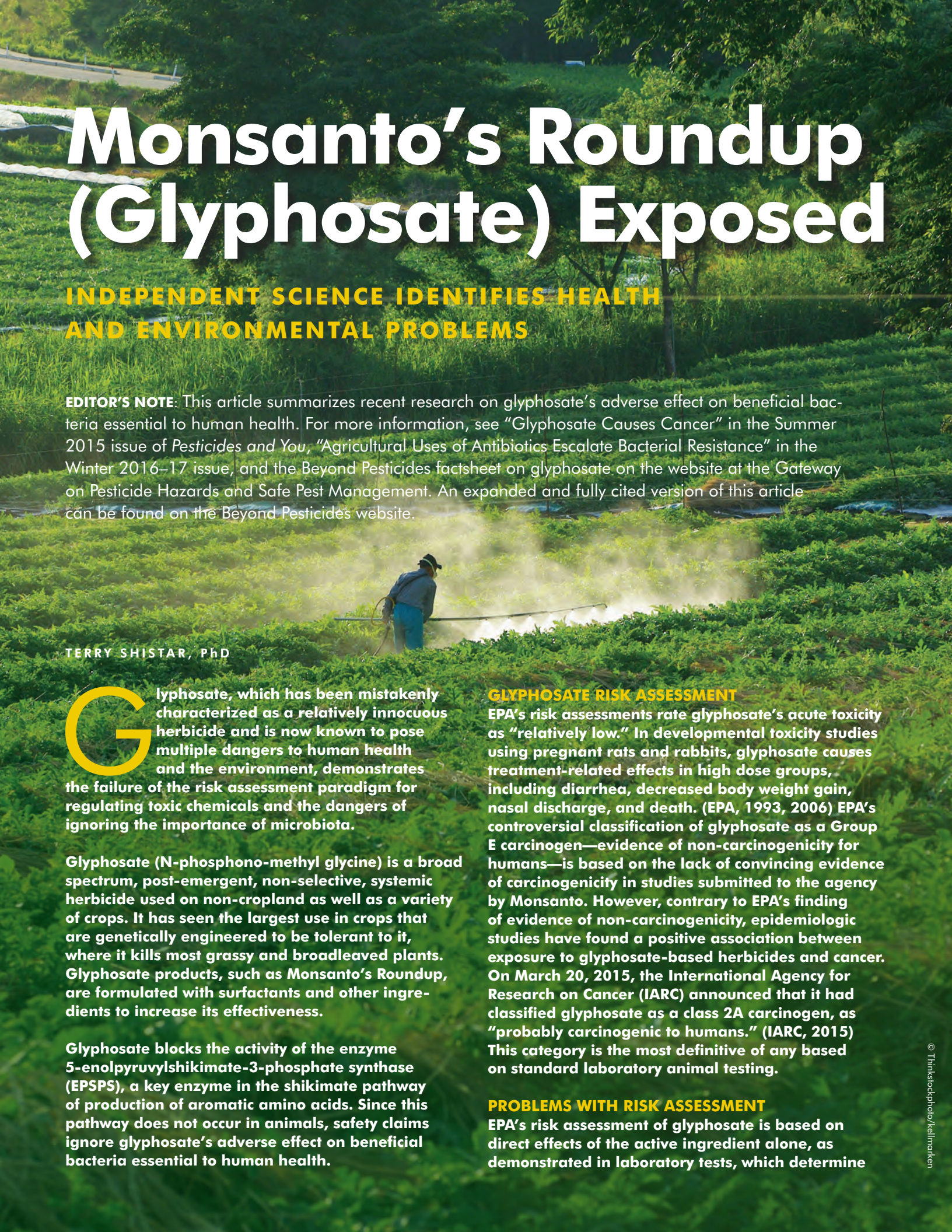
Monsanto's Roundup (Glyphosate) Exposed

INDEPENDENT SCIENCE IDENTIFIES HEALTH AND ENVIRONMENTAL PROBLEMS

EDITOR'S NOTE: This article summarizes recent research on glyphosate's adverse effect on beneficial bacteria essential to human health. For more information, see "Glyphosate Causes Cancer" in the Summer 2015 issue of *Pesticides and You*, "Agricultural Uses of Antibiotics Escalate Bacterial Resistance" in the Winter 2016–17 issue, and the Beyond Pesticides factsheet on glyphosate on the website at the Gateway on Pesticide Hazards and Safe Pest Management. An expanded and fully cited version of this article can be found on the Beyond Pesticides website.



