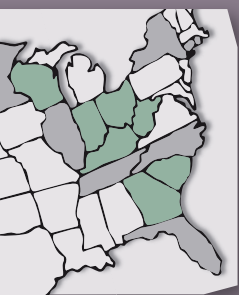


A Story of Health

Childhood Cancer: Stephen's Story



ACKNOWLEDGEMENTS

Primary Development Organizations

The Center for Integrative Research on Childhood Leukemia and the Environment (CIRCLE) at the University of California, Berkeley, Commonweal, the Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (OEHHA), the Science and Environmental Health Network (SEHN), and the Western States Pediatric Environmental Health Specialty Unit (WSPEHSU) teamed up to leverage our combined resources to develop and produce *A Story of Health*.

Primary Development Team

Mark Miller MD MPH, Director Emeritus, [Western States Pediatric Environmental Health Specialty Unit at UCSF](#)

Director (retired), [Children’s Environmental Health Center, Office of Environmental Health Hazard Assessment, California EPA](#)

Associate Clinical Professor, [Division of Occupational, Environmental and Climate Medicine](#) at University of California; San Francisco.

Ted Schettler MD MPH, Science Director, [Science and Environmental Health Network](#)

Maria Valenti, Director, Health and Environment Literacy Project, [Commonweal](#)

Copyright: Portions of this document may be subject to the copyright act. Graphics and illustrations by Stephen Burdick Design may not be reproduced without permission. Do not reproduce and or modify any content or illustration. Any permitted reproduction of content or illustrations must be properly acknowledged.



Update Authors

Catherine Metayer MD PhD, Adjunct Professor of Epidemiology/Biostatistics, Director of the [Center for Integrative Research on Childhood Leukemia and the Environment](#) at University of California; Berkeley.

Mark Miller MD MPH, Director Emeritus, [Western States Pediatric Environmental Health Specialty Unit at UCSF](#)

Director (retired), [Children’s Environmental Health Center, Office of Environmental Health Hazard Assessment](#), California EPA

Associate Clinical Professor, [Division of Occupational, Environmental and Climate Medicine](#) at University of California; San Francisco.

Joseph Leo Wiemels, PhD, Professor, [Center for Genetic Epidemiology, Norris Comprehensive Cancer Center, Keck School of Medicine](#) at University of Southern California

For more information contact: pehsu@ucsf.edu

Suggested citation: A Story of Health. [Childhood Cancer: Stephen’s Story. Commonweal, Science and Environmental Health Network, Western States PESHU. PDF file online.](#)

ART TEAM

Illustrations, eBook design, production
Stephen Burdick Design

Illustrations
Dan Higgins, Artist



SUPPORTERS

In addition to significant in-kind contributions from all of the primary development organizations, we are grateful to the following supporters who have made this project possible:

Center for Integrative Research on Childhood Leukemia and the Environment

The John Merck Fund

The Jacob & Valeria Langeloth Foundation

The Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (OEHHA)

Western States PEHSU

REVIEWERS

We gratefully acknowledge the following people who reviewed draft sections of a Story of Health, noting that their review does not constitute an endorsement of the findings or conclusions.

Any errors or misrepresentations that remain are entirely the responsibility of the authors.

Original Leukemia: Stephen’s Story:

Myles Abbott

Gary Dahl

Maida Galvez

Catherine Metayer

Elizabeth Raetz

Joshua Schiffman

Christopher Vlasses

Joe Wiemels

OTHER CONTRIBUTORS

Videos: Speakers:

Gary Dahl

Mark Miller

Catherine Metayer

Joseph Wiemels

DISCLAIMERS:

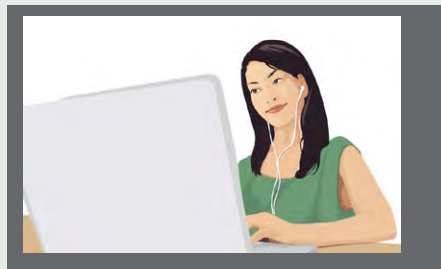
1.This document was supported by cooperative agreement FAIN: NU61TS000296 from the Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry (CDC/ATSDR). The U.S. Environmental Protection Agency (EPA) provided support through Inter-Agency Agreement DW-75-95877701 with CDC/ATSDR. The American Academy of Pediatrics supports the Pediatric Environmental Health Specialty Units as the National Program Office. The findings and conclusions presented have not been formally disseminated by CDC/ ATSDR or EPA and should not be construed to represent any agency determination or policy. Use of trade names that may be mentioned is for identification only and does not imply endorsement by the CDC/ATSDR or EPA..

2. The findings and conclusions in this report are those of the author(s) and do not necessarily represent the official position of the organizations listed as supporters or primary development organizations.

3. The ATSDR, US EPA, NIEHS, and Cal EPA/ OEHHA do not endorse the purchase of any commercial products or services mentioned in this publication.

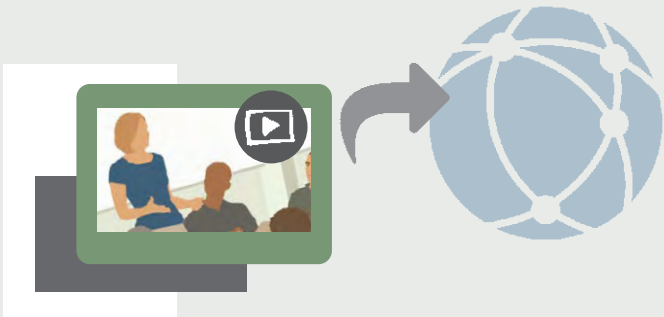
THE INDIVIDUAL STORIES OF HEALTH in this eBook are written to address many audiences. For example, some sections are more technical than others – you can skip sections if you wish.

(Note: underlined words or phrases link to online information that will open in a browser window, prompt downloads or navigate to a related page within the ebook.)



Each of the eBook stories is embedded with a wide range of resources. These help further explain possible environmental and/or genetic “risk factors” – (contributors to the development of a disease, or factors that might make a disease worse) – and how these factors interact.

We also provide links for additional resources, including actions you can take to prevent disease, and “tools you can use.”



Resources include videos, slides with audio commentary, tables, charts, and graphics. Some ‘pop-up’ in the story, and some connect online. Through these links, you can choose to dig deeper and learn more. Refer to icons at right for guidance.

References and Citations: Certain references are cited in the text where we believe they are most warranted. Full references by topic can be found at the end of each story.

Getting Started

Our eBook Navigation: Click on selections in the page headers to navigate back to this **Help Page**, find out about **Continuing Education** opportunities and access further information in **References**.

If you lose your place, use the **Go Back** selection in the navigation bar to return to your previous screen.

Adobe Acrobat Tools

This interactive pdf document is best viewed on a laptop or desktop, downloaded and opened in a current version of Adobe Acrobat Reader. Refer to the top Adobe menu bar for features including:

Magnify - If you want to enlarge a diagram or some text, click (+) button.



Move through pages - You can use the up and down arrows to move through pages.

You can also move through pages using the scroll up and down feature to the right of your screen.

Note: Navigation features may not work properly using other pdf reader platforms.

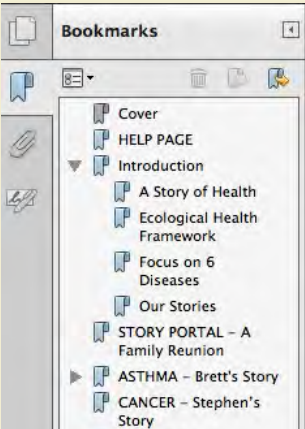


Table of Contents

Use the sidebar **Bookmark Tools** as a table of contents to skip to a section of interest, find your place, or return to this Help page.

Icons

Click on icons that may appear throughout the stories for pop-ups, videos, and links to more information as described.



key
concept



watch a
video



additional
resources,
tools



technical details
for health
professionals



definition

This is one of a series of collected stories about health.

It is a story of how our own health is intimately connected with the health of our families, friends and communities.

It is a story about how human health is interdependent with our surroundings.

The collected stories include a number of fictional people and highlight the many ways our health is influenced by the complex environments where we live, eat, work, play, volunteer, gather and socialize.

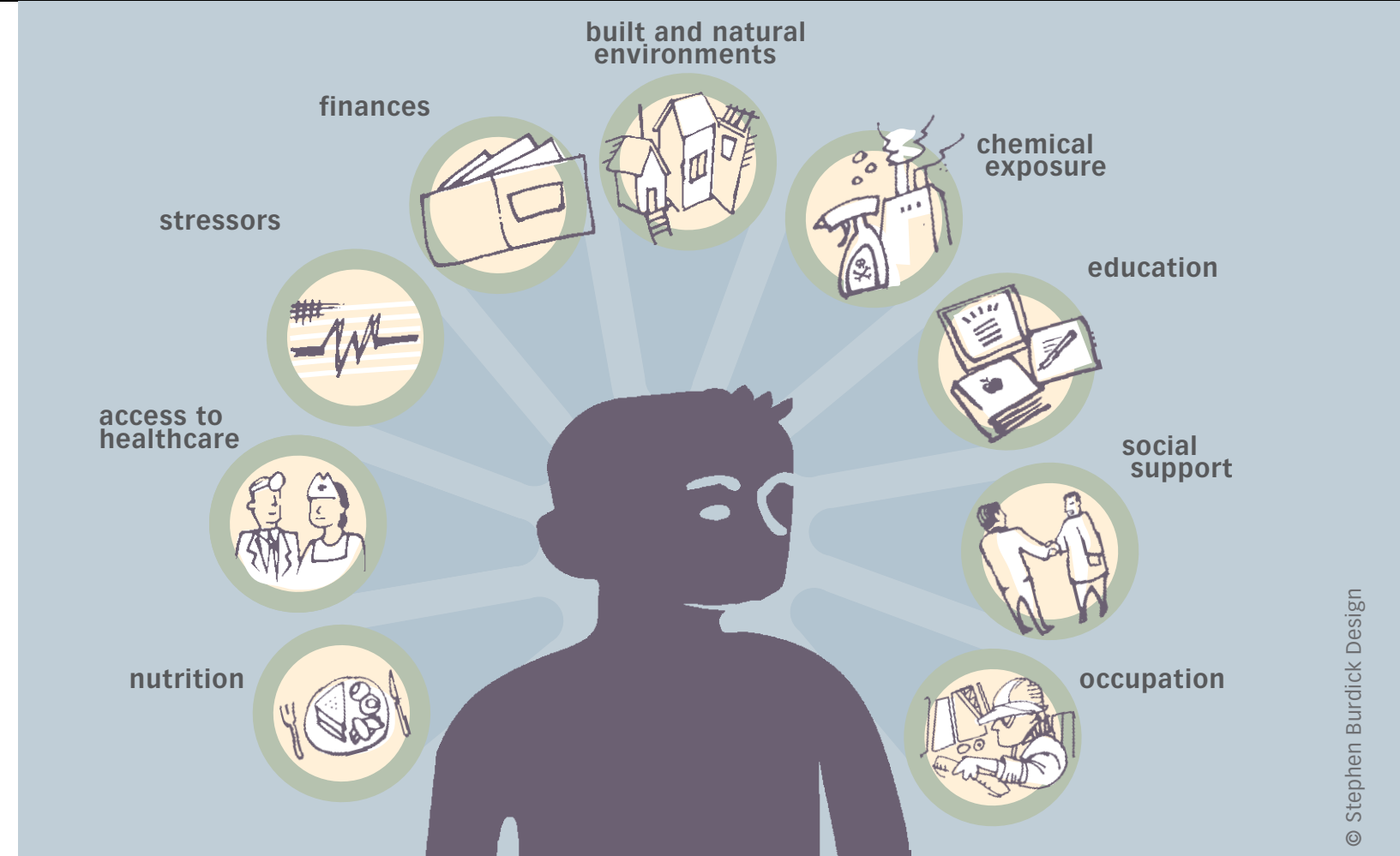


Our stories explore how many aspects of our lives, and what we are exposed to in our environments, influence health across the lifespan—from the beginning of fetal development to elder years—and how they can promote health and resilience, or disease and disability.

Important determinants of health come from the natural, built, chemical, food, economic, and social environments.

These environments are further expressed through such things as education, housing, nutrition, access to health care, social supports and more.

Many of them interact to create the conditions for health and wellness, or vulnerability to disease.



Complex interactions occur among many variables and across individual, community, and societal levels.

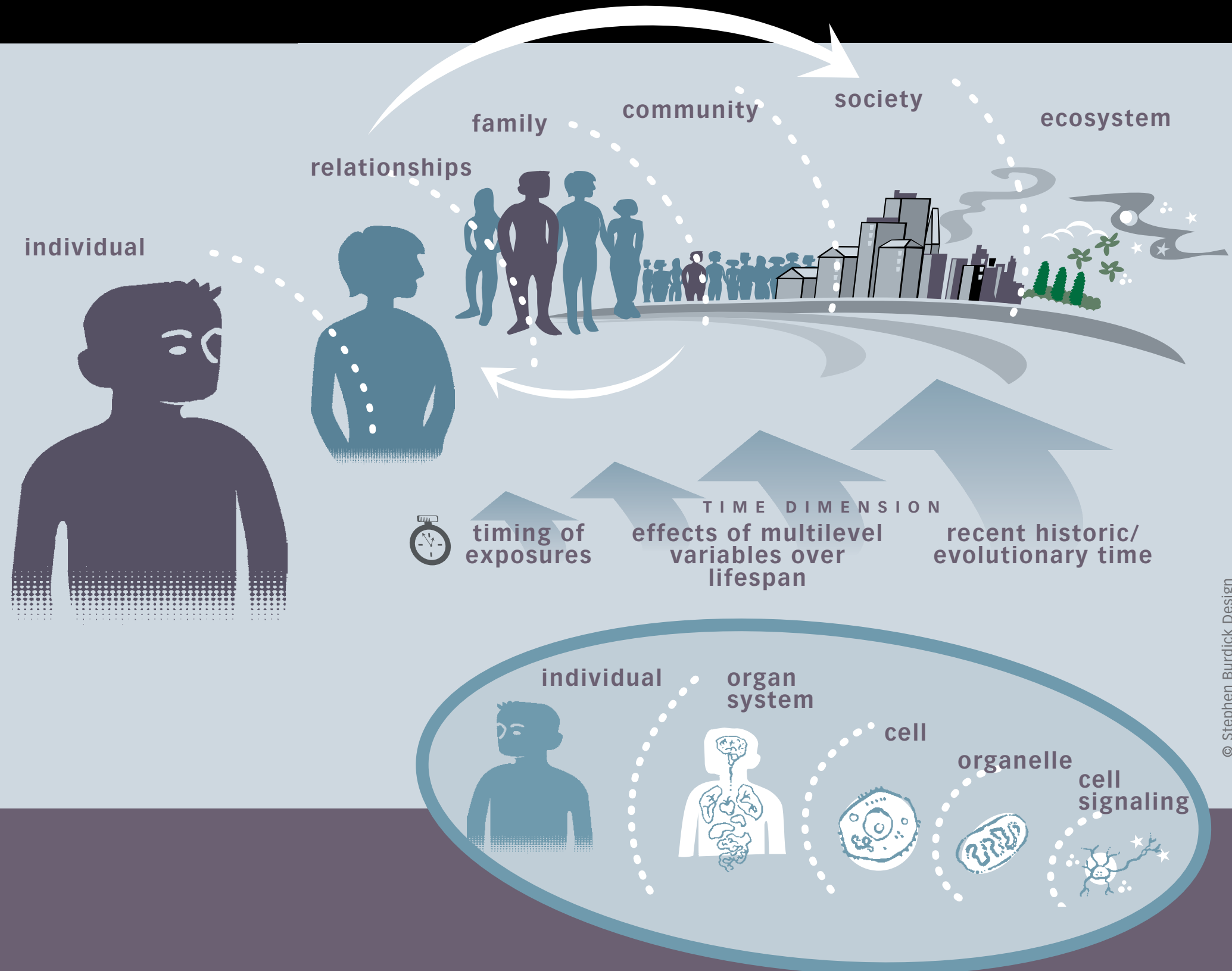
Rarely is one particular thing responsible for health or disease, so we refer to this as a multifactorial (or ecological) approach, the best way to promote health and prevent disease.

INTRODUCTION Ecological Health Framework

The ecological framework can include multiple levels from sub-cellular to societal.

It is not hierarchical in the sense that one level is more important than another, but rather in the sense that individual biology is progressively nested within the person, family, community, society and ecosystem.

The interactions and feedback loops within, across, and among these levels are complex and variable. They exert their influences on health across time.



INTRODUCTION

Six Different Stories

Following is a story of people like you and me, our partners, families and friends, our mothers and fathers, sisters and brothers, children, grandparents, cousins and aunts and uncles.

The personal health stories explored in this series include some of the most common and troubling diseases and exposures of our time. They include:

- **Childhood cancer** (this chapter)
- Asthma
- Wildfire health impacts
- Infertility
- Learning and developmental disabilities
- Cognitive decline



Asthma



**Wildfire
health
impacts**

**Childhood
cancer**



**Cognitive
decline**



Infertility



**Learning and
developmental
disabilities**

INTRODUCTION Free Continuing Education

Information on free Continuing Education offered from the Centers for Disease Control

This fictional *Story of Health* chapter offers free Continuing Education (CE).

To receive continuing education (CE) for SS4677-*A Story of Health – Childhood Cancers: Stephen’s Story*, please visit [CDC TRAIN](#) and search for the course in the Course Catalog using SS4677.

Please review the learning objectives at right. These will help you focus as you read each story, and prepare you for each CE test.

Free Continuing Education available by specialty:

- Continuing Medical Education (CME) for Physicians
- Continuing Nursing Education (CNE) for Nurses
- Continuing Education Units (CEU) for other professionals
- Continuing Education Contact Hours (CECH) for Certified Health Education Specialists (CHES)
- Continuing Education (CPH) for Certified Public Health Professionals



LEARNING OBJECTIVES

Stephen’s Story (Childhood Cancer):

1. Describe the characteristics of childhood cancer.
2. Discuss trends associated with childhood cancer.
3. Discuss environmental risk factors for childhood cancer.
4. Discuss factors that reduce the risk of childhood leukemia.
5. Describe how to improve collaborative practice across the healthcare team regarding preventing risk factors for childhood cancer.

