BEYOND PESTICIDES
INFORMATION FOR ACTION

Monsanto's Roundup (Glyphosate) Exposed

PESTICIDE DISRUPTS SOIL AND HUMAN BIOLOGY, LEADING TO ADVERSE HEALTH AND THE ENVIRONMENTAL EFFECTS

This review 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.

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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 their effectiveness. Glyphosate's major metabolite is aminomethyl phosphonic acid (AMPA).

Glyphosate is translocated to meristematic tissues in the plant (where active cell division occurs.) There it 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, ultimately leading to the plant's death by starvation. Since animals do not use the shikimate pathway, the manufacturer of glyphosate (Monsanto) claims it is "safe" for humans. However, this safety claim ignores glyphosate's adverse effect on beneficial bacteria essential to human health.

GLYPHOSATE USE AND RESIDUES ARE INCREASING

As shown in Figure 1, the use of glyphosate has been increasing steadily. As a result, glyphosate residues are being detected in tissues and excretions of farm animals, as well as human urine. Bøhn et al. found that glyphosate accumulates in Roundup Ready soybeans, genetically engineered to be herbicide-tolerant, and also contains a different nutritional profile from organic and non-genetically engineered soybeans.[4]

GLYPHOSATE RISK ASSESSMENT

EPA's risk assessments –based on data submitted by Monsanto—rate glyphosate's acute toxicity as "relatively low." EPA bases its assessment of chronic risks on Monsanto's developmental tests on glyphosate. 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.[6,7]

EPA classifies glyphosate as a Group E carcinogen—evidence of non-carcinogenicity for humans—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." 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. The chemical must demonstrate a toxic effect that is 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.

"Inert" ingredients in glyphosate products

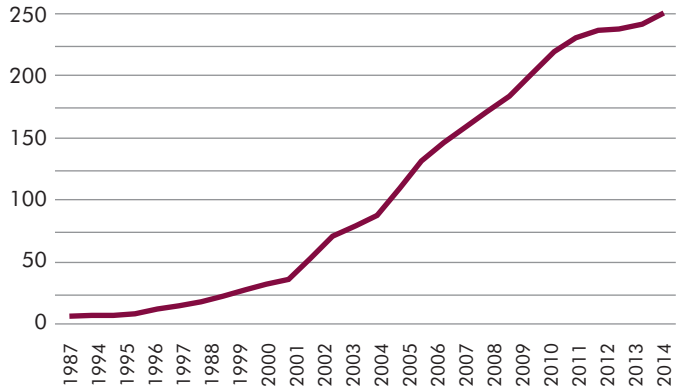
A number of surfactants and other ingredients are added to glyphosate products to make them more effective as herbicides, including 5-chloro-2-methyl 3(2H)-isothiazolone, FD&C Blue No. 1, glycerine, 3-iodo-2-propynyl butyl carbamate, light aromatic petroleum distillate, methyl p-hydroxybenzoate, polyoxyethylene alkylamine, propylene glycol, sodium sulfite, sodium benzoate, sodium salt of o-phenylphenol, and sorbic acid. Health effects that are associated with these so-called "inert" (non-disclosed) ingredients include genetic damage, reduced fertility, thyroid damage, eye irritation, anemia, reduced survival of offspring, and skin irritation.[2] Polyethoxylated tallowamine or POEA—a surfactant used in Roundup and other herbicidal products—has been identified as particularly toxic. [3]

Hazards of glyphosate products

In contrast to the results of the manufacturer's tests of glyphosate alone, an increasing number of studies have found that formulated glyphosate products (e.g., Roundup) are more toxic than glyphosate alone. 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.[4] Glyphosate and its formulated products adversely affect embryonic, placental and umbilical cord cells, and affect fetal development.[5] Chronic exposure to glyphosate-based herbicides can result in significant liver and kidney damage.[6]

Human cell endocrine disruption has also been observed to occur at concentrations well below those considered "acceptable," including disruption at the androgen receptor, inhibition of transcriptional activities on estrogen receptors

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



Source: Benbrook 2016

on HepG2, decreased aromatase activity, DNA damage, and cytotoxic effects.[7]

NEW SCIENCE AND GLYPHOSATE

Besides looking at the total formulation in addition to the active ingredient, newer scientific studies have looked in greater depth at glyphosate's mode of action and the implications for human and ecological health. Glyphosate works

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.

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 beneficial bacteria do use the shikimate pathway, and 90% 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. Looking even deeper at the mode of action of glyphosate, other scientists have found that it starves and sickens the very crop plants that it is supposed to protect.