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Glyphosate, which has been mistakenly characterized as a relatively innocuous herbicide and is now known to pose multiple dangers to human health and the environment, demonstrates the failure of the risk assessment paradigm for regulating toxic chemicals and the dangers of ignoring the importance of microbiota.

Glyphosate (N-phosphono-methyl glycine) is a broad spectrum, post-emergent, non-selective, systemic herbicide used on non-cropland as well as a variety of crops. It has seen the largest use in crops that are genetically engineered to be tolerant to it, where it kills most grassy and broadleaved plants. Glyphosate products, such as Monsanto's Roundup, are formulated with surfactants and other ingredients to increase its effectiveness.

Glyphosate blocks the activity of the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), a key enzyme in the shikimate pathway of production of aromatic amino acids. Since this pathway does not occur in animals, safety claims ignore glyphosate's adverse effect on beneficial bacteria essential to human health.

GLYPHOSATE RISK ASSESSMENT

EPA's risk assessments rate glyphosate's acute toxicity as "relatively low." In developmental toxicity studies using pregnant rats and rabbits, glyphosate causes treatment-related effects in high dose groups, including diarrhea, decreased body weight gain, nasal discharge, and death. (EPA, 1993, 2006) EPA's controversial classification of glyphosate as a Group E carcinogen—evidence of non-carcinogenicity for humans—is based on the lack of convincing evidence of carcinogenicity in studies submitted to the agency by Monsanto. However, contrary to EPA's finding of evidence of non-carcinogenicity, epidemiologic studies have found a positive association between exposure to glyphosate-based herbicides and cancer. On March 20, 2015, the International Agency for Research on Cancer (IARC) announced that it had classified glyphosate as a class 2A carcinogen, as "probably carcinogenic to humans." (IARC, 2015) This category is the most definitive of any based on standard laboratory animal testing.

PROBLEMS WITH RISK ASSESSMENT

EPA's risk assessment of glyphosate is based on direct effects of the active ingredient alone, as demonstrated in laboratory tests, which determine

toxic effects related to the dose received. When this model is applied to glyphosate, it fails to identify the most important impacts of glyphosate as it is used. The first problem is that glyphosate is not used alone.

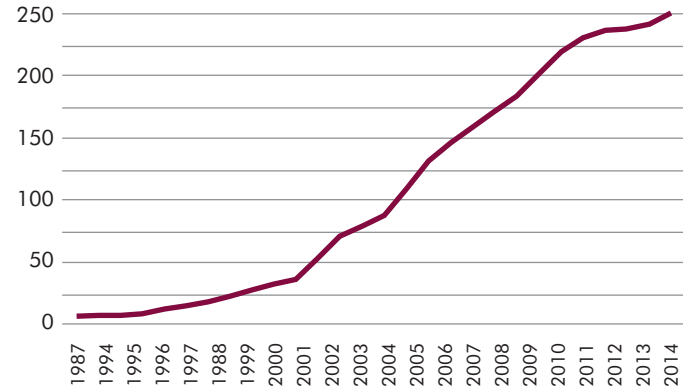
A number of surfactants and other ingredients are added to glyphosate products to make them more effective as herbicides. Some health effects that are associated with these so-called "inert" ingredients are genetic damage, reduced fertility, thyroid damage, eye irritation, anemia, reduced survival of offspring, and skin irritation. (Cox, 2004) Polyethoxylated tallowamine or POEA—a surfactant used in Roundup and other herbicidal products—has been identified as particularly toxic. (Tsui and Chu, 2003)

An increasing number of studies have found that formulated glyphosate products (e.g., Roundup) are more toxic than glyphosate. Symptoms following acute exposure to glyphosate formulations include swollen eyes, face and joints; facial numbness; burning and/or itching skin; blisters; rapid heart rate; elevated blood pressure; chest pains, congestion; coughing; headache; and nausea. (Cox, 2004) Glyphosate and its formulated products adversely affect embryonic, placental, and umbilical cord cells, as well as fetal development. Human cell endocrine disruption at the androgen receptor, inhibition of transcriptional activities at estrogen receptors, and DNA damage and cytotoxic effects occurring at low concentrations have also been observed. (Gasnier et al., 2008)

