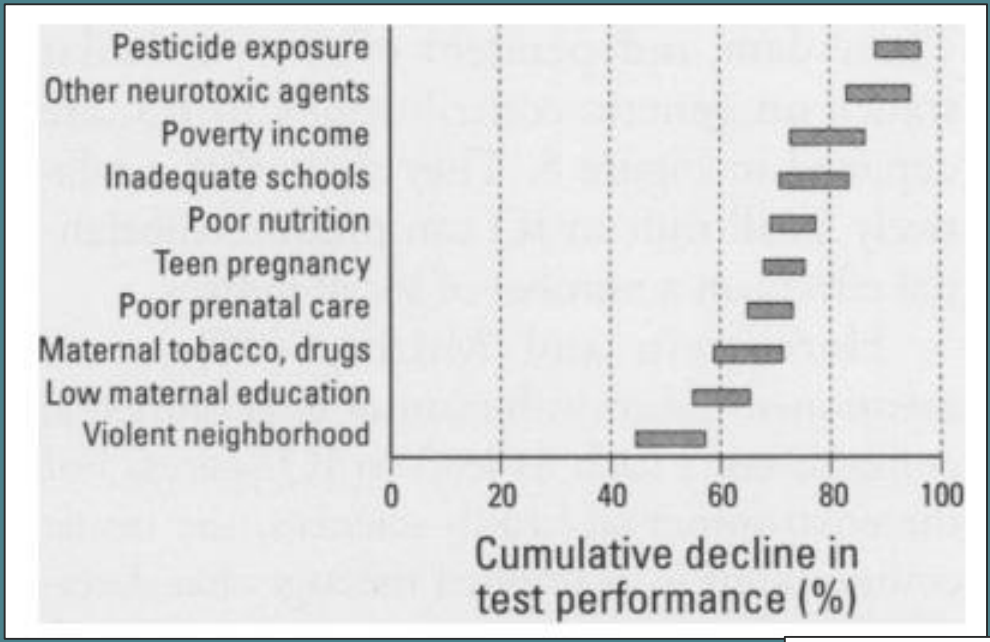
- Magnitude of effects may vary depending on the characteristics of a particular child and his/her environment.
- Effects might be reduced by modifying critical aspects of the environment
- Quality of early rearing environment may play role in magnitude and persistence of deficits.

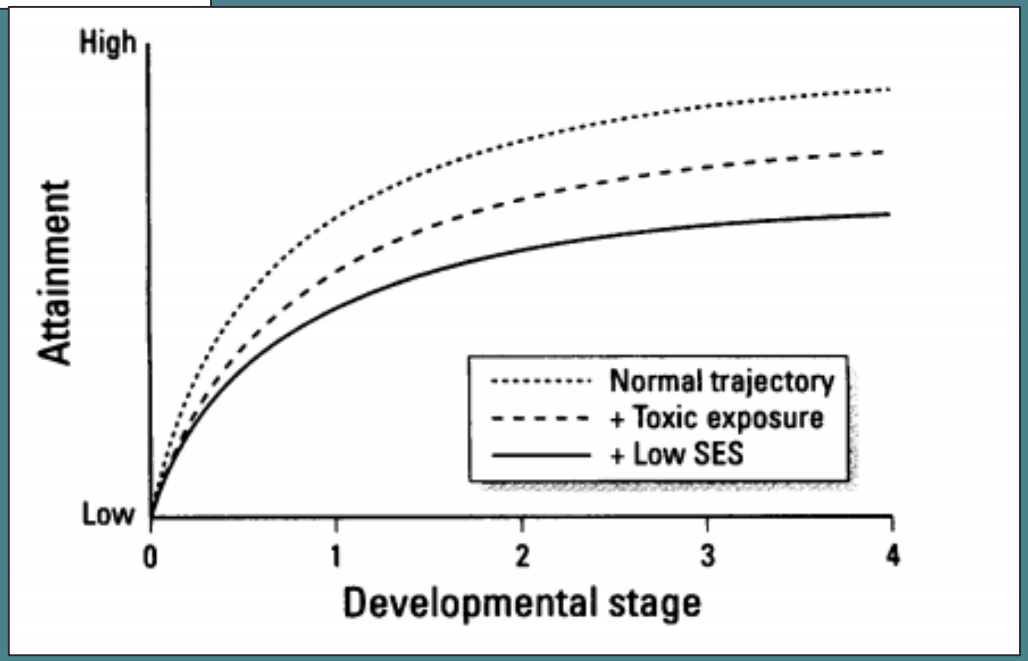
Effectiveness of Early Childhood Education