CHILDHOOD CANCER

Stephen's Story*

Stephen is a 3-year-old boy who lives with his parents David and Tricia in a suburb in Connecticut.

He is an only child, and his parents spend as much time as they can with him even though they manage a successful plant nursery and garden center.

He spends four days a week at child care and is with his parents the other three days, sometimes at their house and sometimes at the garden center.

Stephen had been an active toddler, but during the past month, Tricia noticed that Stephen was not as lively and energetic as usual. His child care providers also mentioned this.

When he became listless and started to run a fever, Tricia became concerned. She took Stephen to see his pediatrician, Dr. Jones.

(*a fictional case)



CHILDHOOD CANCER

Stephen's Story

After talking with Tricia and examining Stephen, Dr. Jones was also concerned. She confirmed that Stephen appeared ill, was very pale, and that the cause could be a number of things. She said she needed laboratory tests to make an accurate diagnosis.

Dr. Jones ordered blood tests that could be done at the local hospital and called to make an appointment for Stephen to get his blood drawn that same day.

Tricia was upset and called her husband David with the news. She started to ask a lot of questions. Dr. Jones tried to calm her and said she would call her as soon as she had the results.

Tricia brought Stephen to the hospital laboratory for the tests and went home very worried.



CHILDHOOD CANCER

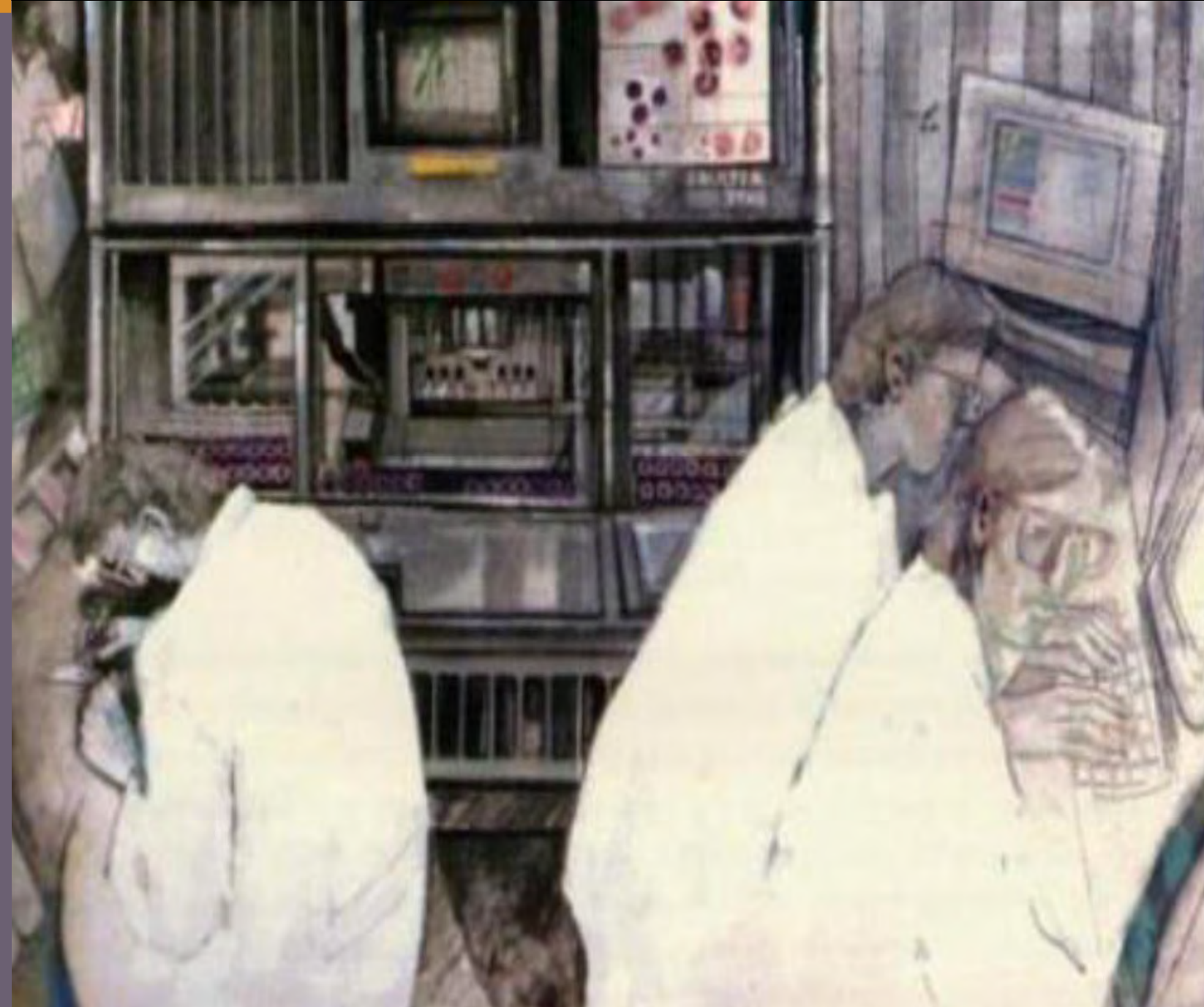
Stephen's Story

When Dr. Jones received the test results she called Tricia and David back into her office. She told them that the test results showed a very high white blood count and very low platelet count.

Dr. Jones said that Stephen would need to see a pediatric oncologist, Dr. Baker. She said she would arrange the appointment for Stephen at Dr. Baker's office next to the hospital and that he should go right over.

Tricia and David were shocked. They knew that oncologists dealt with cancer. Dr. Jones tried to reassure them and said they should wait to speak with Dr. Baker before drawing any conclusions.

They left Dr. Jones office still very worried.



[Go to page 17 for more information
on the artist.](#)

CHILDHOOD CANCER

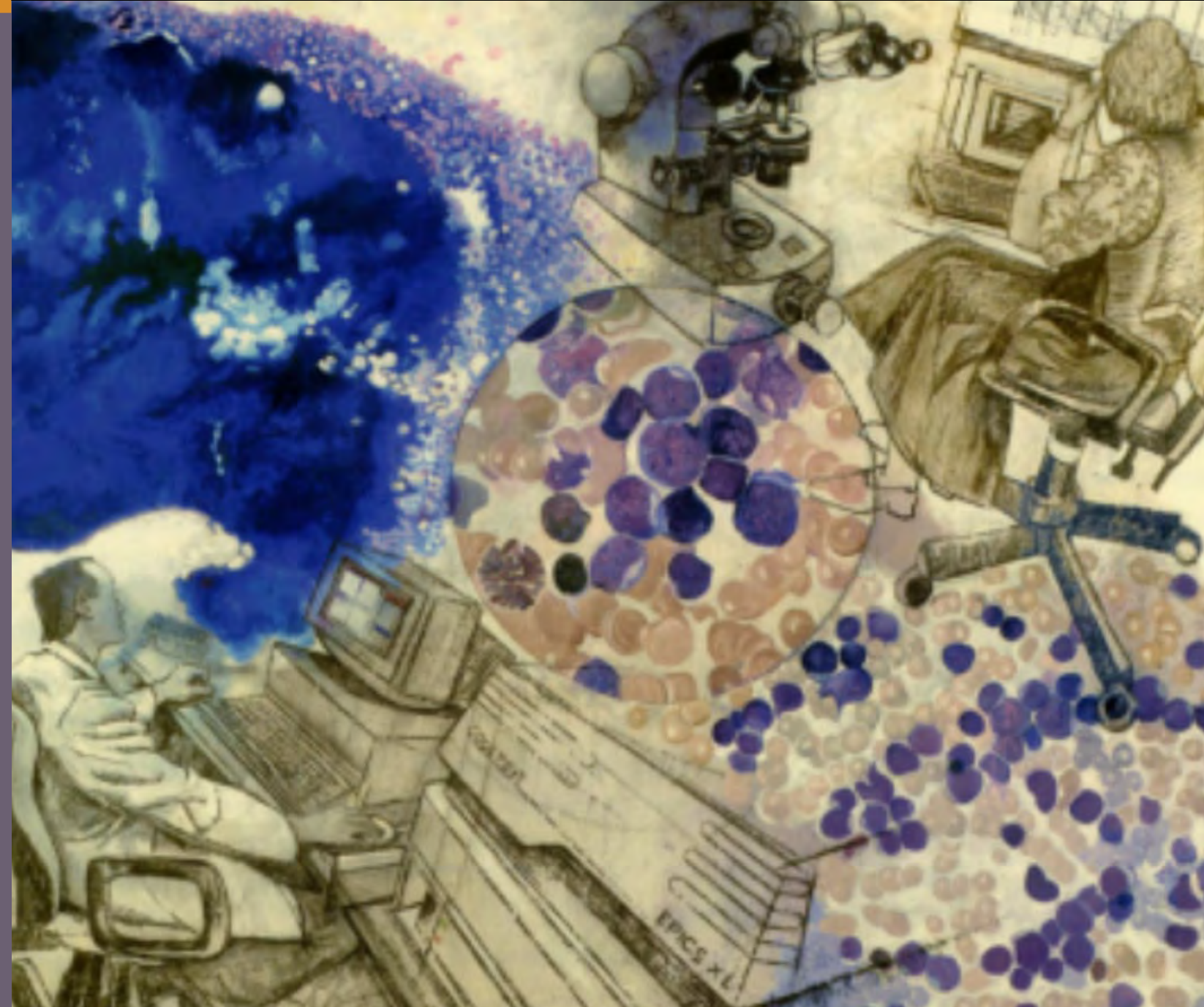
Stephen's Story

The pediatric oncologist, Dr. Baker, looked at Stephen's blood tests to confirm the findings from the laboratory.

After considering the differential diagnosis, Dr. Baker told Tricia and David that he was concerned that Stephen may have leukemia and needed to run more tests to confirm the diagnosis.

Since Stephen had a fever and suppressed immune system, Dr. Baker admitted Stephen to the hospital to start antibiotics and hydration therapy immediately.

Dr. Baker explained to Tricia and David that he would return in the morning to perform a bone marrow aspirate.



[Go to page 17 for more information on the artist.](#)

CHILDHOOD CANCER

Stephen's Story

The next day when Dr. Baker came to visit, Stephen looked well. He no longer had a fever and was playing. Dr. Baker explained the bone marrow procedure to Tricia and David and then performed the aspirate in a special room for procedures.

When he returned to discuss the bone marrow test results, Dr. Baker tried to calm Tricia and David, but they were upset and imagined the worst.

Unfortunately, their fears were realized when Dr. Baker told them that Stephen's test results confirmed that he had leukemia. He said that further tests were being done to find out more about what type of leukemia he had. He said they should know the type of leukemia the following day, and then they can begin treatment.

They were devastated.



Find out more:
[National Cancer
Institute: Cancer
in Children and
Adolescents](#)



Chart Source: California Cancer Registry, California Department of Public Health. Prepared by the California Department of Public Health, California Cancer Registry.

CHILDHOOD CANCER

Stephen's Story

Dr. Baker discussed with them what the course of treatment should be, including intravenous (IV) hydration (liquids), and initiating a course of chemotherapy.

Stephen would need to be in the hospital for this, since the initial treatment is the riskiest time period.

Dr. Baker arranged for Stephen to continue his hospital stay and begin treatment immediately.



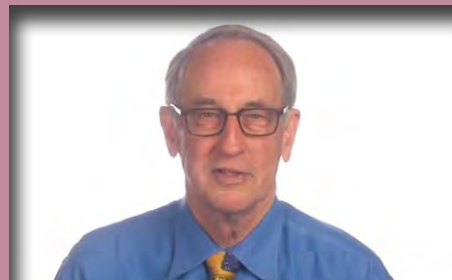
CHILDHOOD CANCER

Stephen's Story

Later Dr. Baker explained that the type of leukemia Stephen had was called acute lymphoblastic leukemia (ALL). Dr. Baker told Stephen that he was sick, and that he would have to be in the hospital for a while so that the doctors can give him medicines to make him better.

Dr. Baker also explained to Tricia and David how the cure rate for children has improved dramatically over the past few decades.

Watch: [Dr. Gary Dahl discusses types of leukemia](#) (4:13 mins.)



Gary Dahl MD, Professor Emeritus of Pediatrics (Hematology/Oncology) at the Lucile Salter Packard Children's Hospital, Stanford School of Medicine



CHILDHOOD CANCER

Stephen's Story

CHILDHOOD LEUKEMIA IS NOT A SINGLE DISEASE

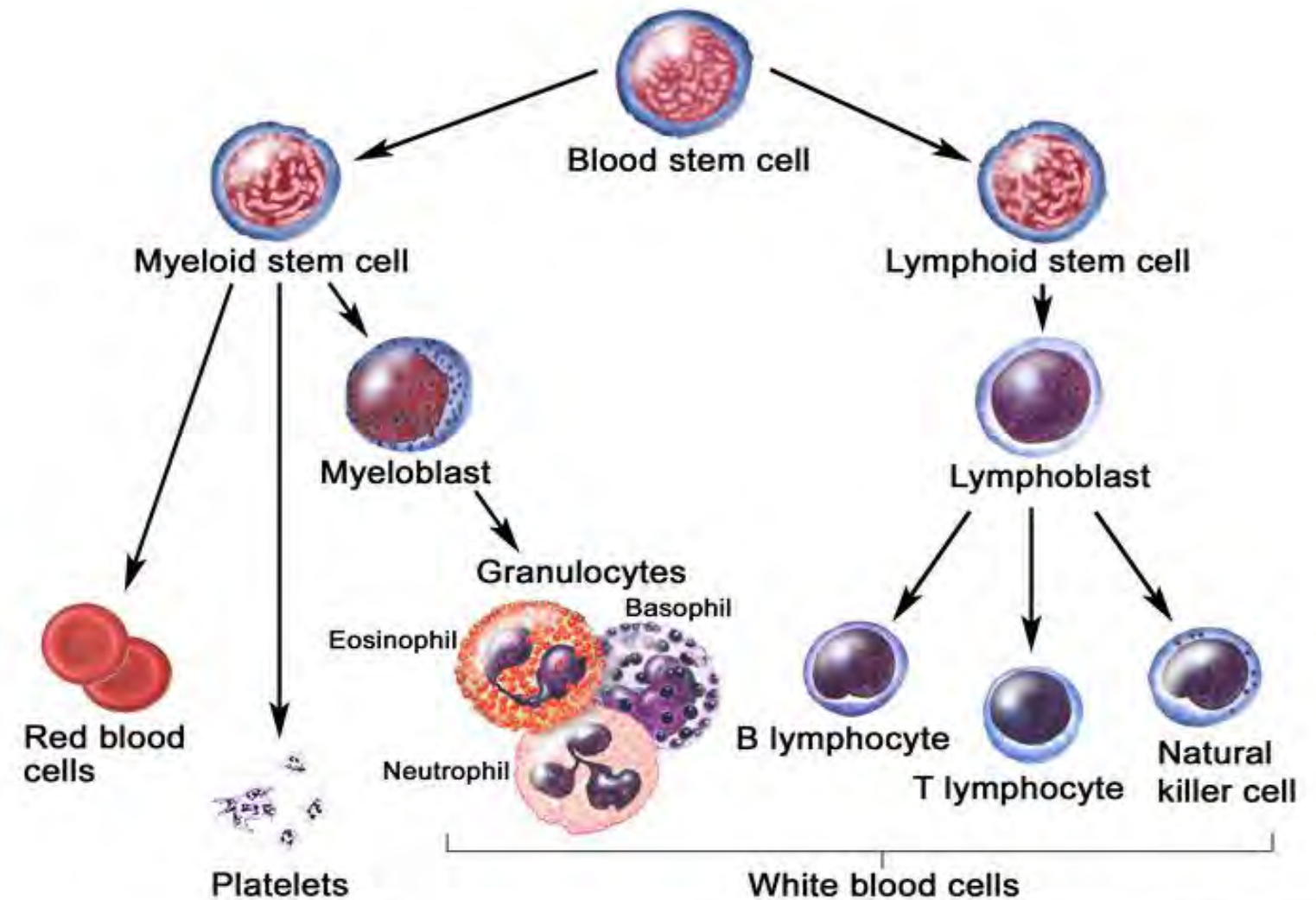
Acute leukemias in childhood comprise a group of related but different diseases. In the United States they represent 31% of malignancies occurring among children under the age of 15.

Eighty percent of acute childhood leukemias, including Stephen's, are acute lymphoblastic leukemia (ALL). Approximately 17% are acute myeloblastic leukemia (AML).

It is important to identify characteristics of the leukemia at its presentation since this information helps to determine the course of treatment as well as prognosis. The types of cells involved in the leukemia (immunophenotype) are used to determine whether a person has ALL or AML.

Factors such as age, initial white blood count at diagnosis, and cytogenetics (the specific differences or changes in DNA) of the leukemic cells at diagnosis are utilized to identify the most appropriate course of treatment.

Leukemias originate in lymphoid and myeloid progenitor cells.



© 2007 Terese Winslow
U.S. Govt. has certain rights.

Graphic: Terese Winslow 2007.
Graphic reproduced with permission.

Stephen spent the first two weeks of his treatment in the hospital, then his protocol was continued on outpatient status. The treatment course would be up to three years with induction, consolidation, and maintenance therapy stages.

Dr. Baker warned Tricia and David that any time Stephen had a fever he would need to be evaluated, and if his white blood count was low he would need to be hospitalized.

Dr. Baker, along with the rest of the hospital team, carefully explained how the chemotherapy medications work and what side effects they might expect. Stephen's hospital stay was difficult for his parents. Stephen hated being away from home and the nausea and vomiting made him uncomfortable.



[Treatment information
for the general public](#)



[Treatment information
for clinicians](#)



click a preview image to view above

CHILDHOOD CANCER

Stephen's Story

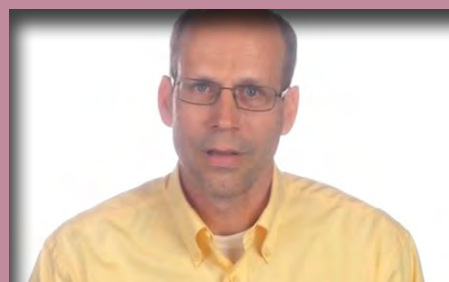
After the initial shock of the diagnosis and while dealing with Stephen's first chemotherapy course, Tricia and David began to ask Dr. Baker and others more questions about what might have been the cause of Stephen's disease.