NEW SCIENCE AND GLYPHOSATE

Newer scientific studies have also looked in greater depth at glyphosate's mode of action and the implications for human and ecological health. Glyphosate works by disrupting a crucial pathway for manufacturing aromatic amino acids in plants—but not animals—and, therefore, many have assumed that it does not harm humans. However, many bacteria do use the shikimate pathway, and 90 percent of the cells in a human body are bacteria. The destruction of beneficial microbiota in the human gut (and elsewhere in and on the human body) is, therefore, a cause for concern—and a major contributor to disease. In addition, the destruction of soil microbiota leads to unhealthy agricultural systems with an increasing dependence on agricultural chemicals. Assessing the mode of action of glyphosate, scientists have found that it starves and sickens the very crop plants that it is supposed to protect. It is dangerous to base the review of chemicals on the assumption that microbiota is irrelevant to assessing dangers. While it is well known that taking a course of antibiotics disturbs microbes that help digest food, disturbing the microbiota has greater consequences than a bout of diarrhea. It can contribute to a whole host of "21st century diseases," including diabetes, obesity, food allergies, heart disease, antibiotic-resistant infections, cancer, asthma, autism, irritable bowel syndrome, multiple sclerosis, rheumatoid arthritis, celiac disease, inflammatory bowel disease, and more.

FIGURE 1: **Glyphosate Use in U.S. Agriculture in Millions of Pounds**



Source: Benbrook 2016

THE HUMAN GUT AND 21ST CENTURY DISEASES

The 90 percent of human cells that are microbial in origin are mostly symbionts who help the human body function as it should. The body is a biological community or "superorganism," a product of coevolution. The microbial community in the mammalian gut reflects the coevolution of host and microbiota, resulting in a mutually beneficial balance. As well as aiding the nutrition of the host human (or other mammal), microbiota contribute to developing and maintaining a healthy immune system. In return, the human host provides a niche in which the individual microbes and their community can persist, providing essential nutrients and habitat. As one review summarized current science, "Recent studies have provided firm evidence that skewing of the commensal community, often referred to as 'dysbiosis,' can result in inflammatory diseases not only of the intestine, but also of organs at distal sites. Such diseases can be triggered not only by pathogenic microbes, but also by otherwise harmless commensal microbes or those that are normally held in check by the microbial ecosystem and/or the metabolic state and immune response of the host. Thus, disturbance of this homeostasis by intrinsic or extrinsic influences, e.g., treatment with broad-spectrum antibiotics, can result in life-threatening dysbiosis." (Littman and Pamer, 2011)

Not all disturbance in the microbiota comes from the conscious use of antibiotics. Swanson et al. (2014) have recently documented that the rise in these same diseases is tightly correlated with the use of the herbicide glyphosate. They have also shown that glyphosate exposure can result in the inflammation that is at the root of these diseases. All of this is not surprising, since glyphosate is patented as an antibiotic. (U.S. Patent number US7771736 B2)

GLYPHOSATE AND GUT DYSBIOSIS

Researchers synthesizing mountains of peer-reviewed research relating to health effects driven by glyphosate's mode of action have shown that a long list of 21st century diseases are linked

to imbalances in the human gut connected to pervasive exposure to glyphosate. (Samsel and Seneff, 2013) Although the precise mechanisms may be unclear, the evidence for a causal link is strong. The evidence comes from two directions—first, that glyphosate causes dysbiosis in the gut microbiota, and second, that gut dysbiosis is a causal factor in many 21st century diseases.

The patent for glyphosate as an antibiotic provides the first piece of evidence. It contains a long list of families of susceptible microorganisms. Scientists who have looked at the impacts on the microbiota of poultry and cattle have found that glyphosate appears to have more negative impacts on beneficial bacteria, allowing pathogens to flourish. For example, Shehata et al. (2013) found that "highly pathogenic bacteria as *Salmonella entritidis*, *Salmonella gallinarum*, *Salmonella typhimurium*, *Clostridium perfringens* and *Clostridium botulinum* are highly resistant to glyphosate. However, most beneficial bacteria such as *Enterococcus faecalis*, *Enterococcus faecium*, *Bacillus badius*, *Bifidobacterium adolescentis* and *Lacto-bacillus* spp. were found to be moderate to highly susceptible."