- A nurturing, supportive home environment can positively influence developmental and behavioral outcomes.
- No studies on impact of early childhood education interventions on neuro outcomes of lead, but…
- Research demonstrates that children with developmental delays benefit from interventions at an early age.

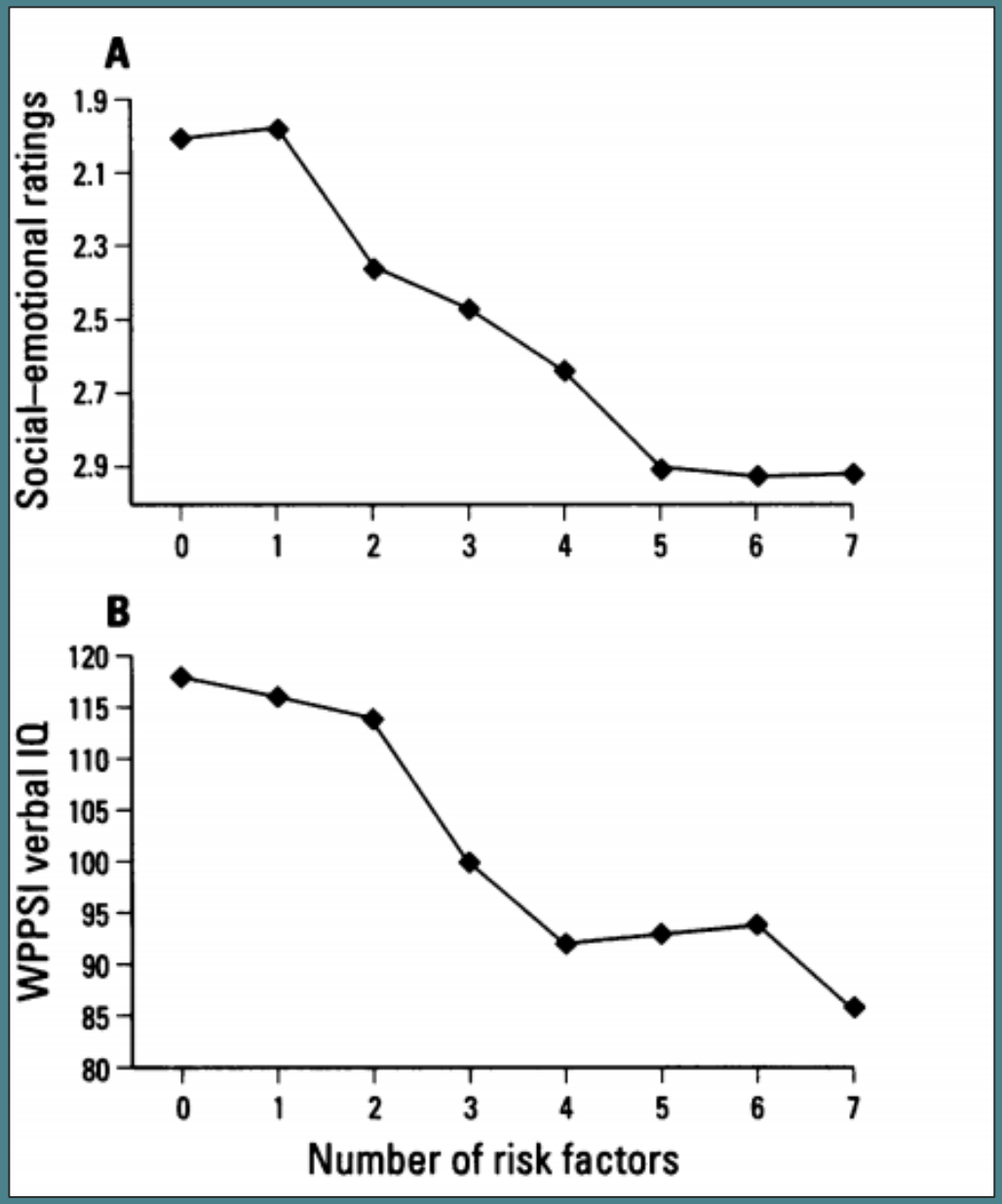
Controversy over Lead-IQ link