Childhood leukemia is difficult to study because it is relatively rare, which limits the design of studies intended to help clarify its etiology (cause). Nevertheless, substantial evidence identifying a number of risk factors has emerged over the past two decades. The etiology is likely to be attributable to a mixture of genetic and environmental factors and may vary by subtype or for ALL, immunophenotype.

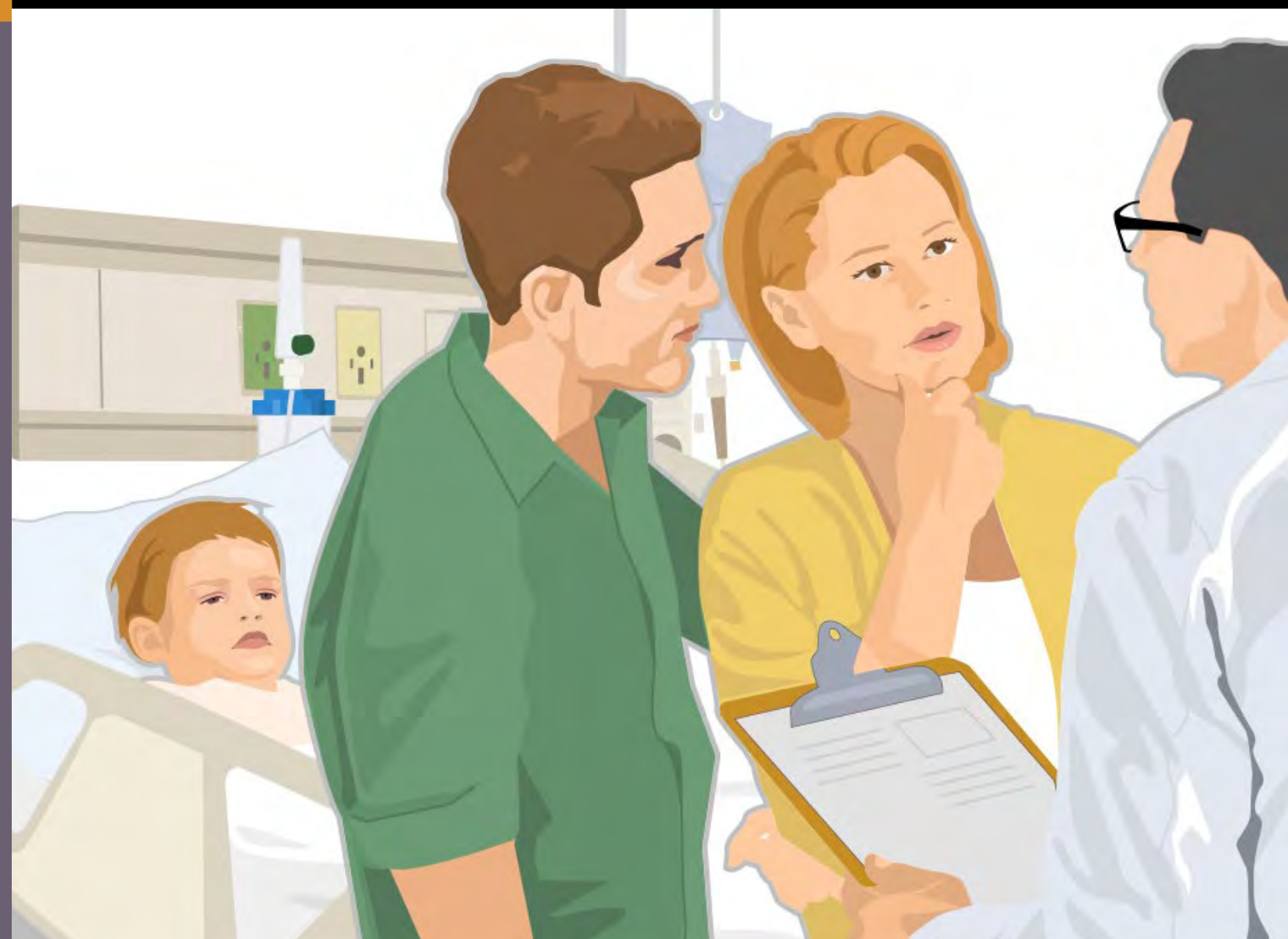
Cancer is considered a multi-step process. It is thought that childhood leukemia is a result of distinct exposures during two or more developmental time periods including preconception, in utero, and postnatal.

Changes to DNA that cause leukemia:

Watch: For clinicians: Dr. Joe Wiemels discusses timing of environmental exposures (2:23 mins.)



Joseph L. Wiemels PhD,
Professor, Center for Genetic Epidemiology,
Norris Comprehensive Cancer Center, Keck School of Medicine, University of Southern California



CHILDHOOD CANCER

Stephen's Story

Since childhood leukemia is a rare disease and it takes many cases to identify environmental risk factors, the Childhood Leukemia International Consortium (CLIC) was established in 2007 (locations represented by the black icons on the map at right). CLIC develops and supports collaborations among member groups to identify factors that influence the risk of childhood leukemia through epidemiological studies and related research.

This consortium serves to strengthen the available data set regarding the role of environmental and genetic risk factors and critical windows of exposure, as well as to provide a more robust translation to clinical audiences worldwide.



CHILDHOOD CANCER

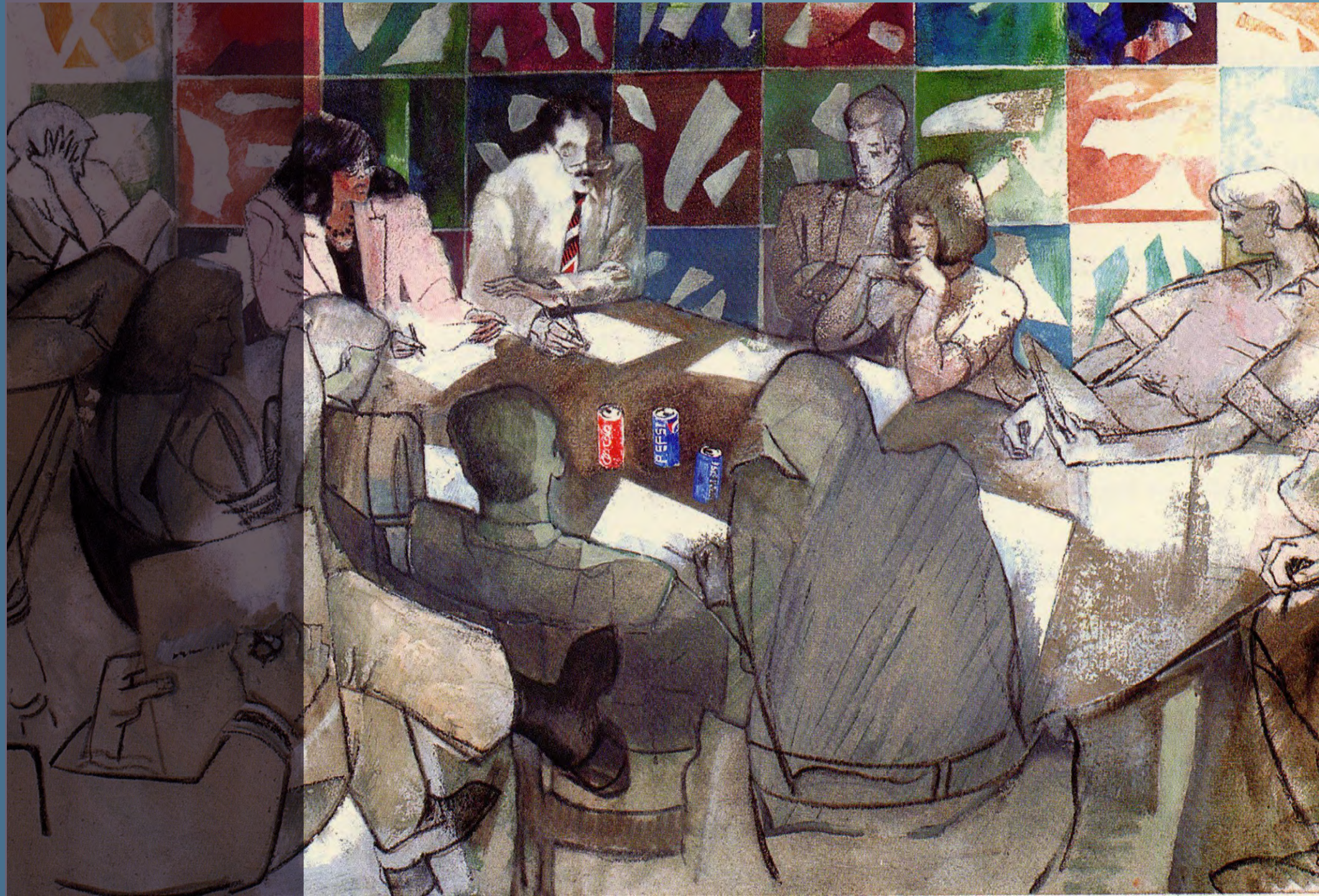
Stephen's Story

FACTORS ASSOCIATED WITH RISK FOR CHILDHOOD LEUKEMIA

One of the hospital's pediatric residents asks Dr. Baker about the risk factors for childhood leukemia.* Dr. Baker mentions that this would be a great topic for everyone to hear at rounds and asked the resident to review the literature and develop a presentation.

The resident reported that there are many epidemiologic (human) studies that find exposures to certain groups of chemicals, air pollution, tobacco smoke, and radiation to be consistently associated with increased risk for a child developing leukemia. Additionally, some factors are associated with a protective effect such as early supplementation with folate. Along with environmental exposures and diet, studies show that inborn genetic factors play a role in risk, and may interact with environmental exposures.

*In the following pages of Stephen's story we describe environmental and genetic factors significantly associated with increased leukemia risk. Keep in mind, however, that childhood leukemia is a relatively uncommon disease. Thus, even if a person were exposed to something that doubled the risk of developing leukemia, the risk for that person would remain quite low.



FACTORS ASSOCIATED WITH RISK FOR CHILDHOOD LEUKEMIA

Dr. Baker is careful to note that, “Scientists and policy makers will continue to study and debate for years to come whether these associations are truly causal. And, there are also ethnic and demographic factors associated with leukemia risk. Interactions among risk factors and their common co-occurrence make it even more difficult to establish the cause of leukemia in a particular person or to identify the most important determinants of leukemia in a population. But, many environmental exposures associated with leukemia are also associated with other health problems, such as neurodevelopmental disabilities, asthma and other respiratory diseases, and reproductive disorders. For all these reasons, most people would want to avoid exposure as much as possible. The association with cancer is an additional reason.”

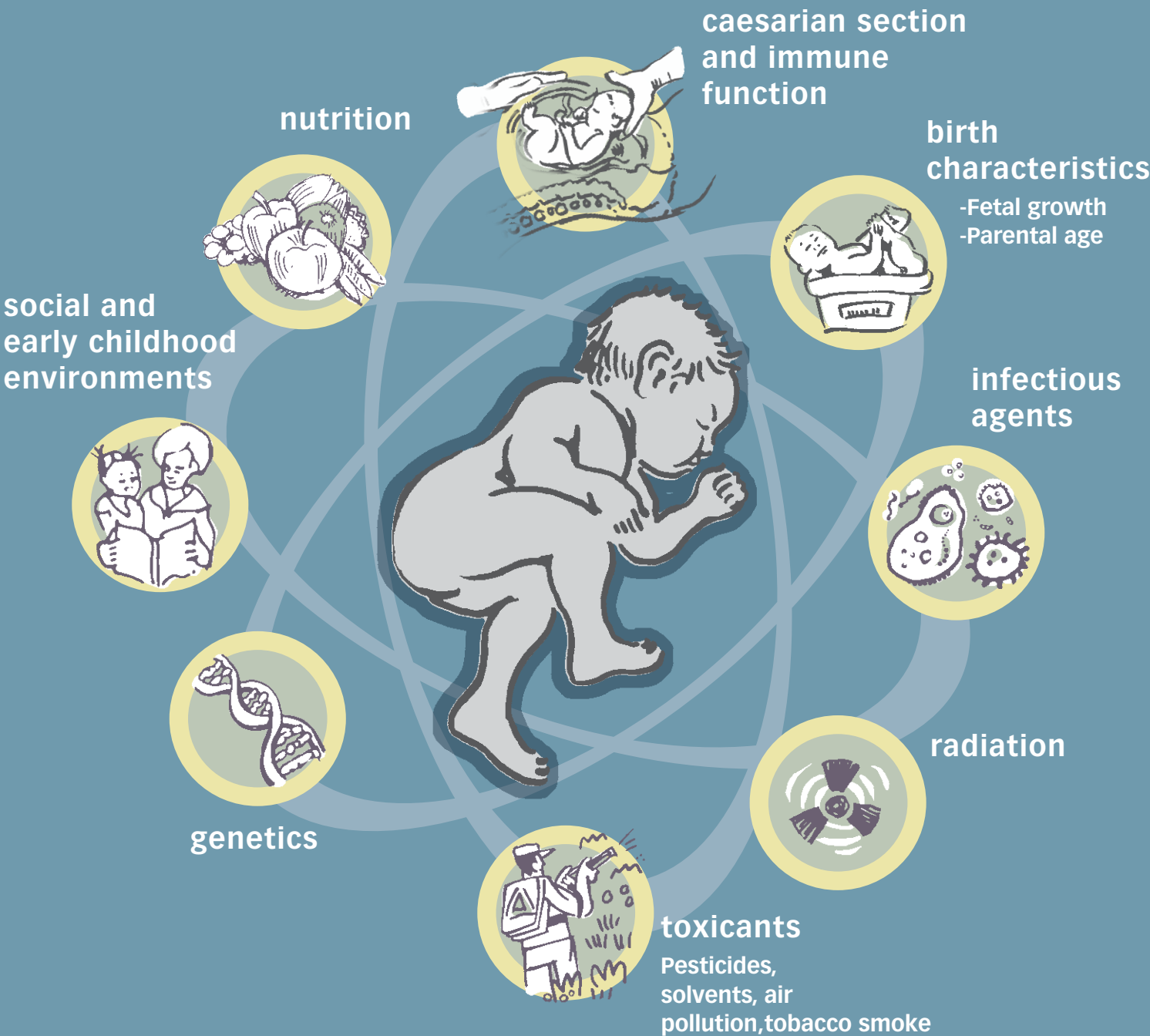
He adds, “Some of these exposures simply cannot be reduced by individual action alone. Rather, in some instances, policy interventions that reduce exposures across the entire population will be necessary and more effective.”

Childhood cancer risk also generally shares a number of common themes that we have seen in other disorders highlighted in *A Story of Health*, such as greater susceptibility during certain periods of development, underlying genetic risk factors, and gene-environment interactions.

Watch: Can we reduce exposure to risk factors associated with childhood leukemia and other cancers?

Mark Miller MD MPH,
Director Emeritus,
Western States Pediatric
Environmental Health
Specialty Unit at UCSF;
Director, Children’s
Environmental Health
Center, Office of
Environmental Health
Hazard Assessment,
California EPA

Multiple Factors Associated with Risk to Childhood Leukemia



©stephen burdick design

References, Birth Characteristics:

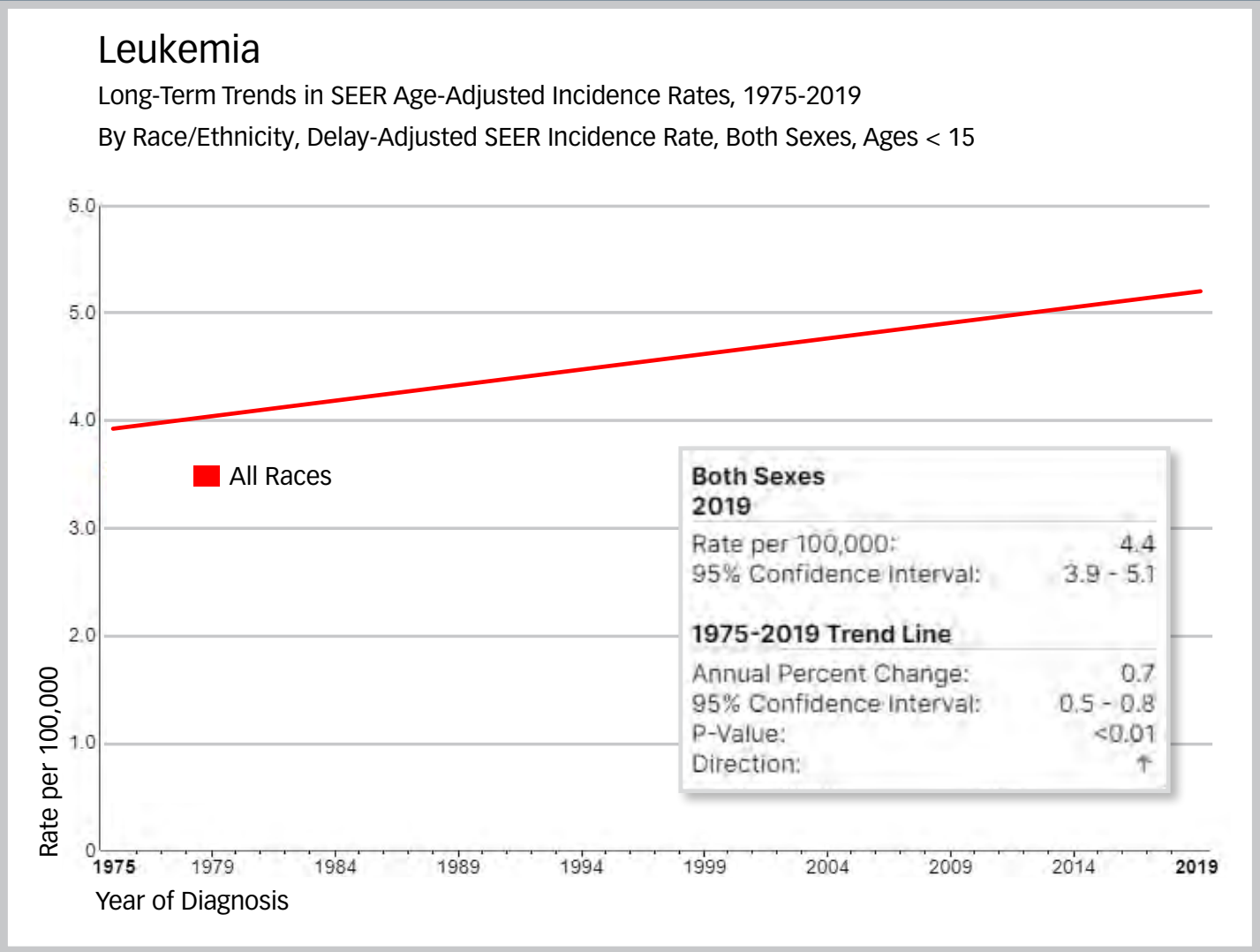
Milne E, et al. Fetal growth and childhood acute lymphoblastic leukemia: findings from the Childhood Leukemia International Consortium (CLIC). *Int J Cancer*. 2013 Dec 15;133(12):2968-79.

