Theo Colborn
A brief biography by Elizabeth Grossman

In the late 1980s, a scientist named Theo Colborn, working at the World Wildlife Fund and The Conservation Foundation in Washington, DC, produced a report that brought together for the first time, what was known about the effects of chemical pollutants on the health of Great Lakes wildlife and of these same contaminants on human health. First released in 1988, the report found many Great Lakes species and their offspring to be suffering from a wide range of adverse health effects, among them: reproductive and immune system problems, behavioral, hormonal and metabolic changes, deformities and tumors as well as overall population decline. The human health effects associated with these Great Lakes contaminants was strikingly similar to those in wildlife and although the precise outcome of the human exposures could not be determined, they were considered significant. Looking back at this research 25 years later this science appears disconcertingly prescient in linking chemical exposures to damaged health in both humans and wildlife.

The term endocrine disruptor was not then in use but the health effects Dr. Colborn's Great Lakes paper outlined have since been identified as among those associated with exposure to what are now known as endocrine disrupting chemicals – substances that, because of their chemical composition and structure, can interfere with the hormones that regulate and maintain many of the body's vital systems. For the past two to three decades, scientists all around the world have been contributing to the rapidly growing body of research into endocrine disruptors. Yet it is without exaggeration to say that the scientist whose work has been instrumental in spurring this enormous increase in scientific research and associated public and government attention is Theo Colborn. She has done this through her work that includes convening the groundbreaking "Wingspread" meetings in Wisconsin, as co-author of the landmark book, *Our Stolen Future*, as founder of the Endocrine Disruption Exchange, and through scores of published, peer-reviewed papers and tireless efforts to advance understanding of the links between common human exposures to chemicals (both indoors and out) and endocrine system health.

It's hard not to overemphasize how revolutionary the recognition of endocrine disruptors has been to toxicology and to understanding how environmental chemicals exposure can affect human health. The effects of toxics have been studied for millennia but the assumption throughout most of scientific history has been that the severity of the health response would always increase as the dose or exposure increased. The study of endocrine disruptors has revealed that very low levels of exposure can produce profound and lasting health effects; that timing as well as size of dose can be key to determining health outcome; that an environmental chemical exposure can have multigenerational effects; and that severity of health effect may not increase with dose in a linear fashion. In short, endocrine disruption science has upset the age-old assumption of how the dose-makes-the-poison. In doing so it has posed numerous challenges to how we assess and prevent harmful chemical exposures.

Born on March 28, 1927 in Plainfield, New Jersey, Theodora Emily Decker Colborn, a life-long bird-watcher and lover of untamed landscapes, began her fascination with the natural world early. "When I was a little kid, all I wanted to do was be outside," said Colborn at age 86, recalling her childhood love of the outdoors.

Colborn's father was a food salesman dependent upon commissions and she assumed there wouldn't be money to send her to college. With the help of an unexpected scholarship facilitated by a school counselor, however, Colborn was able to enroll at Rutgers University College of Pharmacy where she earned her Bachelor of Science degree in 1947. She began her professional career as a lab technician and a pharmacist while continuing to pursue her beloved birding. After she married she recalls how "We'd put the kids in the back of the station wagon and go." Colborn also recalls that her bird-watching friends were involved in local environmental issues, something that also caught her attention.

In 1964 she and her husband sold the pharmacies they owned in New Jersey and decided to move West. They bought what Colborn called "a nice little farm" in western Colorado while they worked as pharmacists. "I always loved the mountains," she said. "The farm had the most beautiful garden," she said, with apple and pear trees and eventually sheep. Her children became active in the local 4H Club and wildlife exploration became part of their lives. By the mid-1970s, Colborn had become acquainted with the Rocky Mountain Biological Station and began learning more about the area's environmental issues and science. "I was always very concerned about environmental health but it wasn't very well understood then," she said.

After Colborn's marriage broke up in the late 1970s, what she wanted to do more than anything was to go back to school to study science. By then she had begun doing field work at the nearby prestigious Rocky Mountain Biological Station, sampling water and insects for toxic elements released by mining activity. "I went back to school to become a Western water quality expert," said Colborn.

In 1981, Colborn completed her Master's degree in Science at Western State College in Gunnison, Colorado. Her specialty was freshwater ecology. By then she knew she wanted to continue on for a doctorate and was accepted by the University of Wisconsin-Madison's program based on the research she'd done in Colorado – examining the effects of cadmium and molybdenum on freshwater aquatic insects. "I'd already begun publishing," she said, "so they took me on the basis of that work."