- Large number of confounders that must be considered when measuring an effect on children's intelligence
- Frequent finding that the more covariates included in regression models, the smaller effect of blood lead on IQ
- Most important confounders are socioeconomic status, parental IQ, and quality of home environment





Weiss B. 2000 EHP



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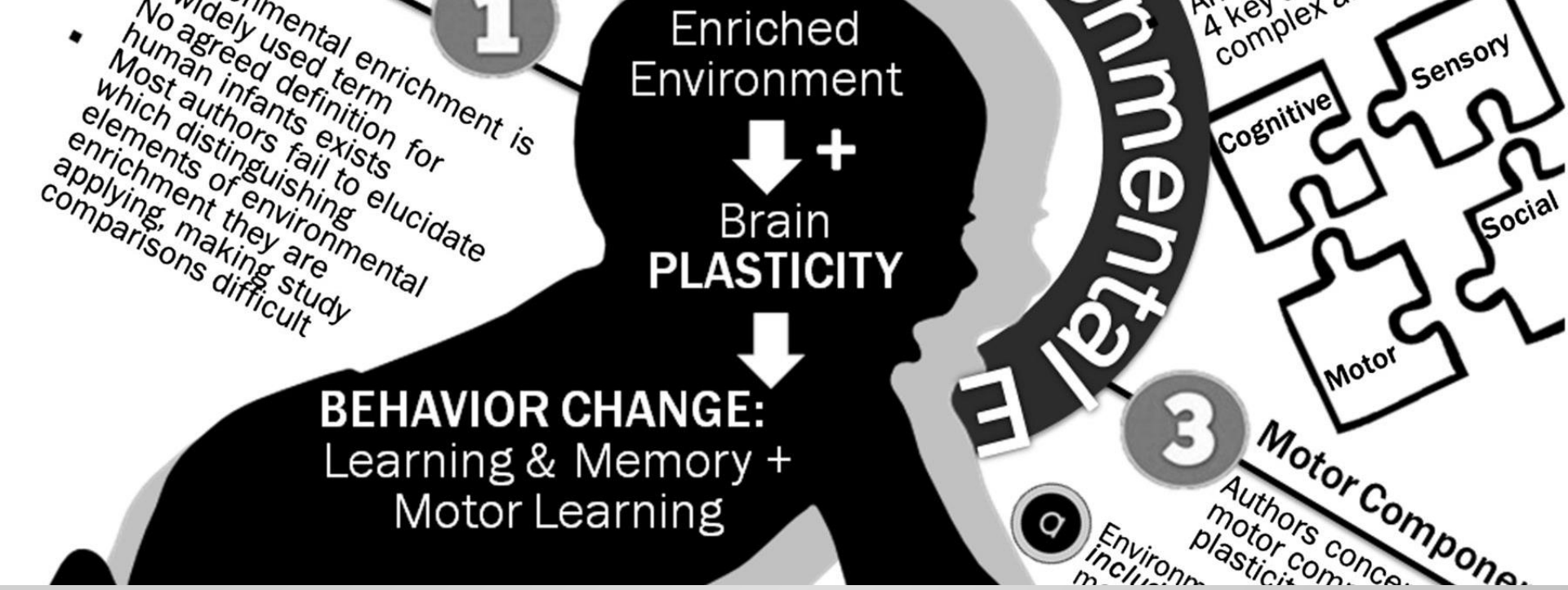