Paltiel O, et al. International Childhood Cancer Cohort Consortium. Birthweight and Childhood Cancer: Preliminary Findings from the International Childhood Cancer Cohort Consortium (I4C). *Paediatr Perinat Epidemiol*. 2015 Jul;29(4):335-45.

CHILDHOOD CANCER: US TRENDS

Although childhood leukemia is still rare, Stephen is one of a growing number of children with this cancer. In the US, between 1975 and 2019, the rate of leukemia among children 0-14 years increased 0.7% per year. This adds up to a 36% increase over 44 years.

Incidence of “all leukemias” in children under 15 years of age has consistently risen at 0.7% per year from 1975 through 2019. Overall this represents a 36% increase in risk over 44 years.



CHILDHOOD CANCER

Stephen's Story

SOURCES OF EXPOSURE TO PESTICIDES

At their next visit to Dr. Baker, Tricia mentions that she heard from a friend that pesticides might cause leukemia. This reminds Dr. Baker of the information on environmental exposures and childhood leukemia that the pediatric resident presented during rounds.

Dr. Baker asks if Stephen could have come into contact with any pesticides and specifically asks about pesticide use in the home and garden. Tricia says that they own a plant nursery and garden center, and they use some pesticides. Stephen sometimes visits the nursery after preschool and on weekends.

Residential exposures to pesticides (from indoor and outdoor personal use or living in proximity to agricultural areas) have also been consistently associated with childhood brain tumors and lymphomas that are the most common cancers in children and adolescents after leukemia.

Possible associations have also been reported for rarer childhood and adolescent cancers such as neuroblastoma, Wilms tumors, Ewing sarcoma, and testicular cancers.



[Pesticide Exposure in Children: Policy Statement from the American Academy of Pediatrics](#)



[Link to EPA website for more information on FIFRA](#)

More Information:

- [+ American Cancer Society: Key Statistics for Wilm's Tumors](#)
- [+ National Cancer Institute: Wilms Tumor and Other Childhood Kidney Tumors Treatment](#)



PESTICIDES

Tricia mentions to Dr. Baker that other families in the neighborhood have regular pesticide applications to the perimeter of their house and some have lawn service, but they do not.

Tricia thought that Stephen's daycare might occasionally use pesticides to spray for ants and flying insects. Dr. Baker consulted the pediatrician at his regional Pediatric Environmental Health Specialty Unit, who confirmed that many studies from around the world have found statistically significant associations between pesticide exposure and childhood leukemia.

The consulting doctor suggested that Dr. Baker share with his team information about environmental exposures that may be risk factors for leukemia so they might be better prepared to answer families' common questions. Dr. Baker replied he agreed and that he also regularly asked pediatric residents to report to the team on potential environmental risk factors.

+ More information:
"5 Key Things to Know about a Meta-Analysis" Scientific American blog post

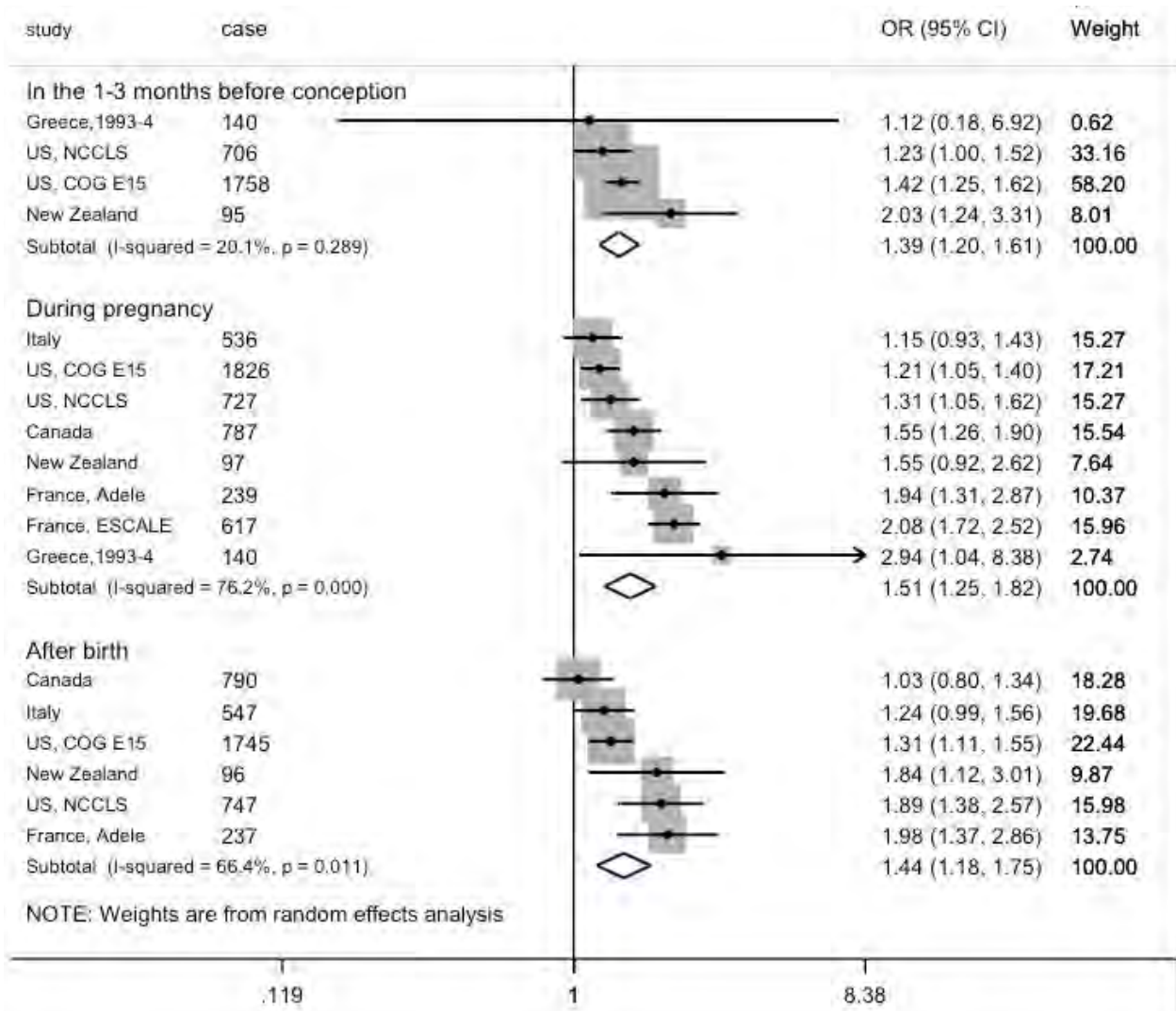
+ Find a local Pediatric Environmental Health Specialty Unit (PEHSU): A respected network of experts in children's environmental health.

Watch: [Dr. Catherine Metayer discusses insecticides and herbicides \(4:15 mins.\)](#)



Catherine Metayer MD PhD, Adjunct Professor, Epidemiology/Biostatistics and Epidemiology, University of California-Berkeley, Principal Investigator, Center for Integrative Research on Childhood Leukemia and the Environment

Residential Pesticide Exposures



Forest plot showing individual and summary odds ratios for home pesticide exposures and the risk of childhood acute lymphoblastic leukemia, using random effects models.

In a meta-analysis by Bailey, et al. (2015) that combined data from 12 studies in the Childhood Leukemia International Consortium, residential insecticide use before conception, during pregnancy, or after birth was associated with increases in the risk of childhood acute lymphoblastic leukemia of 40 to 50% (OR*=1.39 to 1.51). For acute myeloid leukemia, the associations were somewhat similar for pesticide exposure before conception (OR=1.88) and during pregnancy (OR=1.60), but not after birth (OR=1.10).

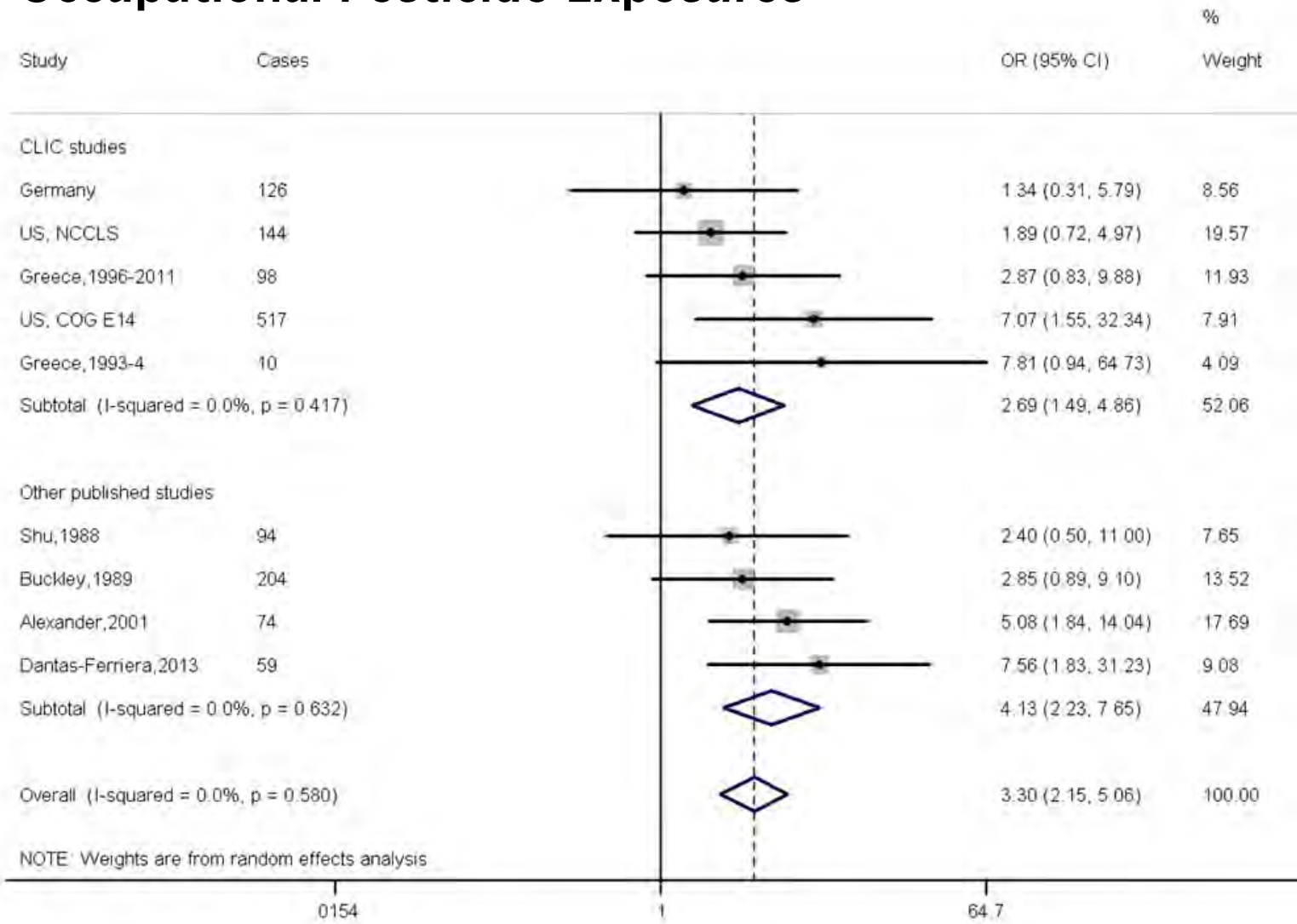
OCCUPATIONAL EXPOSURES DURING PREGNANCY MAY CONTRIBUTE TO CHILDHOOD LEUKEMIA RISK

Dr. Baker asked a few more details about the garden center. Tricia said she worked in the back office while she was pregnant, up until a few months before Stephen was born.

Pesticides, solvents, and other chemicals may cause chromosomal alterations in parents' eggs and sperm cells that increase the risk of their children developing certain cancers, or maternal exposure may affect the child directly while in utero.

Studies have demonstrated a link between maternal occupational exposures to pesticides and childhood leukemia. Maternal use of pesticides at home has also been associated with AML risk. In case studies, maternal exposure to certain insecticides has been associated with translocations seen in children with AML.

Occupational Pesticide Exposures



The largest analysis combining original data from studies (1,329 cases) around the world found a near doubling of risk for AML if mothers were exposed occupationally to pesticides during pregnancy OR 1.94 (CI 1.19, 3.18).

No associations were found for childhood ALL. This forest plot of pooled data shows individual and summary odds ratios for maternal occupational pesticide exposure during pregnancy and the risk of AML in the offspring, using random effects model.

Source: Bailey, et al., 2014.
Reproduced with permission.

CHILDHOOD CANCER

Stephen's Story

PATERNAL OCCUPATIONAL EXPOSURES AROUND TIME OF CONCEPTION MAY CONTRIBUTE TO CHILDHOOD LEUKEMIA RISK

Analysis of data (pooled) from studies around the world, including over 8,000 cases of childhood leukemia showed a 20% increased risk of ALL associated with paternal occupational exposure to pesticides around the time of conception. The risk was about 40% increased in children whose diagnosis was at age 5 years or greater and in those with T cell ALL. This highlights the importance of considering both critical windows of exposure as well as the different sub-types of leukemia when possible.

Though “pesticides” includes a wide variety of different chemicals and these findings do not implicate specific agents, more than 20 pesticides have been classified as “possible” or “probable” human carcinogens by the International Agency for Research on Cancer (IARC).

Paternal exposures to solvents, paints, and employment in motor vehicle-related occupations have also been shown to be associated with childhood leukemia. Paternal exposures before conception could result in germ cell damage or changes in gene expression. Parental exposures after the child is born may result in exposure to the family by materials from work being brought home on clothing.



More information:
[Pesticide Safety
Information for
Farmworkers from
the California EPA](#)



CHILDHOOD CANCER

Stephen's Story

EXPOSURES TO PAINTS AND SOLVENTS MAY INCREASE RISKS

David thought back to painting the nursery while Tricia was pregnant and wondered if using paint or paint thinners had exposed Stephen to substances linked to the development of leukemia.

In a pooled analysis that combined data from 8 studies in the Childhood Leukemia International Consortium (Bailey et al., 2015), home paint exposures before, during, and after birth were consistently associated with modest increases in the risk for childhood ALL; the risks were limited to children who were exposed to oil-based paints (~20% increase in risk). Although information about the scale of individual painting projects was not available, it can be assumed that professional painters tended to be hired for bigger jobs. As such, the observation that leukemia risk was highest when professional painting was reported (OR=1.53 before conception and OR=1.66 during pregnancy) can be interpreted as evidence of a dose-response relationship. Also, it appears that risks were higher for certain cytogenetic subtypes including translocation t(12;21) and MLL rearrangement, suggesting that etiologic pathways may be specific to childhood leukemia subtypes.

Use of solvents in the home was associated with a two-fold increase in AML risk (Scelo et al., 2009).

continued from left

In addition, a number of studies have reported elevated risks of childhood leukemia associated with complex mixtures of solvents such as those found in gasoline and traffic exhaust and from parental occupational exposures (see sections on occupational exposures and air pollution).

Many solvents are recognized carcinogens, with benzene being a well-established leukemogenic agent in adults. A meta-analysis of various sources of benzene (i.e., household use, occupations, and air pollution) showed associations with childhood ALL (OR=1.48) and AML (OR=2.07) (Carlos-Wallace et al., 2016). As evidence of a relationship between paint/solvent exposures and childhood leukemia risk continue to accumulate (Whitehead et al., 2016), parents may wish to avoid paint and solvent exposures (when feasible) during the immediate pre-conception period and pregnancy. This will also help lower the risk of other adverse health outcomes associated with the same agents.



CHILDHOOD CANCER

Stephen's Story

TRAFFIC-RELATED AIR POLLUTION MAY INCREASE CHILDHOOD LEUKEMIA RISK

Living near major roadways results in exposure to many potential carcinogenic substances. Estimates place as much as 10% of the U.S. population and as many as 30-45% of urban residents living near major roadways.

Studies have suggested that chemicals and other components of air pollution may contribute to childhood leukemia. A recent meta-analysis of seven studies from Europe and the United States conducted by the CDC suggests that living near highly trafficked roadways after birth increases children's risk for leukemia by over 50% (OR 1.53; 95% CI 1.12, 2.10) (Boothe et al., 2014).



EARLY PRECONCEPTION AND PRENATAL INTRODUCTION OF VITAMINS AND FOLATE REDUCES RISK OF CHILDHOOD LEUKEMIA

At their next visit, Dr. Baker asks Tricia about her pregnancy with Stephen. Like many other women, she didn't think about taking vitamins before or during the first two months of the pregnancy, especially because she ate a nutritious diet. Otherwise she was very careful to live a healthy lifestyle while pregnant and did not smoke or drink. She started on prenatal vitamins with folate at her first prenatal visit at eight weeks gestation.

Folate supplementation has been associated with reductions in risk for childhood leukemia, at least for those at risk for lower folate consumption. Folate supplementation before conception and early in pregnancy not only appears to be protective in the case of leukemia risk, but also reduces neural tube and other birth defects, and may reduce the risk of developing autism. (Schmidt et al., 2012; Suren et al., 2012, Metayer et al., 2014.)

