



AUTISM: WHAT DO ENVIRONMENT AND DIET HAVE TO DO WITH IT?

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Factors that may contribute to autism are many and complex, but as diagnoses and costs rise, research and prevention are essential.

Background

Autism is one of a growing number of developmental and learning disabilities that now affect 1 in 6 children.¹ Autism is distinctive among these disabilities for its devastating effects on individuals and families, its astronomical costs to society and families and for its disturbing and unexplained increases in incidence. The rate of autism has increased 600 percent over the last two decades. Between 2002 and 2008 there was a 78 percent increase in school age children with an autism diagnosis.² Some of the observed increase in autism incidence is due to better diagnosis, but the increases are too precipitous to be solely attributed to better diagnosis alone.³ Initially, autism spectrum disorders (ASD) were thought to represent developmental disorders that only impair communication and social interaction. Scientists now consider ASD to be a whole body disorder, often presenting with intestinal problems, immune disorders and seizures.⁴ Some have described autism as an allergy of the brain, with numerous environmental triggers.⁵

One in 50 children is now diagnosed with autism in the U.S., compared with 1 in 86 in 2007.⁶

Studies of autism in twins and siblings illustrate that genetics plays a role in autism but it's harder to tease out environmental factors in these studies because twins and siblings share a similar environment. Identical twin studies find that if one twin has ASD, the other twin is affected between 36 and 95 percent of the time. In fraternal twins, the second twin is affected 0 to 31 percent of the time.⁷ Since twins share the same fetal environment, the greater likelihood of occurrence in identical twins illustrates that the genetic contribution is still strong. However, one study estimated that environmental factors explain 55 to 58 percent of the variability in autism spectrum disorders between twins.⁸ With siblings, occurrence of ASD in a second sibling is 2 to 18 percent.^{9,10} Concurrence of autism with other genetic or chromosomal disorders is 83 percent.¹¹



While genes are important, prenatal and postnatal environmental factors are also significant contributors to autism risk.¹² Risk factors for ASD include older parents,¹³ maternal stress,¹⁴ maternal diabetes, complications during pregnancy,¹⁵ premature birth and low birth weight.¹⁶ Premature birth may make a child more susceptible to allergies, environmental toxins, infections and stress which can stimulate brain inflammation.¹⁷ Other risk factors include maternal infections and inflammation, affecting metabolism of nutrients like fatty acids, which can alter gene expression, leading to neuronal dysfunction.¹⁸ Maternal medications during pregnancy are also implicated in increased autism risk.¹⁹

While the etiology of autism is complex, with both genetic and environmental components, it is clear that the role of the immune system is key.²⁰ A child's prenatal and postnatal environments, including diet, clearly impact immune health. Growing evidence suggests environmental and dietary factors play a significant role in increasing the risk for autism.^{21,22,23,24,25}

Immigrant studies may provide valuable clues to impacts of the environment on autism occurrence. A Swedish study found higher rates of autism among offspring of women who migrated just before or during pregnancy.²⁶ Stress and changes in environment could be the operative factors in these situations, but more study is needed. An apparent higher than average incidence of autism among Somali immigrants in Minnesota has been documented,²⁷ but causes remain unexplained. A Center for Disease Control (CDC) surveillance study is underway to examine incidence and possible reasons for higher incidence.

Role of environmental toxins in autism

There is growing evidence that environmental toxins interact with the above factors to contribute to autism risk. Leading scientists at a National Institute of Environmental Health Sciences (NIEHS) workshop on autism identified a list of ten chemicals and mixtures that have been identified as neurotoxins affecting learning and development. They include: lead, methylmercury, PCBs, organochlorine pesticides, endocrine disrupters, automotive exhaust, polycyclic aromatic hydrocarbons (PAHs), brominated flame retardants and perfluorinated compounds.²⁸ While all of these chemicals have not been directly linked to autism, they have been implicated in the growing numbers of children affected by an array of developmental disabilities. Exposure to these chemicals is widespread as evidenced by CDC biomonitoring results showing that almost all women of childbearing age in the U.S. have the following chemicals in their bodies: PFCs, PCBs, PBDEs, bisphenol A, phthalates, organochlorine pesticides and PAHs.²⁹ Prenatal exposure to these chemicals is especially concerning, as they are all endocrine disrupters linked to adverse neurodevelopmental effects. Exposure to some endocrine disrupters can have intergenerational effects. For example, mice exposed prenatally to the endocrine disrupter bisphenol A had transgenerational effects on social interaction and neural expression that impacted up to four generations.³⁰



There are several plausible physiological mechanisms for the effects of pesticides on abnormal brain development, including autism. CC image courtesy of plind via Flickr.