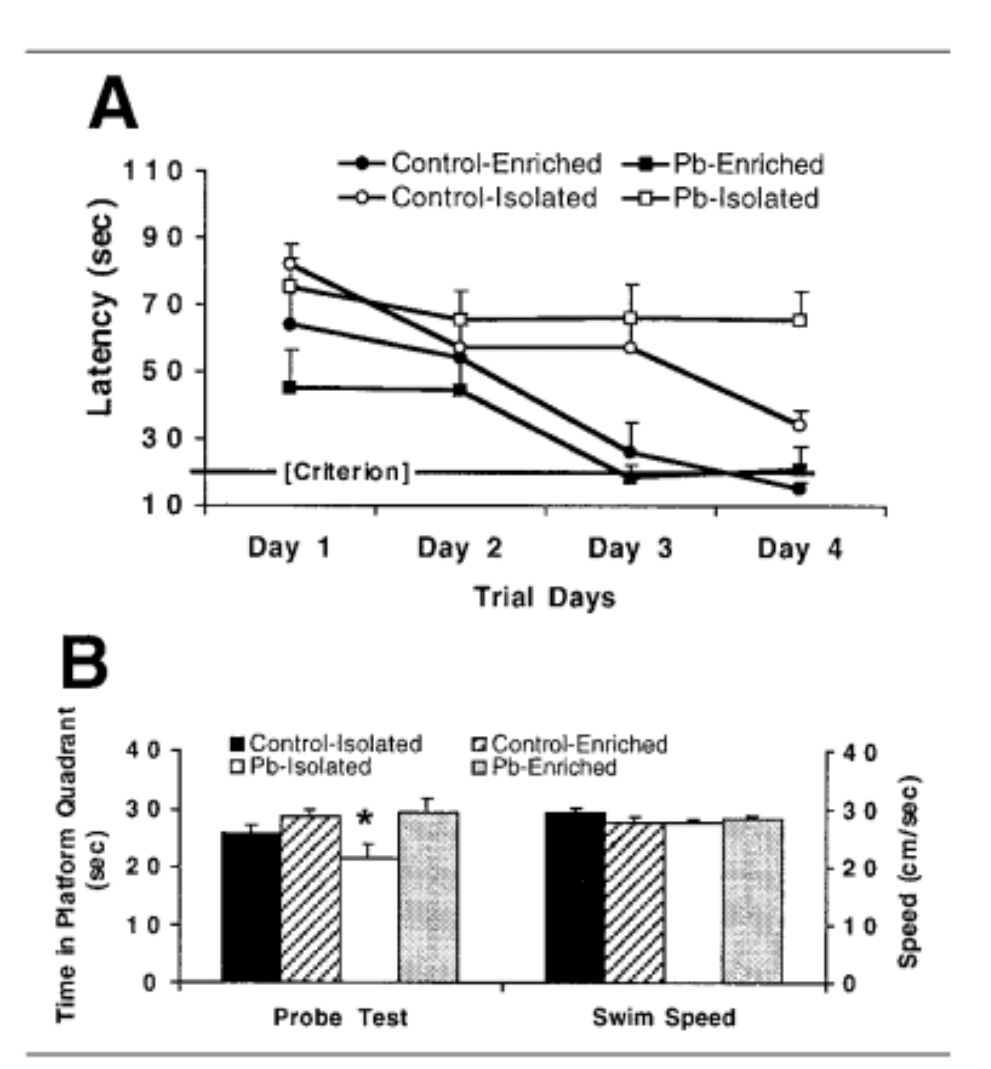
Enrichment Environments

How can we help children with elevated lead levels?