+ More information: [CDC's Preconception care for women and men](#)

+ More information: [Developmental Origins of Health and Disease \(DOHaD\)](#)

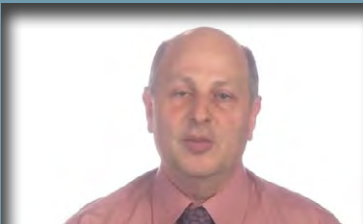


More resources for prenatal care:

- [CDC on pregnancy](#)
- [American Congress of Obstetrics and Gynecology \(ACOG\):](#)
 - [Good Health Before Pregnancy \(pdf\)](#)
 - [Environmental Chemicals](#)
- [UCSF: Program on Reproductive Health and the Environment](#)
- [Royal Congress of OB/GYN:](#)
 - [Chemical Exposures During Pregnancy](#)

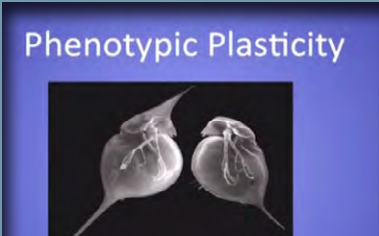
GENETICS AND EPIGENETICS

Cancer is an epigenetic disease as much as it is a genetic disease; fully 10% of the leukemia genome is epigenetically altered compared to normal blood cells. Some of these alterations may be a result of adaptations to our environment very early in our development. Such adaptations may be appropriate at the time, but have consequences later for disease risk. Such an idea was well explained in the Barker Hypothesis (developmental origins of health and disease), now known to have epigenetic mechanisms. As the extent to which epigenetic mechanisms play a role in cancer become better understood, we will also better understand the influence of environmental variables on these mechanisms. This remains a highly active research field.



Watch: [Dr. Mark Miller discusses the Barker hypothesis](#) (1:40 min.)

Mark Miller MD MPH, Director Emeritus, Children's Environmental Health Program, Office of Environmental Health Hazard Assessment, California EPA; Director, UCSF Pediatric Environmental Health Specialty Unit



Watch: [Dr. Mark Miller discusses epigenetics](#) (1:45 mins)

WHAT IS EPIGENETICS?

The genetic code, or DNA sequence, is exactly the same in each body cell. We need some way, however, to express our genes in a correct manner for each cell type, be it blood, bone, muscle, brain, etc. Early in development, our genes are encoded with a set of distinguishing marks on top of genes, or epigenetic marks, that influence gene expression. Epigenetic marks are important to all stages of all cell types, to keep each cell organized within our whole human organism. Exposures to environmental chemicals, infections, and diet can result in the turning of genes on or off. For instance, in a high pollution environment, our bodies can turn on detoxification enzymes. In a low folic acid environ-ment, the body can adjust to retain more folate within our cells.

Polygenic graphic credit: Soyoung Jeon
Reference: Jeon S, de Smith AJ, Li S, Chen M, Chan TF, Muskens IS, Morimoto LM, DeWan AT, Mancuso N, Metayer C, Ma X, Wiemels JL, Chiang CWK. [Genome-wide trans-ethnic meta-analysis identifies novel susceptibility loci for childhood acute lymphoblastic leukemia](#). *Leukemia*. 2022 Mar;36(3):865-868.

Familial Susceptibility graphic licensed under Creative Commons under the following paper: [Increased burden of familial-associated early-onset cancer risk among minority Americans compared to non-Latino Whites](#). Feng Q, Nickels E, Muskens IS, de Smith AJ, Gauderman WJ, Yee AC, Ricker C, Mack T, Leavitt AD, Godley LA, Wiemels JL. *Elife*. 2021 Jun 22;10:e64793.

HEALTHY EATING PROMOTES HEALTH, PREVENTS DISEASE

Holistic nutritional assessments that accounted for both vitamin intake and diet have indicated that maternal prenatal vitamin supplementation – with folic acid or other B-vitamins – and healthy diet at the time of conception and during pregnancy significantly decreased the risk of having a child with leukemia.

Reduction in risk ranged from 10 to 60% depending on the type of data analyzed (B-vitamins or healthy diet index) and the type of leukemia (lymphoblastic or myeloid) (Singer et al, 2015a and 2015b). In contrast, heavy coffee consumption (but not tea) during pregnancy seems to be harmful, based on a pooled analysis from the Childhood Leukemia International Consortium (Milne et al., 2018).

Although findings linking maternal alcohol consumption to childhood leukemia are less consistent, it is prudent to refrain from drinking alcohol during pregnancy as well.

What You Eat Before and During Your Pregnancy

PROTECTS

Your Child from Leukemia

While pregnant, avoid drinks with alcohol or caffeine.



Before and during your pregnancy, eat lots of fruits and vegetables.

Take a prenatal vitamin containing folic acid.

Start Protecting Your Children's Health BEFORE They Are Conceived!

Breastfeeding reduces risk of leukemia

Breast milk contains antibodies and anti-inflammatory substances that have an overall beneficial impact on the infant and child later in life. Several pooled and meta-analyses have confirmed that breastfeeding 6 months and more reduces the risk of childhood leukemia by 15%. These findings provide additional rationale to promote breastfeeding.



+

FIND OUT MORE:
"Rosa and Carlos Plan a Family"
Raising a healthy child begins before pregnancy.
A CIRCLE microsite



CRITICAL WINDOWS OF EXPOSURE TO TOBACCO SMOKE

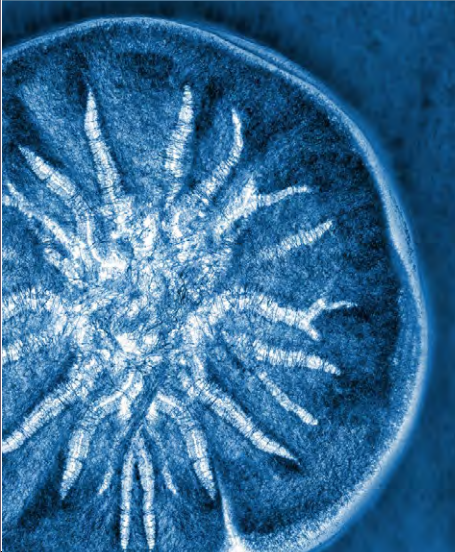
David smoked before Stephen was born but quit when his wife found out she was pregnant.

We know that tobacco smoke could be affecting the development of the fetus and the child during pregnancy and during the early years of life. We also know that tobacco smoke can affect the germ cells.

That means at the time of conception, or even before conception, tobacco smoke may have an effect. Exposures during multiple time periods may add additional risk.

Smoking Cessation Resources:

-  [Free Help to Quit Smoking \(Nat'l Cancer Institute\)](#)
-  [Getting Help to Quit Smoking \(American Lung Assoc.\)](#)



PARENTAL SMOKING INCREASES RISK OF CHILDHOOD LEUKEMIA

At various times during a child's development, parental smoking – by either the mother and/or father – confers an increased risk of childhood leukemia.

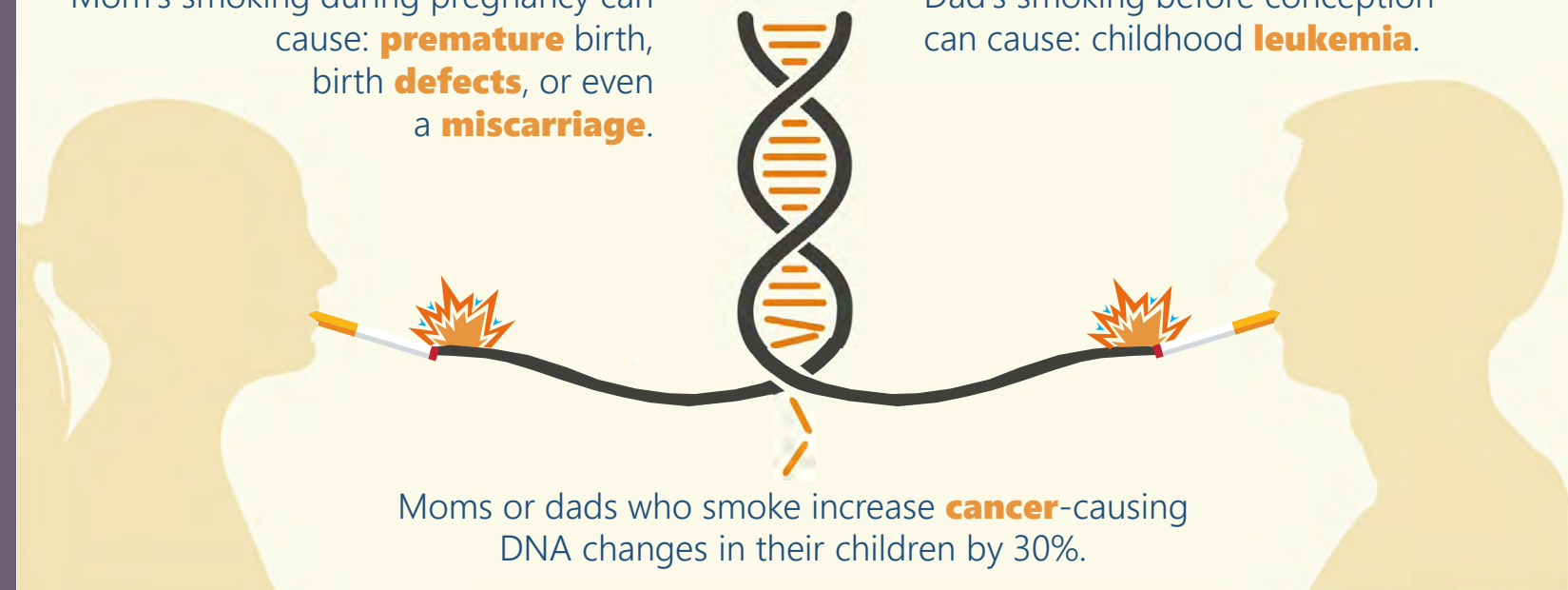
Research from the Childhood Leukemia International Consortium (CLIC) has confirmed that paternal smoking before conception is linked to an increased risk of acute lymphoblastic leukemia (ALL) (Metayer, 2013 – see figure in the Paternal Smoking popup). The effect can be exacerbated if the child continues to be exposed to secondhand smoke after birth.

Interview-based studies of the relationship between maternal smoking during pregnancy and childhood leukemia were initially mostly negative; but recent advancements have pointed to specific at-risk populations. It also appears that certain subtypes of childhood leukemia are uniquely sensitive to maternal smoking. Modern techniques of assessing smoking habits during pregnancy may reveal more about the risks.

Mom's Smoking During Pregnancy is Bad for Baby, but **DID YOU KNOW?** Dad's Smoking *Before* Pregnancy Can Harm the Child, too.

Mom's smoking during pregnancy can cause: **premature** birth, birth **defects**, or even a **miscarriage**.

Dad's smoking before conception can cause: childhood **leukemia**.



Moms or dads who smoke increase **cancer**-causing DNA changes in their children by 30%.

Start Protecting Your Children's Health **BEFORE They Are Conceived!**

CHILDHOOD CANCER

Stephen's Story

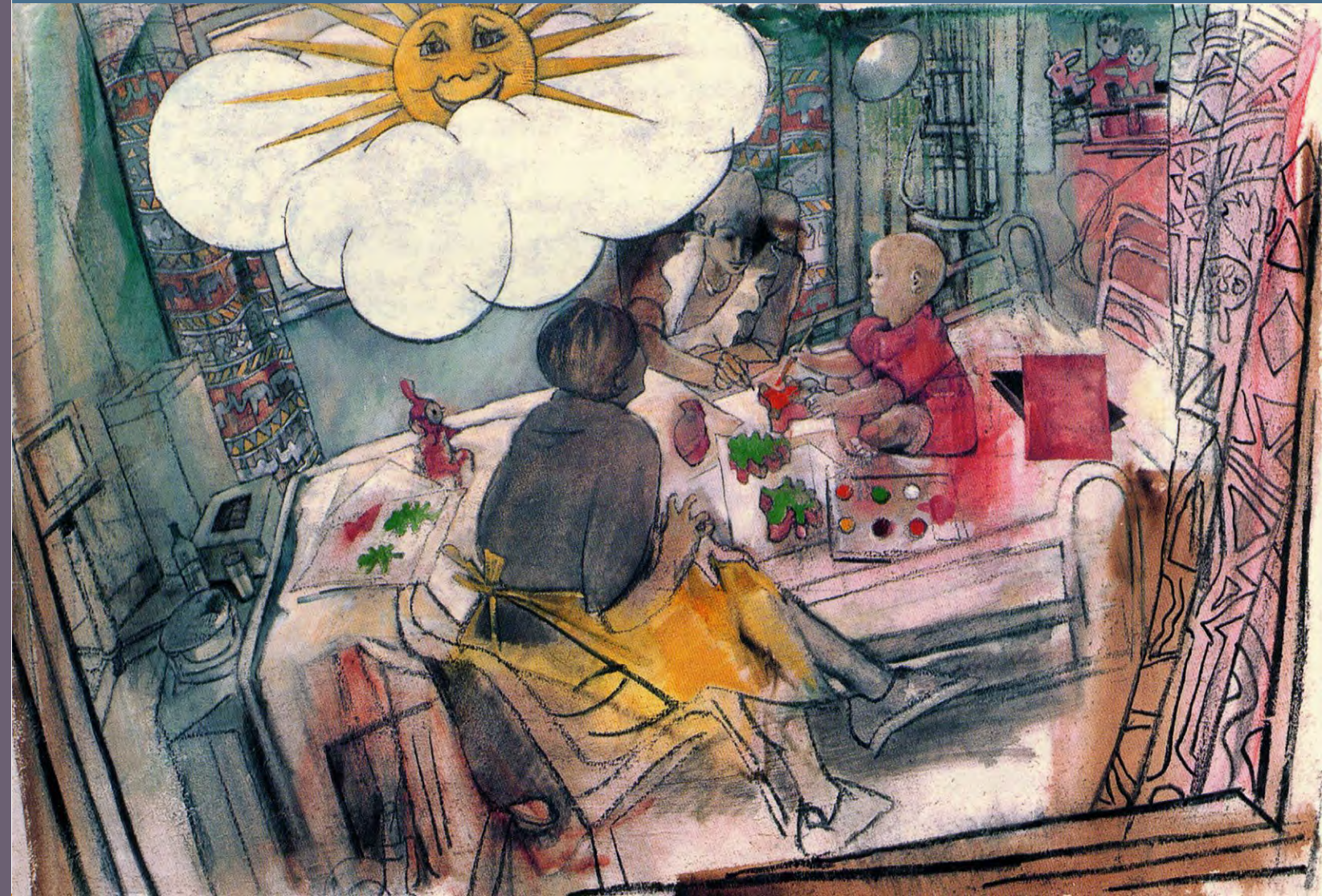
DOCTOR – IS ANY ONE RISK FACTOR THE IDENTIFIABLE CAUSE OF STEPHEN'S LEUKEMIA?

Toward the end of their clinic visit, Tricia and David were visibly distressed about all of the potential factors that could have contributed to their son's leukemia.

Dr. Baker told Tricia and David that they cannot blame themselves for their son's disease. Most complex diseases cannot be explained by a single variable. He said, for example, that studies examining the link between pesticide exposures and leukemia involve fairly large groups of people and cannot be used to establish the cause of disease in an individual. He pointed out that most children exposed to pesticides do not get leukemia and in most cases there is no clear explanation for the cause of a specific child's leukemia.

He added, that due to health concerns about exposures to environmental toxicants, it would be a good idea for everyone to minimize their exposures to them.

Watch: [Dr. Gary Dahl discusses the clinic visit](#)
(3:08 mins.)



CHILDHOOD CANCER

Stephen's Story

SOME CHILDREN ARE AT HIGHER RISK

A few months after Stephen began treatment, Tricia and David start chatting with a customer, Lynn, while she is purchasing plants at their garden center. Tricia recognizes Lynn's daughter Ava in the shopping cart because she used to be in Stephen's child care.

Ava has Down syndrome. Lynn asks about Stephen, who is napping nearby. Tricia explains about Stephen's illness. Lynn mentions that their pediatrician told her that kids with Down syndrome are at higher risk for leukemia (10-20-fold higher risk). Fortunately, fewer than one percent of children with Down syndrome get childhood leukemia.



HOME EXPOSURES VIA DUST

After Stephen's diagnosis, his parents were approached by researchers and asked to participate in a study to analyze their household's dust. Stephen's parents wondered what could possibly be in the house dust that would give researchers clues as to what may cause childhood leukemia. The researchers were very clear that the study is designed to learn about the possible causes of leukemia and would not be able to pinpoint a specific cause of Stephen's leukemia.

The researchers explained that they were going to analyze the dust for polychlorinated biphenyls (PCBs) and structurally-similar polybrominated diphenyl ethers (PBDEs), classes of chemicals that can remain in the environment for long periods of time. A previous single study found that these two classes of chemicals in house dust were associated with an increased risk for childhood leukemia and they are trying to replicate the results (see pop up "PCBs, PBDEs in house dust"). PCBs had many industrial and commercial applications, including electrical equipment and building materials. PBDEs are used as flame retardants in plastics, textiles, and furniture. These chemicals can migrate from consumer products and collect in house dust. Because children crawl on the floor and put their hands in their mouth, they may be exposed to higher amounts of chemicals commonly found in house dust than adults.