The body of science linking environmental toxins and autism is growing and risk from prenatal and early-life exposures to toxic chemicals is increasingly recognized.³¹ In one study, children of mothers with greater knowledge about environmental toxins and lower exposure to toxins were less likely than less informed mothers to have a child with autism.³² Studies have documented increased risk of autism and/or autistic behaviors from numerous environmental toxin exposures, including:

- **POLLUTION.** Living near a pollution site³³ or near an EPA Superfund site.³⁴ Hazardous air pollutants, including metals and chlorinated solvents.³⁵ Maternal residence near a freeway.³⁶
- **PESTICIDES.** Residence near agricultural organochlorine pesticide (OP) applications³⁷ and prenatal exposure to the OP pesticides such as chlorpyrifos.^{38,39} Exposure to OPs is associated with vitamin D deficiency, providing a clue to a possible contributing dietary factor.⁴⁰ There are several plausible physiological mechanisms for the effects of pesticides on abnormal brain development, including autism. Many pesticides can cause excitation and dysregulation of neural signaling in the brain due to inhibition of acetylcholinesterase and disruption of neural receptors, called GABAs.⁴¹
- **PHTHALATES.** Prenatal exposure to phthalates.⁴² Phthalates are chemicals commonly used in plastics and fragranced personal care products.
- **HEAVY METALS.** Exposure to environmental neurotoxins including mercury, aluminum, lead and cadmium.^{43,44,45,46,47,48,49} There is evidence of the biological plausibility of mercury in the etiology of autism. Mercury disrupts sulfur metabolism, which leads to oxidative stress, commonly elevated in people with autism. This analysis is complicated and informed by the fact that individuals have varying sensitivity to mercury. Thus, the interaction of genetic (ability to detoxify) and environmental factors (mercury exposure) may be of significance in autism.⁵⁰ Since mercury builds up in the food chain, a common exposure route is through fish consumption.



Some children's shampoos contain phthalates. CC image courtesy of thejbird via Flickr.

- **PERSISTENT ORGANIC POLLUTANTS.** A Finnish study found that prenatal exposure to high levels of PCBs and DDE (metabolite of DDT) was associated with increased risk for autism in offspring.⁵¹ Both chemicals build up in the food chain and are commonly found in fish, meats and dairy products.
- **PARENTAL OCCUPATION.** Children of mothers with occupational exposure to exhaust and combustion products were at higher risk for autism, while the fathers' exposure did not increase risk.⁵² The risk of autism doubled if either parent worked in a job requiring night work or handling of solvents, with a tripling of risk for mothers in these occupations.⁵³

Exposure to mercury in vaccines has been of wide concern, though childhood vaccines are now mercury-free. Most research on the impact of vaccines on autism has so far failed to show a link.^{54,55} Likewise, there is no established link thus far between exposure to ultrasound and autism risk.⁵⁶

Role of diet in autism

Diet is an important factor in optimal health and specific nutrients play critical roles in metabolic processes that detoxify and eliminate harmful toxins from the body. For example, children exposed to lead who are well nourished absorb less lead into their bodies than poorly nourished children.⁵⁷ Food can also be a source of toxins. Exposure to persistent bioaccumulative toxins in the food supply is routine. Meats, fish and dairy products commonly contain PCBs, dioxins, mercury, pesticides, brominated flame retardants and perfluorinated chemicals (PFCs). Novel ingredients in the food supply, such as mercury in high fructose corn syrup, may provide additional routes of exposure to toxins.⁵⁸ Chemicals in food packaging and cookware, like bisphenol A (BPA), phthalates and PFCs also provide routine exposures to toxins.