GUT DYSBIOSIS AND 21ST CENTURY DISEASES

Normally, the human gut is host to an ecosystem composed of anaerobic bacteria that serve a number of beneficial functions, including assisting in the absorption of nutrients, producing short-chain fatty acids and vitamins, synthesizing amino acids, detoxifying xenobiotics, contributing to host immunity, preventing pathogenic infection, and maintaining the health and integrity of the colon wall. (See Dr. David Montgomery's Forum talk on page 9.) Some of these organisms live only in the human intestinal tract, which suggests a coevolved relationship. (Ding et al., 2016)

The imbalance (dysbiosis) of bacteria in the gut has been associated with many modern diseases. In addition to those cited above, they include diarrhea, inflammatory bowel disease, activation of HIV infection, allergies, infection by *Clostridium difficile* and other pathogenic bacteria, autism, liver disease, atherosclerosis, pancreatitis, fibromyalgia, polycystic ovary syndrome, and others. (Sekirov et al., 2010) The fact that such diseases are linked to dysbiosis of the gut does not in itself prove that glyphosate causes them. However, the increases in these diseases are correlated tightly with increases in the use of glyphosate. Glyphosate use dwarfs the use of antibiotics in human medicine. (Shistar and Curle, 2017) To characterize glyphosate's relationship to these disases, celiac disease and autism will serve as examples.

CELIAC DISEASE

Several studies demonstrate that celiac disease is associated with gut dysbiosis. In particular, it is associated with reduced levels of *Enterococcus*, *Bifidobacteria,* and *Lactobacillus* in the gut and increased pathogenic gram-negative bacteria. (Sanz et al., 2011) *Lactobacillus*, *Enterococcus*, and *Bifidobacteria* have been found to be significantly lower in fecal samples of children with celiac disease compared to controls, while levels of the pathogens *Bacteroides*, *Staphylococcus*, *Salmonella*, and *Shigella* were higher. (Di Cagno et al., 2011) Another study found *Bacteroides*, *Clostridium*, and *Staphylococcus* all to be significantly higher in children with celiac disease. (Collado et al., 2007) The imbalances found by these studies of celiac disease are the same as those seen with glyphosate exposure.

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AUTISM

Another disease that has been linked to glyphosate exposure is autism. Studies show that dysbiosis of the gut is implicated in several neuro-immune and neuro-psychiatric disorders. (Wang and Kasper, 2014) It is beyond the scope of this article to provide a comprehensive review of the literature investigating the interplay between the gut microbiota and the brain, but a brief consideration of autism illustrates the relationship. In addition to autism, other neurological disorders connected with gut dysbiosis include dementia, mood disorders, schizophrenia, depression, and bipolar disorder. (Mangiola et al., 2016)

Autism, a neurodevelopmental disorder characterized by impaired communication and social interactions and restricted interests and behaviors, is on the rise. A growing body of evidence shows that children with autism spectrum disorders (ASD) have a different composition of gut bacteria from controls. These differences, along with results of animal studies, suggest that certain intestinal bacteria –such as *Clostridium* and *Sutterella* species—may contribute to the development of ASD. A recent review of literature on gut dysbiosis and autism concludes, "There is an increasing body of evidence demonstrating the clinical importance of microbes habituating the intestinal tract; compelling links between dysbiosis and many disease states are being formed. . . . [A]t least a subset of the cases comprising ASD are connected to, and perhaps dependent on, the health and well-being of the intestinal microbiota." (Ding et al., 2017)

The linkage between glyphosate and autism is substantiated in a recent case study of triplets diagnosed with ASD (two boys) and possible seizure disorder (one girl). All three children had very high levels of glyphosate in their urine, which decreased dramatically when the children were placed on an organic diet. Glyphosate levels decreased, and diagnoses showed that the children improved after two months on an organic diet. (Shaw, 2017)

ANTIBIOTIC RESISTANCE

The Centers for Disease Control and Prevention (CDC) call antibiotic resistance "one of the world's most pressing public health problems." Many bacterial infections are becoming resistant to the most commonly prescribed antibiotics, resulting in longer-lasting infections, higher medical expenses, the need for more expensive or hazardous medications, and the inability to treat life-threatening infections. The development and spread of antibiotic resistance is the inevitable effect of the use of antibiotics. (O'Brien, 2002) Use of antibiotics like glyphosate in agriculture allows residues of antibiotics and antibiotic-resistant bacteria to emerge on agricultural lands, move through the environment, contaminate waterways, and ultimately reach consumers in food. The human gut, treated farm fields, and contaminated waterways provide incubators for antibiotic resistance.

The Monsanto patent for glyphosate as an antibiotic claims efficacy against the malaria plasmodium and other protozoan parasites. Other research supports this claim and identifies the shikimate pathway as a target for *Mycobacterium tuberculosis*, the cause of tuberculosis. (Schönbrunn et al., 2001) Thus, two of the most troublesome human diseases may be susceptible to antibiotics using glyphosate's mode of action. The use of glyphosate can thus be a contributor to the spread of resistance to medically important antibiotics.