Watch: [Dr. Todd Whitehead on chemical exposures from house dust \(1:56 mins.\)](#)

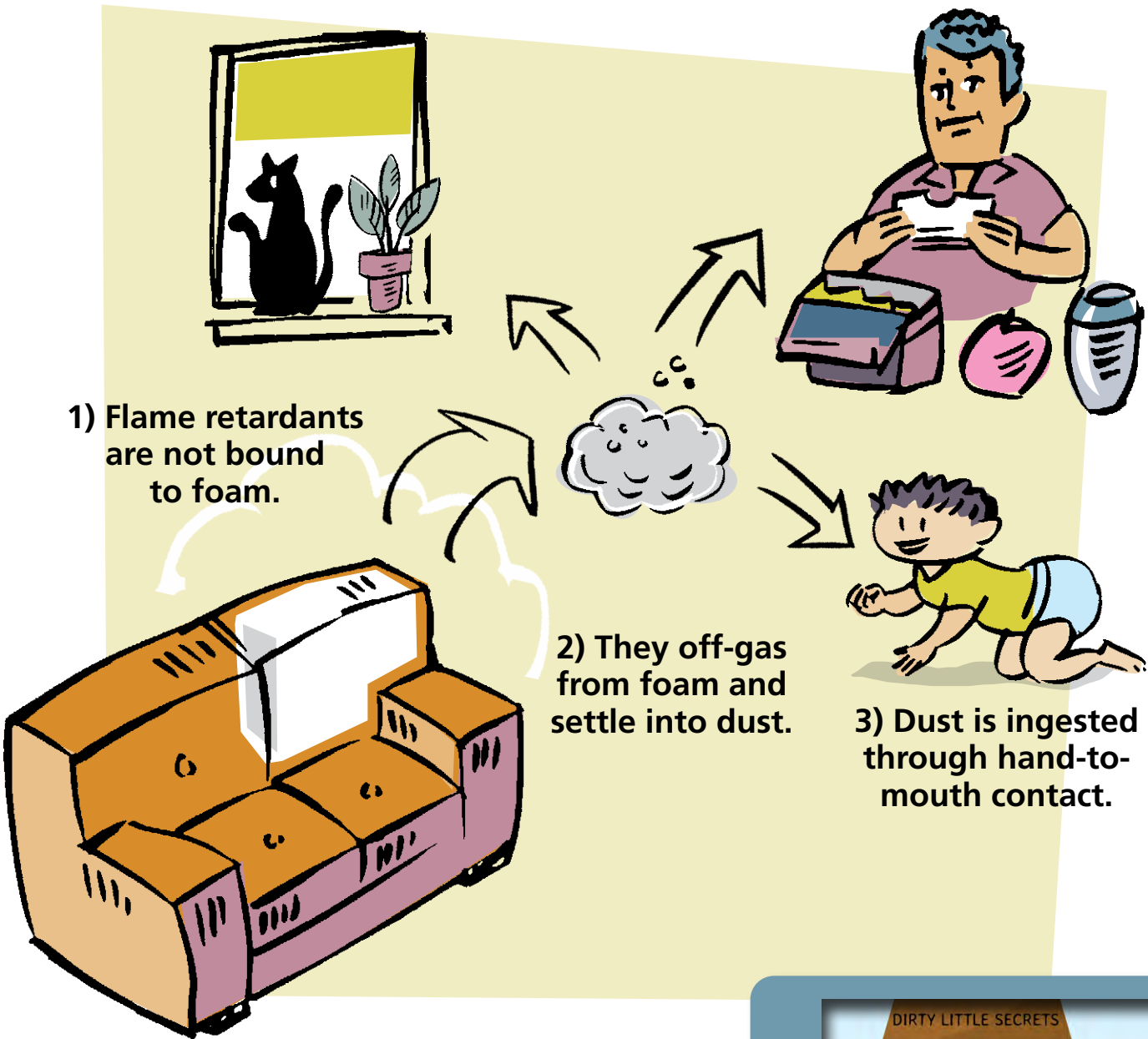


Todd Whitehead PhD, Assistant Researcher, School of Public Health, University of California- Berkeley



Find out more: [Tips to protect children from toxic house dust.](#)

How do we come in contact with flame-retardant chemicals?



© Stephen Burdick Design



Find out more: [Watch "Dirty Little Secrets About House Dust" Film](#)



IMMUNE SYSTEM MODULATION AS A PROTECTIVE FACTOR

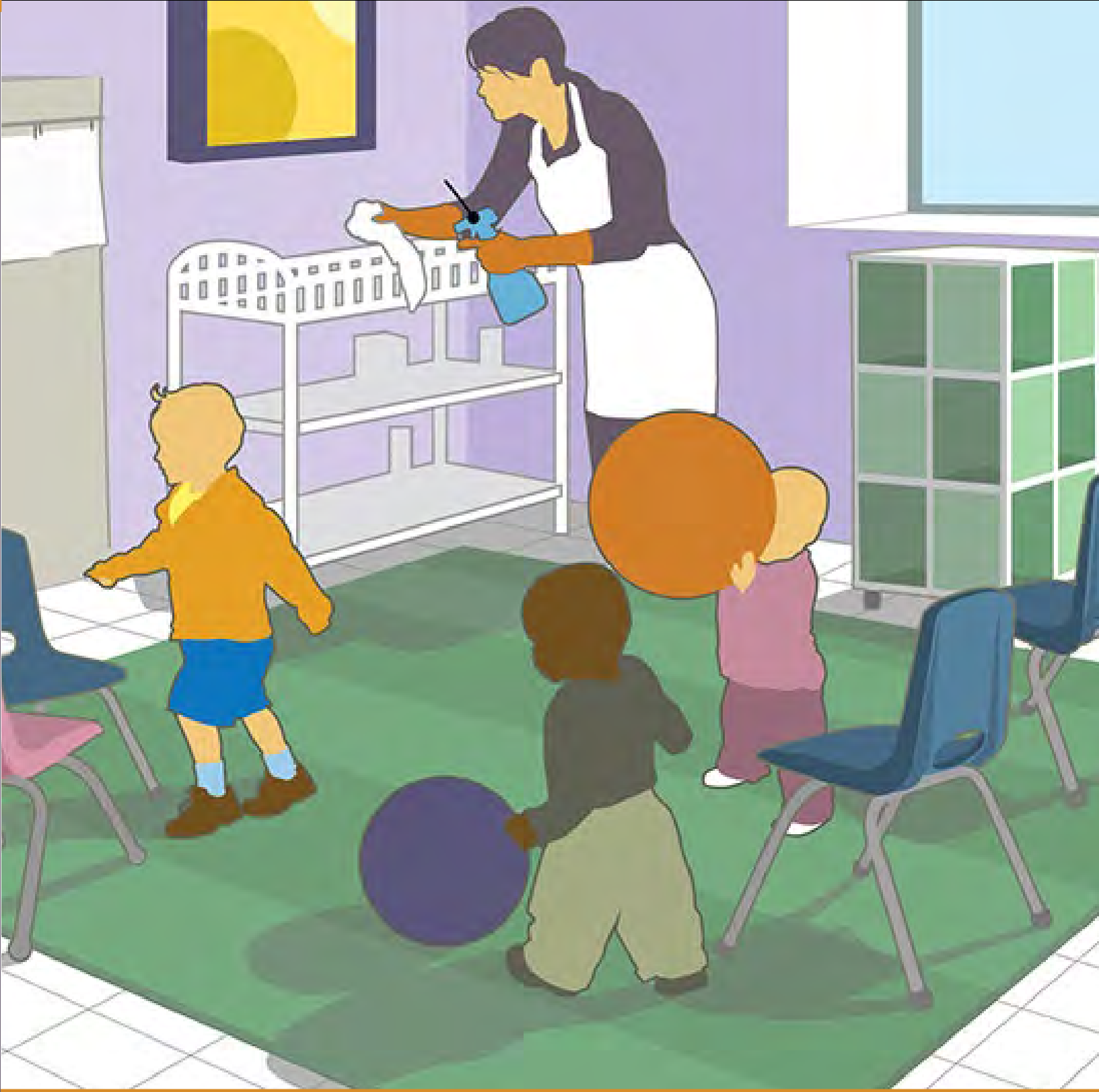
Stephen attended preschool before he started chemotherapy.

One day, Tricia and David ran into parents at the grocery store whose children also attended Stephen's preschool. They mentioned that their daughter had just gotten over a cold. Tricia thought it seemed like she was always hearing about someone getting sick in that school, but it was one of the larger preschools. She started to worry about whether something was going around at school that could have made Stephen sick.

Stephen got several serious infections as a young child and they emailed Dr. Baker about whether this could be related to their son's leukemia.

Dr. Baker responded that going to a large pre-school could actually be protective against childhood cancer, but that children with leukemia report more frequent severe infections throughout their childhood before diagnosis, perhaps indicating an altered or more severe immune system response to common infections.

Watch: [Dr. Joe Wiemels discusses theories about infection and leukemia rates](#) (3:55 mins.)



[Exposure to farm animals and pets reference](#)

Graphic for Infection and leukemia risk used with permission.

Infections reference: Rudant J, et al. [Childhood acute lymphoblastic leukemia and indicators of early immune stimulation: a Childhood Leukemia International Consortium study.](#) Am J Epidemiol. 2015 Apr 15;181(8):549-62.

CANCER CLUSTERS

One day while waiting in the hospital for Stephen's treatment, Tricia and David meet a family that looked familiar from the neighborhood. They realized that they were at the hospital for the same leukemia treatment. They wondered if other families in the neighborhood were facing the same thing, too. They asked their doctor to speak with local health officials to share this information and to see if other doctors might have reported seeing other cases of children with leukemia within the same neighborhood or community. The doctor agreed and told them about a [study that showed a confirmed cluster of leukemia in Woburn, Massachusetts](#).

A cancer cluster occurs when a greater than expected number of cancer cases within a group of tumors or with similar risk factors arise among people in a defined geographic area during a specific time. Due to the nature of the disease and the time it takes for cancers to develop, investigations to determine if a cancer cluster exists and what might be the potential cause or contributing factors are very challenging. However, the Centers for Disease Control and Prevention encourages examinations of unusual patterns of cancer and environmental concerns when they appear through regular monitoring of disease rates or when concerns are brought to the attention of health officials (see CDC's [About Unusual Patterns of Cancer](#)).

Although the causes of many cancers are unknown, some causal relationships have been shown between environmental exposures and development of cancer in specific organs (for example, [exposure to asbestos](#) and the [development of mesothelioma](#)). However, in most investigations of suspected cancer clusters, a cause is not identified.



Find out more:

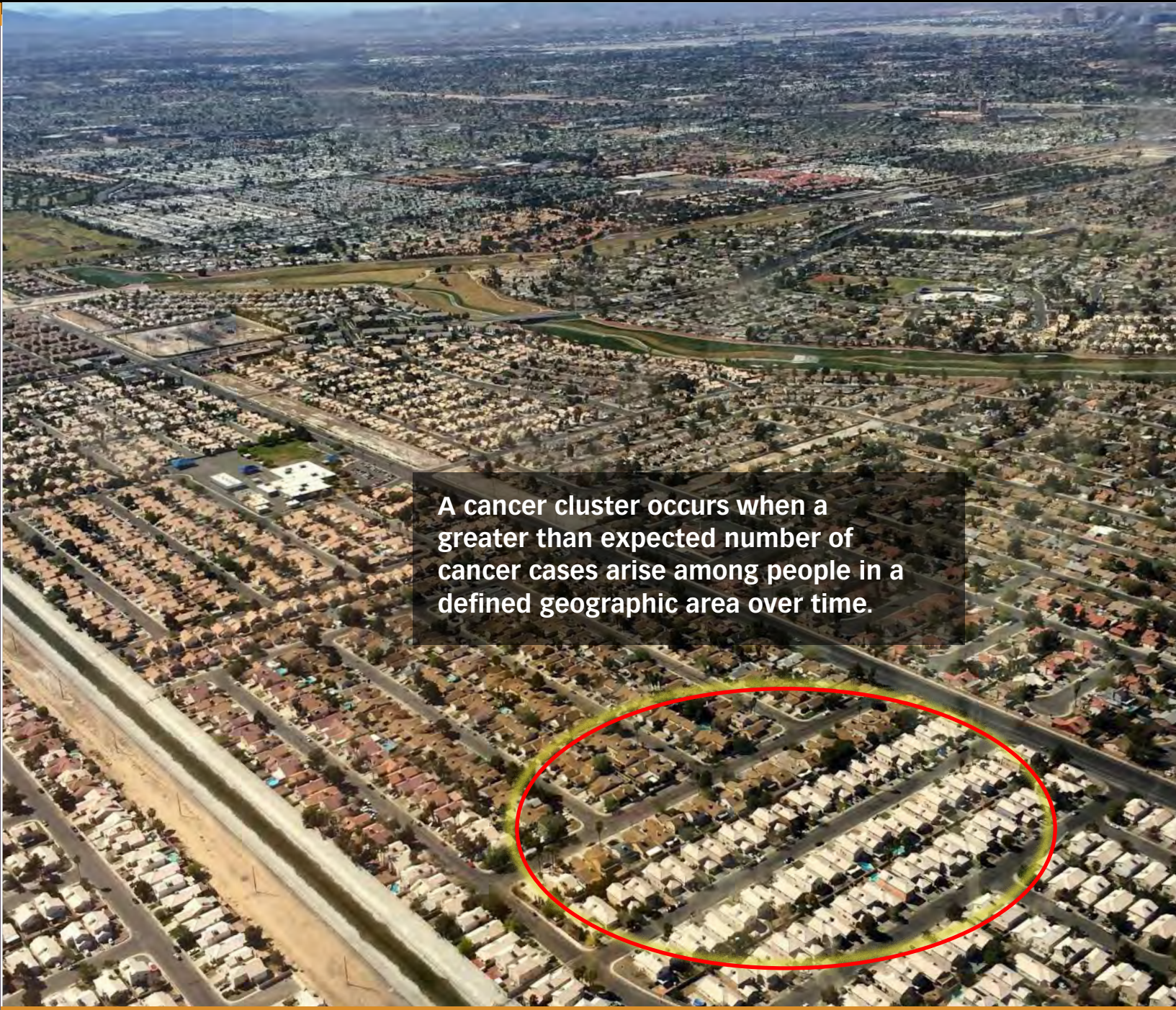
[Community Health Studies and Environmental Contamination](#)

[About Unusual Patterns of Cancer NCEH | CDC](#)

[Wilmington Childhood Cancer Study](#)



[Read the Cancer Clusters Fact Sheet from the National Cancer Institute](#)



IONIZING RADIATION (including X-ray and CT scan) exposure and childhood cancer

Along with the few infections that Stephen had as a baby, he caught pneumonia when he was six months old. This required a trip to the doctor and a few chest x-rays.

Exposure to ionizing radiation from nuclear accidents, x-rays, or radiation therapy has been associated with increased risk of childhood leukemia. Multiple studies have consistently shown in utero exposures to ionizing radiation increase the risk of leukemia by approximately 40% (Baffler et al., 2005).

Due to high radioprotection standards for pregnant women, prenatal exposure to medical radiation is rare, yet child's exposure to medical imaging after birth remains common.

CT-scans are of particular concern for children because children are considerably more sensitive to radiation than adults, they have a longer life expectancy resulting in a larger window of opportunity for expressing radiation damage, and doses are cumulative over a lifetime. CT-scans use has substantially increased in the early 2000's and they often result in higher radiation exposures than X-rays (Linnet et al., 2009).

Pooled analyses showed that diagnostic CT scans given at a young age augments the risk of developing both childhood leukemia and brain tumors (figures 4 and 5 in paper by Abalo et al., 2021), and that the risk increases with increasing levels of exposure (Pearce et al., 2012).

More information:
[National Toxicology Program \(NTP\) Research Overview](#)



National Cancer Institute: [Radiation Risks and Pediatric Computed Tomography \(CT\)](#)

In contrast, there is no definite evidence that X-rays increase the risk of those cancers (Abalo 2021).

However, if the imaging test is necessary and clinically justified, then the parents can be reassured that the benefits will outweigh the long-term cancer risks. In recent years, radiologists and technicians in many hospitals have undertaken steps to reduce the exposure from x-rays and CT scans while maintaining the necessary quality of the image (Lambert et al., 2014). Many clinicians are considering whether a patient evaluation involving radiation exposure is truly necessary, or if the information of interest can be acquired in some other way.

Another source of radiation exposure to the public is environmental background radon, which is an established lung carcinogen. However, studies on childhood leukemia have been inconclusive with both positive and negative results depending on the region/ country and study design (Lu et al., 2020).

Electromagnetic Spectrum graphic:
[EPA: Radiation basics](#)



"Radiotherapy"
by Susan Macfarlane,
reproduced with permission.

SOCIAL SUPPORT

Dr. Baker emphasizes to Tricia and David the importance of Stephen continuing his chemotherapy medications throughout the duration of recommended treatment. Stephen will undergo an intensive therapy period that ranges from 6-9 months, requiring frequent visits to Dr. Baker's office or the hospital. After this time, Stephen will receive maintenance chemotherapy where he visits the oncologist approximately once a month, but the frequency of these visits will depend on how well Stephen tolerates his medications.

A month into Stephen's therapy his parents joined a support group for parents of kids with leukemia and learned about different resources. Studies indicate that social support can improve the quality of life in pediatric cancer patients. These benefits can include reduced anxiety and post-traumatic stress among childhood cancer survivors. More adaptive coping strategies were also observed with family and social support.



[Commonweal Cancer Help Program](#)



Find out more about support groups, community links:

[National Cancer Institute:](#)

[Adolescent and Young Adult Cancer Programs](#)

[Emotional Support for Young People with Cancer](#)

[CureSearch for Children's Cancer](#)

[American Cancer Society – Cancer.org](#)

[The Leukemia & Lymphoma Society \(LLS\)](#)



Watch: [Dr. Gary Dahl on chemotherapy compliance](#) (1:30 mins.)

CHILDHOOD CANCER

Stephen's Story

After learning about the risks of chemical substances in the environment, Stephen's parents are taking steps to reduce exposures to their family and their community.

The nursery that they own will be transitioning to an all organic business model, and they are working with other local businesses like the town's golf course to partner together and use Integrated Pest Management (IPM). They have also become active in the local school board to help Stephen's preschool switch to IPM.

Tricia and David are considering having another child after Stephen completes chemotherapy and is in full remission. They are relieved that the risk of leukemia for siblings remains low.

After researching the possible causes of Stephen's disease and becoming more knowledgeable about how many environmental factors impact health, they will take extra precautions to promote a healthy pregnancy. Tricia will be taking folate supplements before conception and during the pregnancy. She also plans to avoid the various environmental exposures that she has learned about to the extent possible.



More Resources:

Pesticides: [Integrated Pest Management \(IPM\) Principles | US EPA](#)

[Bio-Integral Resource Center \(BIRC\)](#)

[Pesticide Action Network \(PANNA\)](#)

[UC Statewide Integrated Pest Management Program](#)

[IPM in Early Care and Education](#)

CHILDHOOD CANCER

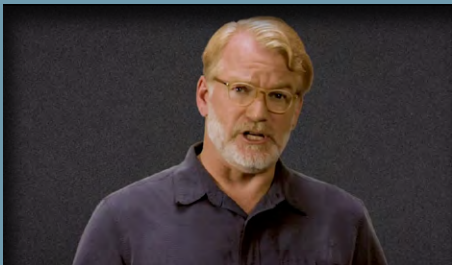
Stephen's Story

When Tricia, David, and Stephen joined the rest of the family at this year's reunion, they were cautiously optimistic about the future.