Maternal diet during pregnancy strongly influences the health of offspring. Both animal and human studies support the critical role of maternal diet and metabolic status in programming brain circuitry that regulates behavior. A high-fat diet

and obesity during pregnancy may make offspring more susceptible to behavior disorders such as ADHD and autism.⁵⁹ Mothers with metabolic disorders, diabetes, hypertension or obesity were at higher risk for having a child with autism.⁶⁰ In one study, exposure to toxic metals, secondhand smoke, maternal fish consumption, along with nutritional deficiencies, were associated with autism risk.⁶¹ Deficiencies in zinc and magnesium may interact with toxic metal burdens to play a role in autism.⁶² Vitamin D deficiency is also implicated in increased risk of autism, which might help explain why autism risk is greater in Northern latitudes, where people are less likely to get their needed dose of vitamin D from the sun.⁶³

Gastrointestinal disorders and metabolic conditions are common in children with autism, though the range of children affected is between 9 and 91 percent.⁶⁴ Immune abnormalities, including inflammation of the intestinal track and increased intestinal permeability or "leaky gut" have been reported in children with autism. Bacteria, oxidative stress and dietary allergens, such as gluten, could contribute to "leaky gut."⁶⁵ Alterations in serotonin, which send signals to the gut, may be implicated in some gastrointestinal dysfunctions.⁶⁶ Certain bacteria in the gut may play a role in the regressive form of autism.⁶⁷

One small study found that participants with autism were more likely to be overweight, have high intake of foods containing gluten and casein and were more likely than controls to have intestinal dysfunctions.⁶⁸

Many parents of children with autism report improvement in behavior and symptoms through specific dietary regimens, including dairy-free and gluten-free diets. However, published studies examining the effects of dietary interventions on autism report mixed results.^{69,70,71,72,73} The lack of a consensus on the effects of various dietary interventions may be due to the fact that such studies can't possibly account for differences in individual dietary needs. Dr. Martha Herbert at Harvard documents successful dietary, environmental and behavioral interventions based on individualized needs that improve or eliminate autistic behaviors in some individuals.⁷⁴

Individual differences, epigenetic changes

The problem is looking at a single environmental toxin, vaccine or dietary factor will not provide the answer to what causes autism. Because every person with autism has unique needs, vulnerabilities and experiences, we will never be able to pinpoint one factor that caused the autism or one intervention that addresses all needs. Scientists such as Dr. Herbert and Dr. Robert Blaylock, are now hypothesizing new theories of causation, based on the intricate interplay of environmental toxins, nutrition and gene expression.^{75,76}

The impact of environmental factors on gene expression is known as epigenetics. Epigenetics refers to heritable changes in gene expression (for example synthesis of a protein), with no change in the underlying DNA sequence. Epigenetic dysregulation (playing havoc with gene expression) is associated with the development of autism.^{77,78} One study of identical twins

with Rett Syndrome, a neurodevelopmental disorder characterized by autistic features, identified differences in severity of symptoms between the twins, indicating that environmental factors and changes in gene expression, in addition to genetics are at play.⁷⁹ Another study of identical twins supports the role of altered DNA methylation in autism.⁸⁰

DNA methylation is essential for normal development and gene expression. It plays a central role in the interface between genetic and environmental factors.⁸¹ Environmental toxins like mercury and pesticides can cause adverse neurodevelopmental impacts through altering DNA methylation and, consequently, gene expression. For example:

- Inorganic mercury may prevent the activation of needed enzyme activity and the body's ability to protect itself against environmental stressors. Toxic exposures can affect sulfur metabolism, which can impair methylation and cause oxidative stress. Some individuals with autism have genetic changes that impair sulfur metabolism, methylation and detoxification.⁸² Oxidative stress impairs the ability of the body to detoxify and is documented in people with autism.⁸³
- Foodborne and chemical "excitotoxins" (food additives that damage brain cells) elevate glutamate levels and can cause neurodegeneration.⁸⁴ Glutamate is a neurotransmitter that is important for learning and memory.
- Dr. Herbert explains that the brain in autism is reacting to having "too much" of the bad things (toxins, bacteria, viruses, poor quality food, stress) and "not enough" of the good things (nutrients, rest). She focuses on two functions that are essential to a healthy brain: a.) creating energy, in which the mitochondria play a role; and b.) eliminating waste, in which the microglia play a role.⁸⁵ When the mitochondria and the microglia are not working correctly, oxidative stress can result.
- Metabolic abnormalities linked to mitochondrial dysfunction may play a role in the etiology of autism and vulnerability to oxidative stress, induced by many environmental toxins.^{86,87}
- Environmental toxins impact the function of microglia to alter gene expression in individuals with Rett Syndrome.⁸⁸ Microglia cells support the nervous system by eliminating waste (toxins, viruses and bacteria).