At the University of Wisconsin, Colborn built on this research, pursuing a course of study toward a Ph.D. in zoology. In 1985, at age 58, Colborn was awarded a Ph.D. in zoology with distributed minors in epidemiology, toxicology and water chemistry – all fields essential to investigating the health effects of environmental chemical exposure.

As Colborn was getting ready to complete her thesis, she was urged to apply for a White House Office of Technology Assistance (OTA) fellowship. Nearly thirty years later, she delights in recalling her arrival in Washington, DC and excitement at winning the fellowship. She began her work with the OTA, first as a Congressional Fellow and then as an analyst in 1985, just as the Clean Air Act was coming up for renewal, when she worked on various air pollution studies that included research on industrial emissions and ozone.

As her tenure with the Office of Technology Assistance was ending she was offered a job with the recently merged World Wildlife und and The Conservation Foundation in Washington, DC.

Working with those organizations with Richard Liroff, Colborn began the research on Great Lakes contaminants that went into seminal reports for Environment Canada, the International Joint Commission's Science Advisory Board, Health Canada and a paper published by the US Environmental Protection Agency's *EPA Journal* in 1990 This research also became part of the landmark book, *Great Lakes, Great Legacy?* Like so much of Colborn's work, this research clearly laid out a deeply problematic biological predicament brought about by toxic chemical pollution.

The health effects described drew on those Colborn had catalogued for her 1988 Great Lakes report. Of what she had brought together, Colborn remarked twenty-five years later, "That little grid changed the world."

The paper starkly laid out the problem: persistent and bioaccumulative substances had entered the Great Lakes, either directly through industrial discharges or indirectly through environmental transport. They were accumulating in sediment and making their way up the food web, thereby posing health threats not only to Great Lakes wildlife but to people who might eat fish contaminated by those substances. In advance of any explicit labeling of suspect chemical "endocrine disruptors", the paper described how, "most importantly, the individual animals suffering the most in wildlife populations are the young. Young birds, fish, mammals, and reptiles exhibit a suite of untoward health effects that eventually cause premature death or abnormal development."

The paper explained that these effects included "metabolic" and "more subtle changes" including to the thyroid, liver and heart and abnormal sexual development. The problems in the offspring began with maternal exposure to one or more toxicants and transfer of those toxicants to the egg or fetus. In most cases," wrote Colborn and Liroff, "the adult animals show no visible signs of ill health, except abnormal behavior."

The 1990 paper described how almost all the toxic substances it discussed produce effects by blocking intercellular communication, interrupting the messages that direct cellular migration and differentiation at early stages of development. This disruption can adversely impact the production of tissue vital to the bones, heart, nervous and reproductive systems among others. It went on to describe how these same chemicals can "activate enzyme systems that under normal conditions would not be activated" and thus, interfere with normal development, including by acting as "female hormones" that disrupt the endocrine system. "In all these cases, timing of exposure is critical," they wrote.

They also noted the difficulty of developing effective standards for these pollutants in the Great Lakes given the low, yet potentially biologically significant, levels at which the substances were present – and the challenges associated with curtailing pollution occurring as a result of long-range atmospheric transport. Colborn and Liroff noted that while exposure to these substances at levels at which most people were exposed to them might not cause cancer or obvious birth defects, these environmental levels were, however, capable of causing functional abnormalities that could set the stage for serious health problems later in life, particularly if the exposures occurred prenatally or at other early stages of development.

They also called for resources to support research into chemicals contaminating the Great Lakes that were also being found in human blood, breast milk and fat tissue and linked to "changes in body functions, such as the nervous, immune, and endocrine systems."

"We knew enough then to do something," said Colborn in December 2013.

It was also in 1990 that Colborn was invited to become a Senior Fellow at the W. Alton Jones Foundation and through this relationship began thinking about bringing together scientists from different disciplines to discuss the prevalence of endocrine disrupting chemicals in the environment. That came about in the "Wingspread" meetings held in Racine, Wisconsin that Colborn was instrumental in convening. The meetings produced a series of scientific statements including the 1991 Wingspread Consensus Statement that, for the first time, clearly characterized the concept of endocrine disrupting chemicals. These meetings also became the basis for additional peer-reviewed published papers.