Stephen was responding well to chemotherapy and the family had found comfort in their local cancer support group and advocacy efforts to bring about change in their Connecticut town.

David tells the family about how far cancer treatments have progressed in recent years and that Stephen has approximately a 90% chance of being free of cancer in 5 years. They were all still concerned about the possibility of a relapse but have grown stronger as a family and as a community.

Watch: [Cause or Cure? Dr. Bruce P. Lanphear – Is the relentless pursuit of a cure hazardous to our health?](#) (4:28 mins.)



Dr. Bruce P. Lanphear, MD MPH,
Professor, Simon
Fraser University



CHILDHOOD CANCER

Stephen's Story

SUMMING UP

Several common themes arise in Stephen's story that are similar to others in *A Story of Health*. These include the importance of critical windows of susceptibility, the consideration of sub-groups within a disease, the multiple risk factors, and the interaction of underlying genetics with the chemical, social and other environments. We are also reminded that population studies can illuminate underlying risk factors of disease (and therefore possible preventive actions), but generally cannot answer the specific question, "what caused this illness in this child?"

Like other chronic diseases that have been increasing in recent years, childhood leukemia is complex. Although there is no consensus amongst experts about its causes, except in a small percentage of cases, evidence implicating a variety of risk factors continues to accumulate. For example, considerable evidence from multiple studies around the world implicates exposures to tobacco smoke, pesticides, radiation, and traffic-related air pollution. The evidence of protective effects of peri-conception folate supplementation, breastfeeding, and early exposures in daycare also has substantial support.

Other associations that we have discussed in Stephen's story (e.g., PCBs and PBDEs) have been examined in only one or two studies and highlight the need for further investigation.

Though it may seem daunting, viewing health and disease as a result of the complex ecology of modern life reveals many key leverage points in which preventive actions may reduce disease incidence and improve health. Several of these are merely reinforcing current recommendations from medical societies and other expert practice guidance.

Many of the risk factors associated with childhood leukemia are also risk factors for other diseases discussed in *A Story of Health*. People will benefit in a variety of ways from avoiding unnecessary exposures to tobacco smoke, pesticides, solvents and other environmental concerns.

Viewing health and disease as a result of the complex ecology of modern life reveals many key leverage points in which preventive actions may reduce disease incidence and improve health



Population studies can illuminate underlying risk factors of disease (and therefore possible preventive actions), but generally cannot answer the specific question, "what caused this illness in this child?"

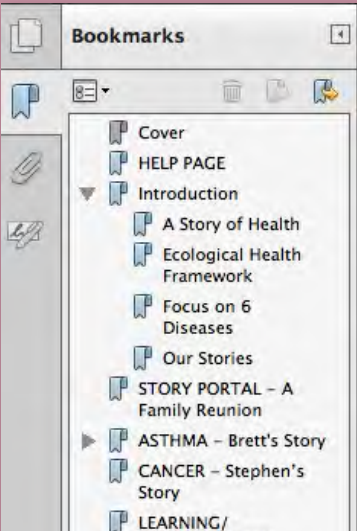
COMMON THEMES

Although the fictional narratives in *A Story of Health* describe the lives of children and adults with different conditions and diseases – childhood cancer, infertility, asthma, developmental disabilities, cognitive decline and health effects of wildfires, common themes resonate. They include:

- Important environmental influences come from the natural, chemical, food, built, and social environments.
- Although there are exceptions, most diseases as well as good health are the result of complex interactions among multiple environmental influences and genetics.
- Early-life experiences, particularly during critical windows of development, can have profound beneficial or detrimental lifelong effects, even into elder years.
- Healthy people and healthy communities are interdependent. All people do not have equal access to nutritious food, clean air and water, safe workplaces, healthy housing, green spaces, peaceful neighborhoods or quality health care.
- Preventing disease and promoting health require actions and commitments from the individual, family, community and society. Health promoting public policies are necessary to make healthy living available to all people.

Bookmarks

We have linked to many useful resources in each story relevant to a wide range of audiences, including clinicians. To quickly access resources on specific topics in each story, use the **Bookmarks** toolbar on the left (which you can open or close), or [return to the Help page](#) for more details on other eBook features.



Additional Resources

Pediatric Environmental Health Toolkit application for mobile devices

The Toolkit is an easy-to-use reference guide for health providers on preventing exposures to toxic chemicals and other substances that affect infant and child health. The new mobile device-ready online version of the PEHT includes links to many related online resources.



Continuing Education

To receive continuing education (CE) for SS4677- *A Story of Health – Childhood Cancers: Stephen's Story*, please visit [CDC TRAIN](#) and search for the course in the Course Catalog using SS4677.

Childhood Cancer Case References and Resources by Topic

Note: there are many topic overlaps

Birth Characteristics as Risk Factor for Childhood Cancer

Milne E, et al. Fetal growth and childhood acute lymphoblastic leukemia: findings from the Childhood Leukemia International Consortium (CLIC). Int J Cancer. 2013 Dec 15;133(12):2968-79.

Paltiel O, et al. International Childhood Cancer Cohort Consortium. Birthweight and Childhood Cancer: Preliminary Findings from the International Childhood Cancer Cohort Consortium (I4C). Paediatr Perinat Epidemiol. 2015 Jul;29(4):335-45. Erratum in: Paediatr Perinat Epidemiol. 2015 Nov;29(6):589.

Petridou ET, et al. Advanced parental age as risk factor for childhood acute lymphoblastic leukemia: results from studies of the Childhood Leukemia International Consortium. Eur J Epidemiol. 2018 May 14.

Wang R, Metayer C, Morimoto L, Wiemels JL, Yang J, DeWan AT, Kang A, Ma X. Parental Age and Risk of Pediatric Cancer in the Offspring: A Population-Based Record-Linkage Study in California. Am J Epidemiol. 2017 Oct 1;186(7):843-856.

Tumors

Brain Tumors

Fisher PG, Reynolds P, Von Behren J, Carmichael SL, Rasmussen SA, Shaw GM. Cancer in children with nonchromosomal birth defects. J Pediatr. 2012 Jun;160(6):978-83.

Johnson et al. Childhood brain tumor epidemiology: a brain tumor epidemiology consortium review. Cancer Epidemiol Biomarkers Prev. 2014 Dec;23(12):2716-36.

Van Maele-Fabry G, Gamet-Payraastre L, Lison D. Residential exposure to pesticides as risk factor for childhood and young adult brain tumors: A systematic review and meta-analysis. Environ Int. 2017 Sep;106:69-90.

Wilms Tumors

Chu A et al. Wilms’ tumour: a systematic review of risk factors and meta-analysis. Paediatr Perinat Epidemiol. 2010 Sep;24(5):449-69.

Cooney MA, Daniels JL, Ross JA, Breslow NE, Pollock BH, Olshan AF. Household pesticides and the risk of Wilms tumor. Environ Health Perspect. 2007 Jan;115(1):134-7.

Kahn A, Feulefack J, Sergi CM. Exposure to pesticides and pediatric Wilms’ tumor. A meta-analysis on pre-conception and pregnancy parental exposure with an IARC/WHO commentary. Hum Exp Toxicol. 2022 Jan-Dec;41:9603271221136211.

Rios P et al. Environmental exposures related to parental habits in the perinatal period and the risk of Wilms’ tumor in children. Cancer Epidemiol. 2020 Jun;66:101706.

Caesarian Section as Risk Factor for Leukemia

Marcotte EL, et al. Cesarean delivery and risk of childhood leukemia: a pooled analysis from the Childhood Leukemia International Consortium (CLIC). Lancet Haematol. 2016 Apr;3(4):e176-85. Erratum in: Lancet Haematol. 2016 Apr;3(4):e162.

Wang R, Wiemels JL, Metayer C, Morimoto L, Francis SS, Kadan-Lottick N, DeWan AT, Zhang Y, MaX. Cesarean Section and Risk of Childhood Acute Lymphoblastic Leukemia in a Population-Based, Record-Linkage Study in California. Am J Epidemiol. 2017 Jan 15;185(2):96-105.

Cancer Clusters, Unusual Patterns of Cancer

About Unusual Patterns of Cancer NCEH | CDC

Abrams B, Anderson H, Blackmore C, et al. Investigating suspected cancer clusters and responding to community concerns: Guidelines from CDC and the Council of State and Territorial Epidemiologists. September 27, 2013 / 62(RR08): 1-14

National Cancer Institute; National Institutes of Health. Cancer Clusters.



Chemical Exposures and Childhood Cancer - Specific Pollutants:

Air Pollution

Boothe VL, Boehmer TK, Wendel AM, Yip FY. Residential traffic exposure and childhood leukemia a systematic review and meta-analysis. Am J Prev Med 2014;46(4):413–422.

Filippini T, Hatch EE, et al. Association between Outdoor Air Pollution and Childhood Leukemia: A Systematic Review and Dose-Response Meta-Analysis. Environ Health Perspect. 2019 Apr;127(4):46002.

Heck JE, Wu J, Lombardi C, et al. Childhood cancer and traffic-related air pollution exposure in pregnancy and early life. Environ Health Perspect 2013;121(11-12):1385-1391).

Mazzei A. Childhood cancer and residential proximity to petrol stations: a nationwide registry-based case-control study in Switzerland and an updated meta-analysis. Int Arch Occup Environ Health. 2022 Jul;95(5):927-938.

Reynolds P, Von Behren J, Gunier RB, et al. Childhood cancer incidence rates and hazardous air pollutants in California: An exploratory analysis. Environ Health Perspect 2003;111(4):663-8.

Steffen C, Auclerc MF, Auvrignon A, et al. Acute childhood leukaemia and environmental exposure to potential sources of benzene and other hydrocarbons; a case-control study. Occup Environ Med 2004;61:773-778.

Vinceti M, Rothman KJ, Crespi CM, et al. Leukemia risk in children exposed to benzene and PM10 from vehicular traffic: A case-control study in an Italian population. Eur J Epidemiol 2012;27(10):781-90

House Dust

Flame retardants: Green Science Policy Institute

U.S. EPA. Polychlorinated biphenyls (PCBs): Basic Information

U.S. EPA Polybrominated Diphenyl Ethers (PBDEs) Action Plan Summary

Ward MH, Colt JS, Metayer C, et al. Residential exposure to polychlorinated biphenyls and organochlorine pesticides and risk of childhood leukemia. Environ Health Perspect 2009;117(6):1007-1013.

Ward MH, Colt JS, Deziel NC, et al. Residential Levels of Polybrominated Diphenyl Ethers and Risk of Childhood Acute Lymphoblastic Leukemia in California. Environ Health Perspect; DOI:10.1289/ehp.1307602

Oil and Gas

Clark CJ, Johnson NP, Soriano M, et al. Unconventional Oil and Gas Development Exposure and Risk of Childhood Acute Lymphoblastic Leukemia: A Case–Control Study in Pennsylvania, 2009–2017. Environ Health Perspect.

Mazzei A, Konstantinoudis G, Kreis C, Diezi M, Ammann RA, Zwahlen M, Kühni C, Spycher BD. Childhood cancer and residential proximity to petrol stations: a nationwide registry-based case-control study in Switzerland and an updated meta-analysis. Int Arch Occup Environ Health. 2022 Jul;95(5):927-938.

McKenzie LM, Allshouse WB, Byers TE, Bedrick EJ, Serdar B, Adgate JL. Childhood hematologic cancer and residential proximity to oil and gas development. PLOS ONE. 2017;12(2):e0170423. <https://pubmed.ncbi.nlm.nih.gov/28199334/>



Pesticides

American Academy of Pediatrics. Policy Statement: Pesticide Exposure in Children. November 2012

Chen M, Chang CH, Tao L, Lu C. Residential Exposure to Pesticide During Childhood and Childhood Cancers: A Meta-Analysis. Int J Hyg Environ Health. 2022 Jan;239:113881

Infante-Rivard C, Weichenthal S. Pesticides and childhood cancer: An update of Zahm and Ward’s 1998 review. J Toxicol Environ Health B Crit Rev 2007;10(1-2):81-99.

Ma X, Buffler PA, Gunier RB, et al. Critical windows of exposure to household pesticides and risk of childhood leukemia. Environ Health Perspect 2002;110(9):955-60.

Metayer C, Buffler PA. Residential exposures to pesticides and childhood leukaemia. Radiation Protection Dosimetry 2008;132 (2):212-9.

Metayer C, Colt JS, Buffler PA, et al. Exposure to herbicides in house dust and risk of childhood acute lymphoblastic leukemia. Journal of Exposure Science and Environmental Epidemiology 2013; 23:363-370.

Natural Resources Defense Council. Superficial safeguards: Most pesticides are approved by flawed EPA process. March 2013

Rull RP, Gunier R, Von Behren J, et al. Residential proximity to agricultural pesticide applications and childhood acute lymphoblastic leukemia. Environ Res 2009;109(7):891-899.

S

wartz SJ, Morimoto LM, Whitehead TP, DeRouen MC, Ma X, Wang R, Wiemels JL, McGlynn KA, Gunier R, Metayer C. Proximity to endocrine-disrupting germ cell tumors (TGCT) among adolescents: A population-based case-control study in California. Int J Hyg Environ Health. 2022 Jan;239:113881

Van Maele-Fabry G, Gamet-Payraastre L, Lison D. Residential exposure to pesticides as risk factor for childhood and young adult brain tumors: A systematic review and meta-analysis. Environ Int. 2017 Sep;106:69-90.

Solvents

Bailey HD, Metayer C, Milne E, Petridou ET, Infante-Rivard C, Spector LG, Clavel J, Dockerty JD, Zhang L, Armstrong BK, Rudant J, Fritschi L, Amigou A, Hatzipantelis E, Kang AY, Stiakaki E, Schüz J. Home paint exposures and risk of childhood acute lymphoblastic leukemia: findings from the Childhood Leukemia International Consortium. Cancer Causes Control. 2015 Sep;26(9):1257-70. doi:

Carlos-Wallace FM, Zhang L, Smith MT, Rader G, Steinmaus C. Parental, In Utero, and Early-Life Exposure to Benzene and the Risk of Childhood Leukemia: A Meta-Analysis. Am J Epidemiol. 2016 Jan 1;183(1):1-14.

Freedman DM, Stewart P, Kleinerman RA, Wacholder S, Hatch EE, Tarone RE, Robison LL, Linet MS. Household solvent exposures and childhood acute lymphoblastic leukemia. Am J Public Health. 2001 Apr;91(4):564-7.

Metayer C, Scelo G, Kang AY, Gunier RB, Reinier K, Lea S, Chang JS, Selvin S, Kirsch J, Crouse V, Does M, Quinlan P, Hammond SK. A task-based assessment of parental occupational exposure to organic solvents and other compounds and the risk of childhood leukemia in California.Environ Res. 2016 Nov;151:174-183.

Scelo G, Metayer C, Zhang L, et al. Household exposure to paint and petroleum solvents, chromosomal translocations, and the risk of childhood leukemia. Environ Health Perspect 2009;117(1):133-139.

Whitehead TP, Metayer C, Wiemels JL, Singer AW, Miller MD. Childhood Leukemia and Primary Prevention. Curr Probl Pediatr Adolesc Health Care. 2016 Oct;46(10):317-352.

Take Home Exposures to Chemicals

Gerson M, Van den Eeden SK, Gahagan P. Take-home lead poisoning in a child from his father’s occupational exposure. Am J Ind Med. 1996 May;29(5):507-8.

Fenske RA, Lu C, Negrete M, Galvin K. Breaking the take home pesticide exposure pathway for agricultural families: workplace predictors of residential contamination. Am J Ind Med. 2013 Sep;56(9):1063-71.

Tobacco Smoke

Cogliano VJ, Baan R, Straif K, et al. Preventable exposures associated with human cancers. J Natl Cancer Inst 2011;103(24):1827-39.

IARC. Tobacco smoke and involuntary smoking. monographs on the evaluation of carcinogenic risks to humans. Volume 83. July 2002

Liu R, Zhang L, McHale CM, Hammond SK. Paternal smoking and risk of childhood acute lymphoblastic leukemia: systematic review and meta-analysis. J Oncol. 2011. Epub 2011 May 29.

Metayer C, Petridou E, Mejía Aranguré JM, Roman E. et al. Parental tobacco smoking and acute myeloid leukemia in children: the Childhood Leukemia International Consortium. Am J Epidemiol. 2016 Aug 15;184(4):261-73.

Metayer C, Zhang L, Wiemels JL, et al. Tobacco smoke exposure and the risk of childhood acute lymphoblastic and myeloid leukemias by cytogenetic subtype. Cancer Epidemiol Biomarkers Prev 2013; 22(9):1600-11.

Milne E, Greenop KR, Scott RJ, Bailey HD, Attia J, Dalla-Pozza L, de Klerk NH, Armstrong BK. Parental prenatal smoking and risk of childhood acute lymphoblastic leukemia. Am J Epidemiol. 2012 Jan 1;175(1):43-53.

Office of Environmental Health Hazard Assessment. Proposed identification of environmental tobacco smoke as a toxic air contaminant. Part B: Health effects 2005. California Environmental Protection Agency.

U.S. Department of Health and Human Services. Chapter Five: Reproductive and developmental effects from exposure to secondhand smoke. In: The health consequences of involuntary exposure to tobacco smoke: A report of the surgeon general. Atlanta, GA: Centers for Disease Control and Prevention, Coordinating Center for Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2006: p. 165-256.

Childhood Cancer Definition, Statistics

Cancer Research UK. Acute lymphoblastic leukaemia.

Cancer Research UK. Childhood cancer incidence statistics.