Table 1 | **Effects of enriched environment**

Condition	Behaviour	Neuroanatomy	Cellular/molecular	References
Brain injury or trauma	Improves memory and motor skills	Increases brain weight and dendritic branching	No data available	34,94–96, 120,121
Stroke/ischaemia	Improves motor skills		Increases NGF A and glucocorticoid receptor mRNA levels; decreases BDNF mRNA levels	97,100, 122,123
Epilepsy	Prevents seizures	Inhibits apoptosis	Enhances growth factor gene expression	72
Ageing	Improves memory	Increases neurogenesis; decreases gliogenesis and prevents decrease in synaptic density	Increases RNA content; increases NGF	14,36,69, 124–126
Stress	No effect			127
Huntington's disease mouse model	Enhances exploration and motor skills, and prevents seizures	Increases peristriatal cerebral volume	Delays disease onset	101
CA1 *NMDAR1* knockout mice	Improves memory	Increases hippocampal synaptic and spine density	No data available	52
Prenatal alcohol	Improves memory		Improves cortical synaptic plasticity	35,128
Learning-impaired 129/SvJ mice	Improves memory	Enhances cell proliferation and neurogenesis	No data available	43

van Praag et al. Nature Reviews Neuroscience 2000



Guilarte et al. Ann Neurol 2003; 53: 50-56

Enriched environments

- Cognition and behavioral scores in 1st graders with history of lead exposure
- Maternal support for a child's school work and extracurricular activities has a greater influence on improved neurocognitive and behavioral outcomes than their own level of education.
- More research is needed on what enrichment interventions should look like.

Moodie et al. Neurotoxicology 2013

Head Start

- Focuses on children's health, nutrition, mental health, and social service needs.
- Children must be low-income, recipients of public assistance, foster children, or homeless, or they must have a diagnosed disability
- Children may begin the preschool experience at a disadvantage as compared with their counterparts in other early childhood education programs
- Children experienced significant gains in cognitive development

Early childhood education: effectiveness in children with disabilities

- Resulted in higher IQ scores, improved visual-spatial skills, and increased language development three to four years after the intervention as compared to children who received a parent training intervention alone
- Increased ability to be in mainstream classrooms at kindergarten entry
- Studies have shown gains are in similar areas that are affected by lead exposures

HOW DO WE GET CHILDREN TO THE PROGRAMS?

Federal programs and policies

- Individuals with Disabilities Education Act (IDEA) (20 U.S.C. § 1400 et seq.) Federal Special Education Law, including
  - Child Find: Gateway to Services.
  - Part C: Early Intervention Services for Children Under Age 3.
  - Part B: Special Education for Children 3-21 Years Old, including Section 619 Preschool Programs and Coordinated Early Intervening Services.
- Rehabilitation Act of 1973, Section 504: Federal Civil Rights Protections.
- Americans with Disabilities Act Amendments Act of 2008.
- Medicaid: Early and Periodic Screening, Diagnosis and Treatment (EPSDT) Program.
- Title V: Maternal and Child Health Block Grant.

Provision	Population	Services	Key Element	Activities
IDEA: Child Find	Children from birth–21 years of age, including those enrolled in all public and private schools.	Policies and procedures to identify, locate, and evaluate children suspected of having a disability.	Coordination with referral sources such as physicians and agencies.	Public awareness, referral, screening, eligibility determination, tracking, and interagency coordination.
IDEA: Part B	Children 3–21 years of age.	Provides for special education and related services.	Individualized education program (IEP) specifying services and supports the child will receive.	Education in the least restrictive environment appropriate. Early intervening services provide additional support to struggling students in general classroom.
IDEA: Part B, Section 619	Children 3–5 years of age (Section 619 preschool program).	Provides grants for preschool services.	Children with disabilities receiving services in inclusive settings.	Transition activities between IDEA Part C and Part B.