Roundup and Monsanto on Trial

Recent reviews of glyphosate and glyphosate-based herbicides demonstrate a growing scientific consensus and concern about their health, environmental, and social impacts. A group of well-known and respected scientists collaborated on a consensus "Statement of Concern," stating that glyphosate is more persistent in the environment than previously believed and evidence has accumulated over the past two decades showing that glyphosate-based herbicides have serious impacts on human health and the environment, the extent of which has yet to be determined.[8]

Pesticide Action Network International published an updated "state of the science" review of a large body of research documenting the adverse human health and environmental impacts of glyphosate and glyphosate-based herbicides. The organization targets glyphosate in its "List of Highly Hazardous Pesticides" targeted for global phaseout.[9]

The International Monsanto Tribunal in 2017 heard evidence resulting in a legal opinion of the activities of Monsanto with respect to international human rights and environmental law. The Tribunal concluded that Monsanto has engaged in practices that have negatively affected the right to: (i) a healthy environment; (ii) food; (iii) health; and (iv) freedom indispensable for scientific research. These activities are recognized in international criminal law as crimes of ecocide. The Tribunal also stated the need to assert the primacy of international human and environmental rights law and hold non-state actors responsible within international human rights law.[10]

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.

Glyphosate Litigation

Two lawsuits –one by Beyond Pesticides and Organic Consumers Association (OCA),[11] and the other by six consumers from states around the country—address claims by Monsanto, manufacturer of Roundup, and Scotts Miracle-Gro Company, a marketer of Roundup brand products, that Roundup's active ingredient, glyphosate, targets an enzyme that is not found 'in people or pets.'" The plaintiffs assert that this is a false and deceptive claim, as this enzyme is found in the gut bacteria of people and pets, and glyphosate can disrupt the health and functioning of their immune system. Beyond Pesticides and OCA, suing in Washington, DC under the District of Columbia's Consumer Protection Procedures Act, ask for equitable relief on behalf of the general public, with all profits earned by Monsanto for sales of Roundup in D.C. to be deposited into a charitable fund for the raising of consumer awareness of the effects of glyphosate. The six consumers ask for "compensation for themselves and Class Members equal to the amount of money they paid for Roundup products that they would not have purchased had they known the truth or, in the alternative, the amount of money they paid based on the false statement."

Beyond Pesticides has also filed several lawsuits against companies that have produced food products containing glyphosate, and then labeled those products "natural." In August 2016, three non-profit organizations filed a lawsuit against General Mills for misleading the public by labeling their Nature Valley™ brand granola bars as natural. In November 2016, Beyond Pesticides and OCA, represented by Richman Law Group, filed a lawsuit in Superior Court in the District of Columbia against Sioux Honey Association, for the deceptive and misleading labeling of its Sue Bee and Aunt Sue's honey brands. These cases are in various stages in the legal process, with some conflicting decisions, and pending appeals.

THE HUMAN GUT AND 21ST CENTURY DISEASES

The 90 percent of human cells that are microbial in origin are not (mostly) pathogenic, nor are they (mostly) just along for the ride. They are (mostly) symbionts who help the human function as it should. The human body, rather than being a distinct organism, is a biological community or "superorganism," the 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

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sites. Such diseases can be triggered not only by pathogenic microbes, but also by otherwise harmless commensal microbes [those that naturally live within our bodies] 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."[12]

Not all disturbance in the microbiota comes from the conscious use of antibiotics. Swanson et al. have recently documented that the rise in these same diseases is tightly correlated with the use of the herbicide glyphosate.[13] 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 has been patented as an antibiotic.[14]

Glyphosate and gut dysbiosis

Researchers Samsel and Seneff, starting with documents obtained from EPA through the Freedom of Information Act (FOIA), synthesized mountains of peer-reviewed research relating to health effects driven by glyphosate's mode of action. They and others have shown that the long list of 21st century diseases are linked to imbalances in the human gut connected to pervasive exposure to glyphosate.[15] Although Samsel and Seneff have speculated about the precise mechanisms involved in the causation of these diseases, the evidence for a causal link is strong. The evidence comes from two directions—first, that glyphosate causes dysbiosis (imbalance) 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.[16] Scientists have described the interaction between glyphosate and the shikimate pathway "in atomic detail."[17] Those 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.[18] For example, Shehata et al. 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."[19]