Greaves MF. Childhood leukaemia. BMJ. 2002;324:283

Metayer C, Milne E, Clavel J, et al. The Childhood Leukemia International Consortium. Cancer Epidemiol 2013;37(3):336-47

National Cancer Institute. General information about childhood acute lymphoblastic leukemia (ALL) – Health Professional Version

SEER*Explorer: An interactive website for SEER cancer statistics

Siegel RL et al. Cancer statistics, 2022

U.S. National Library of Medicine. [MedlinePlus: Bone marrow aspiration](#)

Ward E, DeSantis C, Robbins A, Betsy Kohler, et al. Childhood and Adolescent Cancer Statistics, 2014. [CA Cancer J Clin](#) 2014;64:83-103

Wiemels J. Perspectives on the causes of childhood leukemia. [Chem Biol Interact.](#) 2012 Apr 5; 196(3):59-67

Genetics

Curtin K, Smith KR, Fraser A, Pimentel R, Kohlmann W, Schiffman JD Familial risk of childhood cancer and tumors in the Li-Fraumeni spectrum in the Utah Population Database: implications for genetic evaluation in pediatric practice. [Int J Cancer.](#) 2013 Nov 15;133(10):2444-53

Feng Q et al. Increased burden of familial-associated early-onset cancer risk among minority Americans compared to non-Latino Whites. [Elife.](#) 2021 Jun 22;10:e64793.

Foss-Skiftesvik J, Li S, Rosenbaum A, Hagen CM, Stoltze UK, Ljungqvist S, Hjalmars U, Schmiegelow K, Morimoto L, de Smith AJ, Mathiasen R, Metayer C, Hougaard D, Melin B, Walsh KM, Bybjerg-Grauholm J, Dahlin AM, Wiemels JL. Multi-ancestry genome-wide association study of 4,069 children with glioma identifies 9p21.3 risk locus. *Neuro Oncology*, in press.

Jeon S et al. Genome-wide trans-ethnic meta-analysis identifies novel susceptibility loci for childhood acute lymphoblastic leukemia. [Leukemia.](#) 2022 Mar;36(3):865-868.

Knapke S, Zelle K, Nichols KE, et al. American Society of Clinical Oncology. 2012. [Identification, management, and evaluation of children with cancer-predisposition syndromes.](#) 2012

Li S, Chiang CWK, Myint SS, Arroyo K, Chan TF, Morimoto L, Metayer C, de Smith AJ, Walsh KM, Wiemels JL. Localized variation in ancestral admixture identifies pilocytic astrocytoma risk loci among Latino children. [PLoS Genet.](#) 2022 Sep 7;18(9):e1010388.

Healthy Eating

Milne E, Greenop KR, Petridou E, Bailey HD, Orsi L, Kang AY, Baka M, Bonaventure A, Kourti M, Metayer C, Clavel J. Cancer Causes Control. Maternal consumption of coffee and tea during pregnancy and risk of childhood ALL: a pooled analysis from the Childhood Leukemia International Consortium. [2018 Jun;29\(6\):539-550.](#)

Singer AW, Carmichael SL, Selvin S, Fu C, Block G, Metayer C. Maternal diet quality before pregnancy and risk of childhood leukaemia. [Br J Nutr.](#) 2016 Oct;116(8):1469-1478. Epub 2016 Oct 11.

Singer AW, Selvin S, Block G, Golden C, Carmichael SL, Metayer C. Maternal prenatal intake of one-carbon metabolism nutrients and risk of childhood leukemia. [Cancer Causes Control.](#) 2016 Jul;27(7):929-40.

Immune System, Infections

Greaves MF. Infection, immune responses and the aetiology of childhood leukaemia. [Nat Rev Cancer.](#) 2006;6:193–203

He JR, et al. Common maternal infections during pregnancy and childhood leukaemia in the offspring: findings from six international birth cohorts. *International Childhood Cancer Cohort Consortium.* [Int J Epidemiol.](#) 2022 Jun 13;51(3):769-777.

Marcotte EL, Ritz B, Cockburn M, et al. Exposure to infections and risk of leukemia in young children. *Cancer epidemiol biomarkers Prev* 2014. DOI: 10.1158/1055-9965.EPI-13-1330

Rudant J, Lightfoot T, Urayama KY, Petridou E, Dockerty JD, Magnani C, Milne E, Spector LG, Ashton LJ, Dessypris N, Kang AY, Miller M, Rondelli R, Simpson J, Stiakaki E, Orsi L, Roman E, Metayer C, Infante-Rivard C, Clavel J. Childhood acute lymphoblastic leukemia and indicators of early immune stimulation: a Childhood Leukemia International Consortium study. [Am J Epidemiol.](#) 2015 Apr 15;181(8):549-62.



Urayama KY, Buffler PA, Gallagher ER, et al. A meta-analysis of the association between day-care attendance and childhood acute lymphoblastic leukaemia. [Int J Epidemiol](#) 2010;39(3):718-732.

Maternal Infection

He JR, et al. Common maternal infections during pregnancy and childhood leukaemia in the offspring: findings from six international birth cohorts. *International Childhood Cancer Cohort Consortium.* [Int J Epidemiol.](#) 2022 Jun 13;51(3):769-777.

Occupational Exposures

Bailey HD, Fritschi L, Infante-Rivard C, et al. Parental occupational pesticide exposure and the risk of childhood leukemia in the offspring: Findings from the childhood leukemia international consortium. [Int J Cancer](#) 2014; DOI: 10.1002/ijc.28854.

Borkhardt A, Wilda M, Fuchs U, et al. Congenital leukaemia after heavy abuse of permethrin during pregnancy 3. [Arch Dis Child Fetal Neonatal](#) Ed 2003;88:F436–7.

Colt JS, Blair A. 1998. Parental occupational exposures and risk of childhood cancer. [Environmental Health Perspectives](#) 106 (Suppl. 3):909-925. 42 4314

Coste A, Bailey HD, Kartal-Kaess M, Renella R, Berthet A, Spycher BD. Parental occupational exposure to pesticides and risk of childhood cancer in Switzerland: a census-based cohort study. [BMC Cancer.](#) 2020 Aug 28;20(1):819.

Etzel RA, Balk SJ (eds.). Pediatric Environmental Health. [American Academy of Pediatrics Council on Environmental Health.](#) 4th Ed. 2018

Feulefack J, Khan A, Forastiere F, Sergi CM. Parental Pesticide Exposure and Childhood Brain Cancer: A Systematic Review and Meta-Analysis Confirming the IARC/WHO Monographs on Some Organophosphate Insecticides and Herbicides. [Children \(Basel\).](#) 2021 Nov 28;8(12):1096.

Feychting, M., N. Plato, G. Nise, and A. Ahlbom. 2001. Paternal occupational exposures and childhood cancer. [Environ Health Perspect](#) 109 (2):193-6

Infante-Rivard C, Siemiatycki J, Lakhani R, Nadon L. Maternal exposure to occupational solvents and childhood leukemia. [Environ Health Perspect](#) 2005;113 (6):787-92.

LaFiura KM, Bielawski DM, Posecion NC, et al. Association between prenatal pesticide exposures and the generation of leukemia-associated t(8;21). [Pediatr Blood Cancer](#) 2007;49:624–8.

Mavoungou S, Rios P, Pacquement H, Nolla M, Rigaud C, Simonin M, Bertrand Y, Lambilliotte A, Faure L, Orsi L, Clavel J, Bonaventure A. Maternal exposure to pesticides and risk of childhood lymphoma in France: A pooled analysis of the ESCALE and ESTELLE studies (SFCE). [Cancer Epidemiol.](#) 2020 Oct;68:101797.

Patel DM, Jones RR, Booth BJ, Olsson AC, Kromhout H, Straif K, Vermeulen R, Tikellis G, Paltli O, Golding J, Northstone K, Stoltenberg C, Håberg SE, Schüz J, Friesen MC, Ponsonby AL, Lemeshow S, Linet MS, Magnus P, Olsen J, Olsen SF, Dwyer T, Stayner LT, Ward MH; International Childhood Cancer Cohort Consortium. Parental occupational exposure to pesticides, animals and organic dust and risk of childhood leukemia and central nervous system tumors: Findings from the International Childhood Cancer Cohort Consortium (I4C). [Int J Cancer.](#) 2020 Feb 15;146(4):943-952.

Rossides M, Kampitsi CE, Talbäck M, Mogensen H, Wiebert P, Feychting M, Tettamanti G. Risk of Cancer in Children of Parents Occupationally Exposed to Hydrocarbon Solvents and Engine Exhaust Fumes: A Register-Based Nested Case-Control Study from Sweden (1960-2015). [Environ Health Perspect.](#) 2022 Jul;130(7):77002.

Rossides M, Kampitsi CE, Talbäck M, Mogensen H, Wiebert P, Tettamanti G, Feychting M. Occupational exposure to pesticides in mothers and fathers and risk of cancer in the offspring: A register-based case-control study from Sweden (1960-2015). [Environ Res.](#) 2022 Nov;214(Pt 1):113820.

Rossides M, Kampitsi CE, Talbäck M, Wiebert P, Feychting M, Tettamanti G. Childhood cancer risk in offspring of parents occupationally exposed to dusts: A register-based nested case-control study from Sweden of 5 decades. [Cancer.](#) 2022 Apr 15;128(8):1637-1648.

Wigle DT, Arbuckle TE, Turner MC, et al. Epidemiologic evidence of relationships between reproductive and child health outcomes and environmental chemical contaminants. [J Toxicol Environ Health B Crit Rev](#) 2008;11(5-6):373-517.

Wigle DT, Turner MC, Krewski D. A systematic review and meta-analysis of childhood leukemia and parental occupational pesticide exposure. [Environ Health Perspect](#) 2009;117:1505-1513.

Prenatal/Preconception Care, Nutrition, Folic Acid

ACOG Practice Bulletin No. 44 Neural Tube Defects. American College of Obstetricians and Gynecologists. [Obstet Gynecol](#) 2003;102 (1):203-213.

ACOG FAQ: [Nutrition During Pregnancy.](#) 2013

Bailey HD, Miller M, Langridge A, de Klerk NH, van Bockxmeer FM, Attia J, Scott RJ, Armstrong BK, Milne E. Maternal dietary intake of folate and vitamins B6 and B12 during pregnancy and the risk of childhood acute lymphoblastic leukemia. [Nutr Cancer.](#) 2012;64(7):1122-30

Lambrot R, Xu C, Saint-Phar S, Chountalos G, Cohen T, Paquet M. Suderman M, Hallett M, and Kimmins S. Low paternal dietary folate alters the mouse sperm epigenome and is associated with negative pregnancy outcomes. [Nature Communications](#) 4. 2013; Article number:2889

Lyall K, Schmidt R, Hertz-Picciotto I. Maternal lifestyle and environmental risk factors for autism spectrum disorders. [Int J Epidemiol](#) 2014;43(2):443-464.

Metayer C, Milne E, Dockerty JD, et al. Maternal supplementation with folic acid and other vitamins and risk of leukemia in the offspring: a childhood leukemia international consortium study [Epidemiology.](#) 2014 Nov;25(6):811-22

Schmidt RJ, Tancredi DJ, Ozonoff S, et al. Maternal periconceptional folic acid intake and risk of autism spectrum disorders and developmental delay in the CHARGE (Childhood Autism Risks from Genetics and Environment) case-control study. [Am J Clin Nutr](#) 2012;96:80–9.

Surén P, Roth C, Bresnahan M, Haugen M, Hornig M, Hirtz D, Lie KK, Lipkin WI, Magnus P, Reichborn-Kjennerud T, Schjølberg S, Davey Smith G, Øyen AS, Susser E, Stoltenberg C. Association between maternal use of folic acid supplements and risk of autism spectrum disorders in children. [JAMA.](#) 2013 Feb 13;309(6):570-7.

U.S. Preventive Services Task Force. Folic acid for the prevention of neural tube defects: U.S. Preventive Services Task Force recommendation statement. [Ann Intern Med.](#) 2009; 150:626-631.

Radiation

Ionizing Radiation

Arthurs O, Bjorkum A. Safety in pediatric imaging: an update. [Acta Radiol.](#) 2013; 54(9):983-990.

Bartley K, Metayer C, Selvin S, Ducore J, Buffler P. Diagnostic X-rays and risk of childhood leukaemia. [Int J Epidemiol.](#) Dec 2010; 39(6): 1628–1637. doi: 10.1093/ije/dyq162.

Boice JD Jr, Miller RW. Childhood and adult cancer after intrauterine exposure to ionizing radiation. [Teratology](#) 1999;59(4):227-33.

Buffler, P.A., M.L. Kwan, P. Reynolds, and K.Y. Urayama. 2005. Environmental and genetic risk factors for childhood leukemia: appraising the evidence. [Cancer Investigation](#) 23 (1):60-75.

Chokkalingam AP, Bartley K, Wiemels JL, et al. Haplotypes of DNA repair and cell cycle control genes, X-ray exposure, and risk of childhood acute lymphoblastic leukemia. [Cancer Causes Control](#) 2011;22(12):1721-1730

Doll R, Wakeford R. Risk of childhood cancer from fetal irradiation. [Br J Radiol](#) 1997;70:130-139.

Fisher PG, Reynolds P, Von Behren J, Carmichael SL, Rasmussen SA, Shaw GM. Cancer in children with nonchromosomal birth defects. [J Pediatr.](#) 2012 Jun;160(6):978-83.

Foucault A. Childhood cancer risks estimates following CT scans: an update of the French CT cohort study. [Eur Radiol.](#) 2022 Aug;32(8):5491-5498.

Johnson KJ, Cullen J, Barnholtz-Sloan JS, Ostrom QT, Langer CE, Turner MC, McKean-Cowdin R, Fisher JL, Lupo PJ, Partap S, Schwartzbaum JA, Scheurer ME. Childhood brain tumor epidemiology: a brain tumor epidemiology consortium review. [Cancer Epidemiol Biomarkers Prev.](#) 2014 Dec;23(12):2716-36.

Johnson KJ, Cullen J, Barnholtz-Sloan JS, Ostrom QT, Langer CE, Turner MC, McKean-Cowdin R, Fisher JL, Lupo PJ, Partap S, Schwartzbaum JA, Scheurer ME. Childhood brain tumor epidemiology: a brain tumor epidemiology consortium review. [Cancer Epidemiol Biomarkers Prev.](#) 2014 Dec;23(12):2716-36.

Infante-Rivard C, Mathonnet G, Sinnett D. Risk of childhood leukemia associated with diagnostic irradiation and polymorphisms in DNA repair genes. [Environ Health Perspect](#) 2000;108(6):495-8.

Lambert J, MacKenzie J, Cody D, Gould R. Techniques and tactics for optimizing CT dose in adults and children: state of the art and future advances. [J Am Coll Radiol.](#) 2014; 11(3):262-266.

Linet M, Kim K, Rajaraman P. Children's exposure to diagnostic medical radiation and cancer risk: epidemiologic and dosimetric considerations. [Pediatr Radiol](#) 2009; 39 Suppl 1:S4-26.

Talibov M., Parental occupational exposure to low-frequency magnetic fields and risk of leukaemia in the offspring: findings from the Childhood Leukaemia International Consortium (CLIC). [Occup Environ Med.](#) 2019 Oct;76(10):746-753.

Non-ionizing Radiation

Abalo KD, et al. Early life ionizing radiation exposure and cancer risks: systematic review and meta-analysis. *Pediatr Radiol.* 2021 Jan;51(1):45-56. doi: 10.1007/s00247-020-04803-0. Epub 2020 Sep 10. Erratum in: *Pediatr Radiol.* 2020 Oct 22.

Ahlbom A, Day N, Feychting M, et al. A pooled analysis of magnetic fields and childhood leukaemia. [Br J Cancer.](#) 83 (2000). pp. 692–698.

Amoon AT, Swanson J, Magnani C, Johansen C, Kheifets L. Pooled analysis of recent studies of magnetic fields and childhood leukemia. [Environ Res.](#) 2022 Mar;204(Pt A):111993. doi: 10.1016/j.envres.2021.111993. Epub 2021 Sep 3.

Chen G, Xu Z. Global protein expression in response to extremely low frequency magnetic fields. [Adv Exp Med Biol.](#) 2013; 990:107-110.

Falcioni L, et al. Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. [Environ Res](#) 2018 Aug;165:496-503.

Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA. A pooled analysis of magnetic fields, wire codes, and childhood leukemia Childhood Leukemia-EMF Study Group. Epidemiology. 11 (2000), pp. 624–634

IARC. Non-Ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 80. March 2002

Kheifets L, Ahlbom A, Crespi CM, et al. Pooled analysis of recent studies on magnetic fields and childhood leukaemia. Br J Cancer. 103 (2010), pp. 1128–1135

Lu Y, Liu L, Chen Q, Wei J, Cao G, Zhang J. Domestic radon exposure and risk of childhood leukemia: A meta-analysis. J BUON. 2020 Mar-Apr;25(2):1035-1041.

National Toxicology Program: Cell Phone Radio Frequency Radiation

Pearce MS, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 2012 Aug 4;380(9840): 499-505. doi: 10.1016/S0140-6736(12)60815-0. Epub 2012 Jun 7.

Simkó M. Cell type specific redox status is responsible for diverse electromagnetic field effects. Curr Med Chem. 2007; 14(10):1141-1152.

Slusky DA, Does M, Metayer C, Mezei G, Selvin S, Buffler PA. Potential role of selection bias in the association between childhood leukemia and residential magnetic fields exposure: A population-based assessment. Cancer Epidemiology 2014; 38: 307-313.

Wertheimer N, Leeper E. Electrical wiring configurations and childhood cancer. Am J Epidemiol 1979: 109: 273-284.



Social Support

Kazak AE, Barakat LP, Meeske K, Christakis D, Meadows AT, Casey R, Penati B, Stuber ML. Posttraumatic stress, family functioning, and social support in survivors of childhood leukemia and their mothers and fathers. J Consult Clin Psychol. 1997 Feb;65(1):120-9.

Trask PC, Paterson AG, Trask CL, et al. Parent and adolescent adjustment to pediatric cancer: Associations with coping, social support, and family function. Journal of Pediatric Oncology Nursing 2003;20:36-47 DOI: 10.1053/jpon.2003.5

Trends

Ekanayake R, Miller M, Marty, M. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. Report to the Legislature, Children's Environmental Health Program. February 2014.

Howlader N, Noone AM, Krapcho M, Garshell J, Miller D, Altekruse SF, Kosary CL, et al., (eds). SEER Cancer Statistics Review, 1975-2011, National Cancer Institute. Bethesda, MD, July 2014.

SEER*Explorer: An interactive website for SEER cancer statistics

Siegel RL et al. Cancer statistics, 2022

Ward E, DeSantis C, Robbins A, Kohler B, Jemal A. Childhood and Adolescent Cancer Statistics, 2014. CA Cancer J Clin. 2014 Mar-Apr;64(2):83-103 ♦