CDC. 2015. Educational Interventions for Children Affected by Lead

IDEA: Part C	Children birth through third birthday. State option—extended Part C service from third birthday through kindergarten.	Provides early intervention services for infants and toddlers with developmental delays or diagnosed conditions with high probabilities of resulting in developmental delays.	Uses an individualized family service plan (IFSP) specifying services for a child and his/her family.	Provides services and education to children in their natural environment.
IDEA: Part B, CEIS	Students from kindergarten through grade 12 (with a focus on kindergarten through grade 3).	Provides scientifically based academic and behavioral interventions.		Professional development for teachers and other school staff in scientifically based academic and behavioral interventions, including literacy instruction and, where appropriate, instruction on the use of adaptive and instructional software. Providing educational and behavioral evaluations, services, and supports, including scientifically based literacy instruction.

CDC. 2015. Educational Interventions for Children Affected by Lead

Child Find

- Ensures that no children with disabilities are denied a free appropriate public education because they have not been located.
- Ensure cooperation between educational agencies and others such as health, mental health, and developmental disabilities agencies; social services; corrections departments; private schools; and private agencies.
- Enables the states and local education agencies to appropriate funds, plan and deliver programs, and be held accountable to all children with disabilities.

Part C: zero to 3 years

- Provides funding for services to infants and toddlers with disabilities
- Children must meet state's eligibility definition of developmental delay OR have diagnosed physical or mental condition that carries the high probability of causing developmental delays
- Established conditions include disorders secondary to exposure to toxic substances (e.g., fetal alcohol syndrome)

Eligibility for Part C

General Mention of Lead	Mention of Specific Elevated Blood Lead Level	General Mention of Exposure to Toxic Substances	No Reference to Lead Exposure
Delaware: Lead poisoning with elevated blood levels requiring chelation.	Connecticut: ≥ 45 µg/dL	Arizona	Alabama
Idaho: Illness of a chronic nature with prolonged convalescence (e.g., lead poisoning…).	Georgia: ≥ 20 µg/dL	Arkansas	Alaska
Louisiana: Elevated blood lead level requiring chelation	Iowa: ≥20 µg/dL	Hawaii	California
Nebraska: Lead poisoning	Kansas: ≥ 45 µg/dL	Indiana	Colorado
New Hampshire: Lead poisoning	Michigan: ≥ 10 µg/dL	Maryland	Florida
New Mexico: Central nervous system toxins, e.g., lead poisoning	Minnesota: ≥ 15 µg/dL	Missouri	Illinois
Wisconsin: Central nervous system toxins, e.g., lead poisoning	Ohio: ≥ 10 µg/dL	Montana	Kentucky
	Oregon: ≥ 10 µg/dL	New Jersey	Maine
	Rhode Island: ≥ 15 µg/dL	New York	Massachusetts
	Tennessee: ≥ 10 µg/dL	North Dakota	Mississippi
	Vermont: ≥ 20 µg/dL	Oklahoma	Nevada
	West Virginia: ≥ 15 µg/dL	Virginia	North Carolina
		Wyoming	Pennsylvania
			South Carolina
			South Dakota
			Texas
			Utah
			Washington