The imbalance (dysbiosis) of bacteria in the gut has been associated with many modern diseases including diarrhea, inflammatory bowel disease, activation of HIV infection, allergies, and infection by Clostridium.

MICRONUTRIENT IMBALANCE

Some researchers have dived more deeply into the mechanisms by which glyphosate achieves its toxic effects. (See box, page 22.) A recent review article suggests, "As a metal chelator, glyphosate could deprive plants of important nutrients which have major roles as enzymatic co-factors and biomolecular constituents." (Gomes et al., 2014) In addition, several scientists have suggested that through interactions with rhizosphere microorganisms, glyphosate causes diseases that kill plants –including glyphosate-resistant crops. Glyphosate varies in its impacts on microbes—some species are inhibited by glyphosate, some are resistant, and still others may use glyphosate or its metabolite as a food source. (Kremer and Means, 2009) There are reports that glyphosate interferes with nitrogen fixation in glyphosate-resistant soybeans.

Disrupting the Integrity of Nature—Pesticides and Genetic Engineering

DON HUBER, PhD

EDITOR'S NOTE: *Don Huber, PhD, professor emeritus of plant pathology at Purdue University, spoke on glyphosate at Beyond Pesticides' 35th National Pesticide Forum, "Healthy Hives Healthy Lives, Healthy Land: Ecological and Organic Strategies for Regeneration", April 28–29, 2017. Excerpts of his talk follow.*

The U.S. uses 300 million pounds of glyphosate in agriculture and almost an equal amount for nonagricultural uses—for roadsides, rights-of-way, waterways, and other land areas. Looking at the increase over time, you can see the stimulation that genetic engineering [of crops designed to be herbicide tolerant] provided for the consumption, application, and indiscriminate use of this very simple, but very complex, chemical.

Glyphosate is a very persistent material. The half-life in soil can be from a year and a half to as long as 22 years.

Glyphosate was first patented as a mineral chelator to clean boilers and pipes. It is a broad-spectrum chelator—it chelates all kinds of cations [molecules or atoms with a positive charge]. That was in 1964. In 1974, Monsanto recognized it as a broad-spectrum herbicide. It is a broad-spectrum herbicide because it is a broad-spectrum chelator—and mineral ions are essential cofactors for physiological functions. In 2010, Monsanto also patented it as a very broad-spectrum antibiotic. It is an antibiotic against beneficial organisms, which we rely on in our GI [gastrointestinal) track or in the environment to supply us with minerals and the aromatic amino acids that we cannot produce ourselves. However, pathogenic microorganisms are over 4,000 times less sensitive than are the beneficial organisms.

Glyphosate is a very persistent material. The half-life in soil can be anywhere from a year and a half to as long as 22 years. It may take generations to eliminate it from some of our soils without some extra help. The carbon-phosphorous lyase enzyme required to degrade glyphosate is extremely rare in nature.

Glyphosate is a synthetic amino acid that has many other physiological functions that have only rarely been studied. It interferes with nutrient uptake. Reduced nutrition is available in the plant and in the seed. Farmers will say, "My crops aren't as vigorous as they used to be." They are starving. They do not have those micronutrients they need, and the consequence is that over 40 plant diseases and 32 human and animal diseases are now reaching epidemic proportions. These did not exist or were not a problem for us with our old controls.

The genes in these engineered plants are very promiscuous. We see it with the Roundup Ready creeping bent grass that is now an invasive weed in Idaho, Oregon, and Washington, and spreading out into the Pacific now. We know how to get the genes in; we do not know how to get them out when they are not wanted.

We have many more problems. The University of Wisconsin just released a study that says that one-third of a pound of phosphorous from glyphosate is going into Lake Erie every year from every acre of soil in the watershed. It is no longer being tied up because the system is already saturated.

Adverse impact on bees

Three of the factors responsible for colony collapse disorder in bees are a function of glyphosate. Then you combine glyphosate with the neonicotinoids, another endocrine disrupting chemical. Lorrin Pang, MD tells us that when you have two endocrine disrupting chemicals, it is not a one plus one equals two—it is a one plus one equals 30,000 times more damage. Glyphosate is a very potent antibiotic to the gut microbiome. Bees have to have *Lactobacillus* and *Bifidobacteria* in the honey crop in order to digest food. They are starving to death while they have plenty of honey and bee bread in the hive because they do not have the organisms there. Bees cannot utilize the food and their tissues are starved.