Gut dysbiosis and 21st century diseases

Normally, the human gut is host to an ecosystem composed of anaerobic bacteria that are (mostly) non-pathogenic and (mostly) 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. Some of these organisms live only in the human intestinal tract, which suggests a coevolved relationship.[20]

Disrupting the Integrity of Nature—Pesticides and Genetic Engineering

DON HUBER, PhD

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.*

The imbalance (dysbiosis) of bacteria in the gut has been associated with many modern diseases. They include diarrhea, inflammatory bowel disease, activation of HIV infection, allergies, infection by *Clostridium difficile* and other pathogenic bacteria, autism, liver disease, atherosclerosis, pancreatitis, diabetes, obesity, fibromyalgia, polycystic ovary syndrome, and others.[21] The fact that such diseases are linked to dysbiosis of the gut does not in itself prove that glyphosate causes them. However, the increase in these diseases is correlated tightly with increases in the use of glyphosate. Glyphosate is the most widely used antibiotic in agriculture, and agricultural use of antibiotics dwarfs the use of antibiotics in human medicine.[22] To characterize glyphosate's relationship to these diseases, celiac disease and autism serve as examples.

Celiac disease

Several studies demonstrate that celiac disease is associated with gut dysbiosis.[23] In particular, it is associated with reduced levels of *Enterococcus, Bifidobacteria*, and *Lactobacillus* in the gut, and increased pathogenic gram negative bacteria.[24] *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 pathogenic *Bacteroides, Staphylococcus, Salmonella,* and Shigella were higher.[25] Another study found *Bacteroides, Clostridium*, and *Staphylococcus* all to be significantly higher in children with celiac disease.[26] The imbalances found by these studies of celiac disease are the same as those seen with glyphosate exposure.

Autism

Another disease that has been linked to glyphosate exposure is autism. To many people, the linkages between disorders of the central nervous system and gut dysbiosis may seem unlikely. However, as stated by Wang and Kasper, "Studies are revealing how diverse forms of neuro-immune and neuro-psychiatric disorders are correlated with or modulated by variations of microbiome, microbiota-derived products and exogenous antibiotics and probiotics. The microbiome poises the peripheral immune homeostasis and predisposes host susceptibility to CNS [central nervous system] autoimmune diseases such as multiple sclerosis. Neural, endocrine and metabolic mechanisms are also critical mediators of the microbiome-CNS signaling, which are more involved in neuropsychiatric disorders, such as autism, depression, anxiety, stress."[27] It is beyond the scope of this piece to provide a complete review of the literature investigating the interplay between the gut microbiota and the brain, but a brief consideration of autism illustrates the possibilities. In addition to autism, other neurological disorders connected with gut dysbiosis include dementia, mood disorders, schizophrenia, depression, and bipolar disorder.[28]

Autism, a neurodevelopmental disorder characterized by impaired communication and social interactions and restricted interests and behaviors, is on the rise. Due to difficulties in

diagnosis, it is unclear exactly how much the incidence of autism has increased, but it is generally believed to be increasing.[29] A growing body of evidence shows that children with autism spectrum disorders (ASD) have a different composition of gut bacteria from controls. Researchers find that 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."[30]

The linkage between glyphosate and autism was substantiated by 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.[31]

Antibiotic Resistance

The spread of antibiotic resistance is a health care crisis of major proportions. The Centers for Disease Control and Prevention (CDC) call it "one of the world's most pressing public health problems."[32] 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.[33] Bacteria evolve quickly, and antibiotics provide strong selection pressure for those strains with genes for resistance.

With the explosion of antibiotic resistance in the U.S. and worldwide, antibiotic use in crop and livestock production is a major public health issue. 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. Both the human gut and contaminated waterways provide incubators for antibiotic resistance.

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In addition to the promotion of weed resistance by widespread application of glyphosate and use of glyphosate-resistant genes in agriculture, there is evidence that glyphosate at levels used in agriculture results in bacterial resistance to antibiotics important in fighting human pathogens and infections.[34] It may not be widely appreciated that use of

Microorganisms Susceptible to Glyphosate

In its patent, Monsanto claims that the following is a non-exhaustive list of microorganisms that are susceptible to glyphosate.[48]

Species of the Phylum Apicomplexa
- *Toxoplasma gondii*
- *Cryptosporidium parvum*
- *Neospora caninum*
- *Eimeria spp.*
- *Isospora spp.: I. belli*
- *Theileria spp.: T. parva and T. annulata*
- *Plasmodium spp.: P. falciparum, P. vivax, P. malariae, and P. ovale.*
- *Babesia spp.: B. microti, B. divergens, B. canis, B. bigemina, B. bovis, B. ovis, B. caballi, B. equi, B. gibsoni, and B. felis.*