This work, and Colborn's collaboration with John Peterson Myers, then Director of the W. Alton Jones Foundation, led to the publication, in 1996 of *Our Stolen Future*. The book, co-authored with Myers and Dianne Dumanoski, dramatically presents the science of endocrine disruption, describing how certain synthetic chemicals, by virtue of their composition and structure, can biochemically hijack and derail the healthy working of the naturally occurring hormones involved with virtually every vital body system. It also explained how the US has allowed tens of thousands of synthetic chemicals into commercial use without full information about their biological effects – and certainly without knowledge of potential endocrine system effects.

Our Stolen Future includes a foreword by Vice President Al Gore, in which he wrote: "Last year I wrote a foreword to the thirtieth anniversary edition of Rachel Carson's classic work, *Silent Spring*. Little did I realize that I would so soon be writing a foreword to a book that is in many ways its sequel. …*Our Stolen Future* takes up where Carson left off and reviews a large and growing body of scientific evidence linking synthetic chemicals to aberrant sexual development and behavioral and productive problems….*Our Stolen Future* raises compelling and urgent questions that must be addressed."

Colborn also raised these questions in articles published by *Environmental Health Perspectives* in 1995 that made a strong case for the need to shift the United States' toxicological and environmental health research agenda away from its focus on carcinogen exposure risk assessments to research that would proactively addresses exposure to endocrine disruptors.

This call for dedicated research into endocrine disruptors appeared to have prompted a response in 1996 when the US Environmental Protection Agency (EPA) launched its Endocrine Disruptor Screening Program and established the Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC).

Ten EDSTAC meetings were held between 1996 and 1998 and a final report was presented to the EPA in September 1998. But it wouldn't be until October 2009 that the EPA released its initial list of chemicals for the first tier of screening. It is to Colborn's dismay and frustration, that in its nearly twenty years, the EPA's Endocrine Disrupter Screening Program has made such little

progress, either in generating new information or prompting federal action to prevent exposure to endocrine disrupting chemicals.

It's hard to overstate what a sea-change in regulatory toxicology endocrine disruptor research implied. Historically, toxicology has focused on determining at what level of exposure to a particular toxic acute adverse effect levels would be observed, at what dose half of the experimental animals exposed died and how long it took them to succumb. While these sound like very blunt instruments, they are the measures that regulatory toxicology continues to emphasize today together with evidence of gross effects on bodily organs. The prevailing regulatory testing regimen – the basis for judgments about the safety of chemicals introduced into the marketplace – pays little or no attention to metabolic changes, outcomes for development and behavior and the transfer of scrambled chemical messages that affect subsequent generations. What Colborn and her colleagues proposed, that very low levels of chemical exposure – levels that might be present in the daily environment – could prompt subtle changes in cellular chemistry potentially resulting in a range of adverse health effects, was utterly radical to traditional toxicology.

At age 87, Colborn is impatient and disheartened at the policy-makers' failure to respond to the abundant scientific evidence of an environmental health crisis – and their willingness to accede to the chemical industry's doubts about endocrine disruption effects. "I am thoroughly convinced this is all real," said Colborn. "The science is there. We don't need more science. We need work in a different sphere entirely," she said.

At this juncture in time, it is a fool's errand to ask Colborn about her hopes for the future. She reels off the environmental health statistics. Since the 1980s, metabolic disorders have risen precipitously among both US adults and children. Neurodevelopmental, cognitive and behavioral problems are so common among children worldwide that leading pediatricians, endocrinologists, developmental biologists, and other scientists call the problem a pandemic. Reproductive health problems are rising and widespread. Childhood cancer and congenital malformations are now among the principal causes of disability and death in American children.

Colborn is particularly concerned about the neurological problems that are disrupting nurturing relationships between parents and children. What she sees all too often in the current generation of children reminds her disturbingly, of what she saw in Great Lakes wildlife now two generations ago. "It's at the population level and it's dire," she said in December 2013.

"My concern is that we've let this go on for so long that we're now into the fourth generation of those exposed to the post-World War II plethora of synthetic chemicals," said Colborn in December 2013.

Yet while voicing frustration at the world's failure to respond to clear signs of an urgent world health crisis, in many ways, Colborn's actions belie her avowed pessimism. In 2003, at age 76, she founded The Endocrine Disruption Exchange (TEDX) (www.endocrinedisruption.org), a non-profit research organization devoted to "prevention driven" endocrine disruptor research. Responding to a growing local environmental problem, Colborn embarked on yet a new avenue of research: the environmental health effects of chemicals associated with the rapidly expanding

natural gas extraction, particularly through hydraulic fracturing.