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Glyphosate in food

The quantity of glyphosate that is in our food is almost immoral. The USDA refuses to do the analysis because it knows what the levels are and what is happening. We see it in our youth and our wildlife. All of those consequences come from endocrine hormone disruption and the mineral deprivation that we have in those tissues.

A study shows an allergic response to the new proteins in GMO foods. When we feed genetically modified (GMO) foods to animals or people, you can see in their stomachs ulcerations and and deterioration of the gut linings and all of the diseases that go along with it.

And then we see the tragedy that is going on in Yakima, where researchers have been censored and threatened by the federal government if we talk about it. It started when Yakima began adding Rodeo to the water for invasive weed control in 2008, and the result was an epidemic of anencephaly. (Washington State Department of Health, 2016) There are also the spinal bifida, cleft palate, and other deformities now. And our children are at risk. Nobody is permitted to talk about it and to explain what is happening. Yet, if you look at Steve Druker's book *Altered Genes, Twisted Truths*—and I would recommend this to all of you, Steve shows how the venture to genetically engineer our food has subverted science, corrupted government, and systematically deceived the public.

The collusion and corruption in the system are why we have the problems that we have today. These two systems, the genetically engineered program and the chemicals that we are using are all impacting everything that we value in life. To summarize, future historians may well look back and write about our time, not about how many pounds of pesticides we did or did not apply, but about how willing we are to sacrifice our children and jeopardize future generations with this massive experiment we call genetic engineering that is based on false promises and flawed science, just to benefit the "bottom line" of a commercial enterprise.

Don Huber, PhD *is professor emeritus of plant pathology at Purdue University. His agricultural research the past 50 years has focused on the epidemiology and control of soil borne plant pathogens with emphasis on microbial ecology, cultural and biological controls, and physiology of host-parasite relationships. His research also includes nitrogen metabolism, micronutrient physiology, inhibition of nitrification, and nutrient-disease interactions. In addition to his academic positions and research, he is internationally recognized for his expertise in herbicide-nutrient-disease interactions, techniques for rapid microbial identification, and cultural control of plant diseases.*

Glyphosate adsorbed to soil particles may move in wind or water, affecting organisms off the target field.

(Zobiole et al., 2012) Several researchers have documented a number of diseases that increase in frequency or severity when grown in soil in which glyphosate is used to burn down weeds or cover crops prior to planting or applied to the previous year's crop. These diseases include *Corynespora* root rot of soybean, take-all of cereal crops, diseases caused by *Xylella fastidiosa*, and *Fusarium* diseases. Mechanisms observed for these increases in plant diseases include reduction in plant defensive compounds and reduced plant nutrition. (Johal and Huber, 2009) The reduced nutrition reaching plants from their microbial partners also affects the nutritional content of the crop, which has led to concern about impacts on the animals eating the crop. (Zobiole et al., 2010)

ECOLOGICAL IMPACTS

In addition to recent science showing the much greater toxicity of glyphosate products than the technical active ingredient to aquatic and semi-aquatic organisms (Tsui and Chu, 2003), glyphosate-resistant plants release glyphosate into the soil, where it has a continued impact. Glyphosate is also released to the soil by dead plants. "Once in soil, glyphosate may be adsorbed onto soil particles, degraded by microbes, or transferred to deeper soil horizons, migrating via soil pores or root canals. However, some agricultural practices, such as phosphorous amendment, may re-solubilize glyphosate in soils, making it available for leaching and movement to the rhizosphere of non-target plants." (Gomes et al., 2014) Glyphosate adsorbed to soil particles may move in wind or water, affecting organisms off the target field. Its use in agriculture has had a significant impact on monarch butterfly populations through the reduction of milkweed stands. (Pleasants and Oberhauser, 2013) However, the potentially much greater impact of glyphosate through its effects on soil microbiota is not fully studied.

CONCLUSION

The recent science on glyphosate—and this article has only looked at the tip of the iceberg—reveals the inadequacy of the risk assessment model for protecting humans and the environment from pesticides. From toxicity testing of the technical active ingredient, glyphosate appeared to have minimal health and environmental effects. But when scientists looked at the effects of the complete product—and more importantly, the effects as mediated by microbiota in the soil and the gut—it is shown to have health and environmental effects that threaten the lives of myriad species, including humans.

For an expanded, fully cited version of this article, see bp-dc.org/RoundupExposedCited.