As we learn more about autism, it appears that the etiology of autism has much in common with that of cancer in that there is never one cause, but is the result of multiple assaults on the immune system. One of these assaults then tips the person over a threshold into the autism state.

Autism is costing us

The cost to raise a person with autism is \$3.2 million over a lifetime.⁸⁹ Estimated costs for educational and medical services to serve people with autism spectrum disorders in the U.S. are more than \$126 billion a year.⁹⁰ Out-of-pocket costs incurred by families are not included in this figure.

- The cost to educate a child with autism was \$18,800 a year in 2005, three times more than a student without autism.⁹¹ Today's costs are likely even higher.
- The number of children served in special education programs in Minnesota increased from 2,783 in 1999–2000 to 12,596 in 2008–2009.⁹²
- After graduation, students with autism typically become the lifelong financial burden of their parents. The cost to family quality of life, marriages, family budgets is extreme, as parents often leverage their homes and retirement savings to afford the \$72,000 in treatments and services it can cost for one year of autism support.⁹³
- Costs for medical care are estimated to be between \$4,110 and \$6,200 higher for people with ASD.⁹⁴ Costs were six times higher for children in the Medicaid program with an ASD diagnosis compared with those without ASD.⁹⁵
- The cost of behavioral interventions for children with ASD can range between \$40,000 and \$60,000 per year.⁹⁶
- Medical costs for children with autism and co-occurring conditions like epilepsy, intellectual disability or ADHD range between \$9,500 and \$19,200 per year, according to the Centers for Disease Control.



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Autism research

We don't yet fully understand exactly how the genetic, dietary, immunologic and environmental pieces of the autism puzzle fit together, but we are learning more about the physiological mechanisms involved with autism, which will help fill in the gaps. Additional research and exposure data will contribute to a greater understanding of environmental contributors to autism. We need data on geographic patterns, environmental chemical exposures in homes and communities, blood and urine levels of common toxins such as lead and arsenic, and maternal exposures to chemicals in the workplace, particularly during the prenatal period. There is also a need to systematically document case studies of parental dietary interventions to demonstrate the effectiveness of a variety of strategies.

Through the National Institute of Environmental Health Sciences, four long-term studies are looking at prenatal, neonatal and early-life environmental exposures, as well as development of new research tools. Dr. Hertz-Picciotto at U.C. Davis is leading two large studies to discover possible environmental factors like exposures to metals, pesticides and infectious agents in the development of autism.⁹⁷ In addition, the National Children's Study is examining how genetic and environmental factors affect children during different phases of their development.

Public health prevention

By learning more about the factors that contribute to autism, perhaps we can stem the tide of the autism epidemic through prevention. Public health approaches, including education and nutritional interventions, are needed to address the growing numbers of children with autism spectrum disorders in schools, homes and clinics. Education of women of child-bearing age and expecting parents on environmental and dietary factors linked to autism could help reduce exposures that might trigger autism. Behavioral interventions for children with autism should be supplemented with dietary interventions. Numerous studies point to the benefits of nutritional supplements for patients with autism, including omega-3 fatty acids, probiotics, vitamins and minerals.⁹⁸ Prenatal care should include an assessment of nutritional status and a close look at treating and preventing metabolic disorders that increase the risk of autism.⁹⁹

Chemical policy needs

We are likely to find that there's no one chemical or no one exposure that causes autism. Therefore, implementing policies that prevent unnecessary exposures to neurotoxins and hormone disrupting chemicals is a smart public health prevention strategy.

One of the first policy steps to reduce exposures to toxic chemicals is to reform the Toxic Substances Control Act, our outdated and ineffective law that allows thousands of toxic, untested chemicals to continue to be used in consumer products, including in food packaging, without basic information about effects on human health. Learn more at saferchemicals.org.

In addition to federal action to reduce exposures to toxic chemicals in our environment, state action to protect citizens, especially children, from toxic chemicals in everyday consumer products is also important. Implementing policies such as regulation of chemicals in children's products, as proposed by Minnesota's Toxic Free Kids Act, will contribute to a healthy environment for the optimal growth and development of our children. Learn more at healthylegacy.org.

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