In 2009, Colborn worked to advance federal legislation that would have established a new endocrine research program at the US National Institute of Environmental Health Sciences (NIEHS). The bill did not pass, but the effort is a testament to Colborn's ongoing dedication to conveying this science's significance.

"One of my biggest concerns is the next generation of science," says Colborn in December 2013. She's convinced that that cross-disciplinary environmental health research is not being adequately supported. Yet she is unrelenting in her personal efforts, continuing to mentor and nurture scientists 60 years her junior. Her work at TEDX has been a testament to these efforts, including ongoing support for women scientists. It's far from the first topic she'll broach but having forged such a unique path herself, Colborn is almost fierce about encouraging young women scientists. She understands implicitly the challenges they often face. While professional topics take precedence in her conversation, Colborn's profound caring for family, friends and colleagues is never far from the surface.

In 2012, at age 85, Colborn was a co-author – with scientists spanning three generations – on yet another landmark publication, "Hormones and Endocrine-Disrupting Chemicals: Low-Dose Effects and Non-monotonic dose Responses," a paper that reviewed the literature on endocrine disruptors' ability to prompt biological responses at very low levels of exposure and these chemicals' ability to produce effects that do not follow a straight line dose-response path from high to low doses. If one were to compose a slide of landmark environmental health literature, it could picture *Silent Spring*, *Our Stolen Future* and this paper – all encapsulate scientific watersheds.

It was also in 2012 that Colborn delivered a TEDx talk (not to be confused with TEDX) in Washington, DC, reading an open letter to President Barack Obama, articulating the urgency of preventing ongoing environmental chemical exposure. In it, Colborn merged her current focus on the health impacts of fossil fuel extraction with her longstanding emphasis on endocrine disruption. "By drilling deep into the bowels of the earth for coal, oil and natural gas we have unwittingly and catastrophically altered the chemistry of the biosphere and the human womb," wrote Colborn.

A year later, at home in Paonia, she explained the connection between fossil fuel chemicals and endocrine hormones. "As we evolved over time, the first living pieces of organisms are based on a benzene ring, whether it's in a plant or an animal," Colborn said. The benzene ring, she explained, forms the basis of the complex molecules such as the hormones that define an individual organism's health. "We interfere with that chemistry at our peril," she said. By interfering with the hormones that define human health, "we're changing humanity," said Colborn. "I want people protected," she said.

At age 87, Colborn's own health is frail but her profound concern for the health of vulnerable populations both of humans and wildlife, remains undiminished. She relies on an oxygen tank to help her get enough air into her lungs whose compromised health she says dates back to cadmium, a toxic element to which she exposed herself decades ago doing field work in

Colorado's mountain streams. She's begun to parcel out possessions between her four children. But she has far from slowed down. On a wintry day, she is on the phone with her office, conferring on upcoming reports and conference calls, talking with reporters, and making sure family, colleagues and neighbors are cared for. She talks about her dream of a research institute devoted to what she calls "inner space," what goes on inside the human body.

She is now working to ensure that TEDX continues her seminal integrative work. She has become "President Emeritus", having passed primary leadership of TEDX to Executive Director, Dr. Carol Kwiatkowski. TEDX's staff reflects Colborn's interdisciplinary approach, being composed of scientists – all women – with Ph.D.'s in cognitive science, entomology and integrative physiology. Scientists and regulators continue to look to TEDX's talented staff for leadership and visionary thinking.

In the final chapter of *Our Stolen Future* called "Flying Blind," Colborn and co-authors described the twentieth century as a time of profound change in the relationship between humans and the Earth. "With that transformation, we have been altering the fundamental systems that support life. These alterations amount to a great global experiment–with humanity and al life on Earth as the unwitting subjects," they wrote. The only way out of this experiment, they concluded, is to "find better, safer, more clever ways to meet basic human needs and, where possible, human desires." We must also have "the courage to be cautious, for the stakes are very high," they counseled. "We owe that much, and more, to our children," they wrote.

Reading these words nearly thirty years after the book's publication they sound like guide posts for Theo Colborn's life and work: Courage, high stakes and a deep and abiding commitment to the welfare of others.

It is no exaggeration to say that our knowledge of the chemicals to which we are exposed to throughout our lives would not be the same without Theo Colborn's work. Hers has been a steady and outspoken voice urging this work forward, connecting people and groundbreaking research, and unstintingly promoting efforts of the next generation. The problems posed by endocrine disruptors are a long way from being solved but thanks to Theo Colborn's herculean and inimitable efforts, we are no longer flying completely blind.