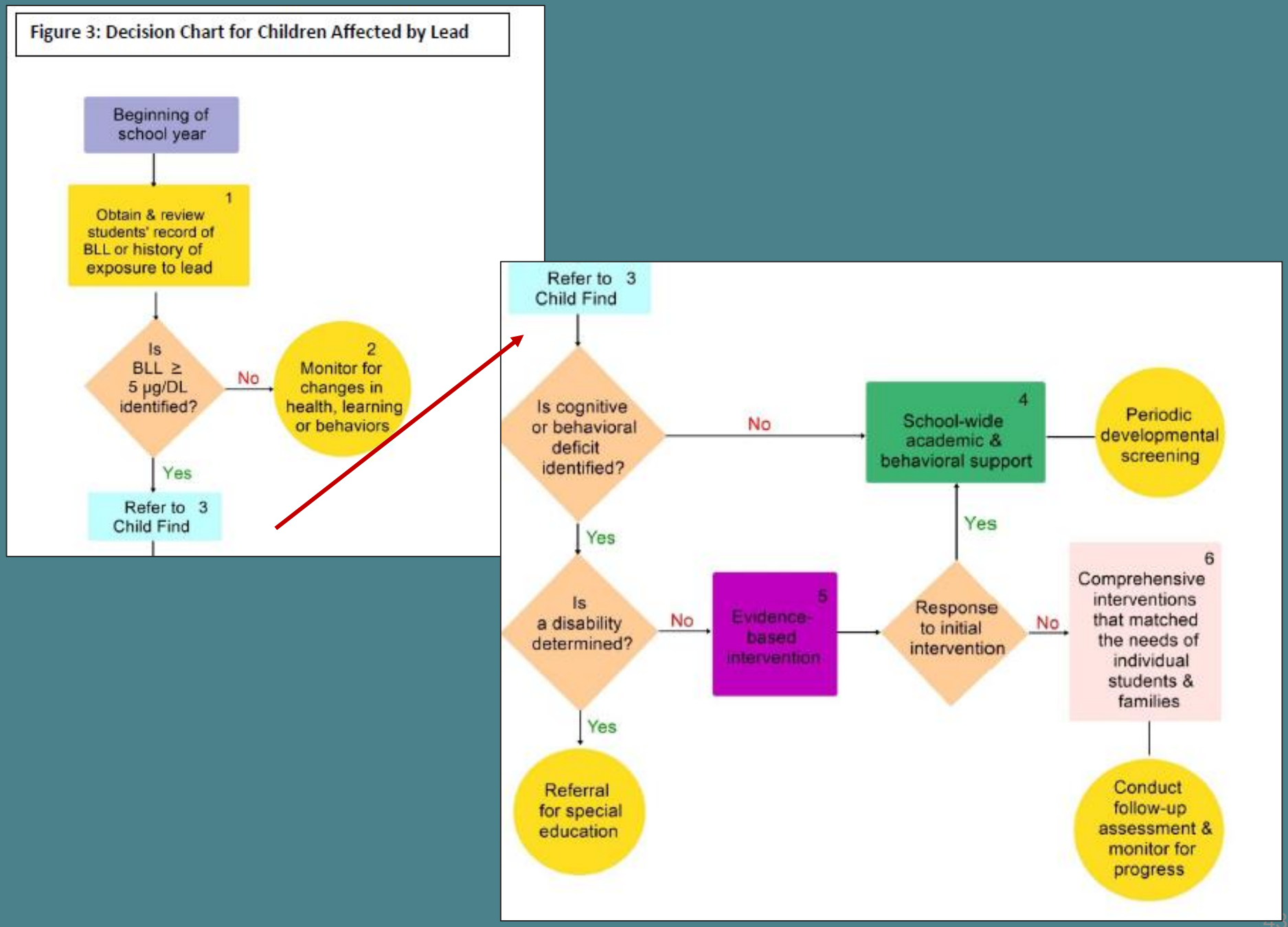
CDC. 2015. Educational Interventions for Children Affected by Lead

Linking education community to lead exposed children EARLY

- Children who have been exposed to lead may not be identified in school records or appropriately tracked.
- Educators need information from lead poisoning prevention programs and providers to ensure that they understand and fulfill their unique roles

Education for at-risk children

- Children with lead exposures at risk for academic failure but with different levels of delay
- Connecting children to early education is key to reducing long-term effects.
- Early identification of children who can be helped at key transitions (1st, 4th, and 6th grades)
- Early behavioral interventions as children develop self-regulation and interpersonal skills.



CDC. 2015. Educational Interventions for Children Affected by Lead

Who must be at the table when a child is found to have an EBL?

- Health Department
- Department of Education/School District
- Health care provider
- Child care provider
- Parent

Summary

- Lead is known to cause adverse health effects in children at levels as low as 5 mcg/dL
- Neurodevelopmental delays can occur but may not be seen until later in childhood
- Enriched environments and early education have been shown to improve outcomes in children with developmental disabilities
- Multidisciplinary approach at time of diagnosis may be key in improving outcomes for children

Questions?