Species of the Family Neisseriaceae
- *Neisseria meningitidis*
- *Neisseria gonorrhoeae*
- *Moraxella spp.: M. lacumata, M. nonliquefaciens, M. urethralis, M. catarrhalis, and M. bovis,*
- *Klingella spp.: K. dentrificans and K. kingae*
- *Eikenella spp.: E. corrodens.*

Species of the Family Enterobacteriaceae
- *Escherichia coli*
- *Edwardsiella ictaluri*
- *Klebsiella spp.: K. pneumonia and K. oxytoca*
- *Salmonella spp.: S. typhimurium, S. typhi, S. paratyphi, S. enteritidis and S. cholerasuis*
- *Serratia spp.: S. marcesans and S. liquifaciens*
- *Shigella spp.: S. dysenteriae, S. flexneri, S. boydii and S. sonnei*
- *Yersinia spp.: Y. enterocolitica, Y. pestis, Y. pseudotuberculosis and Y. ruckeri*
- *Citrobacter spp.: C. freundii and C. diversus*
- *Enterobacter spp.: E. aerogenes, E. agglomerans and E. cloacae*
- *Morganella spp.: M. morganii*
- *Proteus spp.: P. mirabilis and P. vulgaris*
- *Providencia spp.: P. alcalifaciens, P. rettgeri and P. stuartii.*

Species of the Family Pasteurellaceae
- *Pasteurella multocida*
- *Actinobacillus pleuropneumoniae*
- *Haemophilus spp.: H. influenzae, H. parainfluenzae, H. ducreyi, H. aphrophilus and H. aegyptius.*

Species of the Family Mycobacteriaceae
- *Mycobacterium spp.: M. tuberculosis, M. bovis, M. africanum, M. microtti, M. leprae, M. kansasii, M. avium-intracellulare, M. scrofulaceum, M. ulcerans and M. marinum.*

Species of the Family Nocardiaceae
- *Nocardia spp.: N. asteroides, N. brasiliensis and N. caviae.*

Species of the Family Brucellaceae
- *Brucella spp.: B. abortus, B. suis, B. melitensis and B. canis.*

Species of the Family Trypanosomatida
- *Leishmania spp., including but not L. tropica, L. major, L. donovani, L. braziliensis and L. mexicana.*

Species of the Family Streptococcaceae
- *Streptococcus spp.: S. pneumoniae, S. pyogenes, S. agalactiae, S. mutans, S. milleri, S. sanguis, S. anginosus, S. bovis, S. equisimilis, S. salivarius and S. mitis.*

Species of the Family Alcaligenaceae
- *Bordetella spp.: B. pertusis, B. parapertusis, B. brochiseptica, B. avium and B. hinzii.*

Species of the Family Micrococcaceae
- *Staphylococcus spp.: S. aureus, S. epidermidis, S. saprophiticus, S. lugdunensis, S. haemolyticus, S. warneri, S. schleiferi and S. intermedius.*

Species of the Family Trichocomaceae
- *Aspergillus spp.: A. fumigatus, A. flavus, A. amstelodami, A. avenaceus, A. candidus, A. cameus, A. caesiellus, A. clavatus, A. glaucus, A. granulosus, A. nidulans, A. niger, A. oryzae, A. quadrilineatus, A. restrictus, A. sydowi, A. terreus, A. ustus and A. versicolor.*

Species of the Family Bacillaceae
- *Bacillus spp.: B. anthracis, B. subtilis and B. halodurans*
- *Clostridium spp.: C. perfringens, C. tetani, C. difficile and C. botulinum.*

Species of the Family Chlamydiaceae
- *Chlamydia spp.: C. trachomatis and C. pneumoniae*
- *Chlamydophila spp.: C. pneumoniae, C. abortus and C. psittaci.*

Species of the Family Listeriaceae
- *Listeria spp.: L. monocytogenes, L. innocua and L. ivanovii.*

Species of the Family Pseudomonadaceae
- *Pseudomonas aeruginosa.*

Species of the Family Enterococcaceae
- *Enterococcus faecalis and E. faecium.*

Species of the Family Cardiobacteriaceae
- *Dichelobacter nodosus.*

Species of the Family Campylobacteriaceae
- *Campylobacter jejuni.*

Species of the Family Aeromonadaceae
- *Aeromonas hydrophila and Aeromonas salmonicida.*

Helicobacterpylori
- *Candida albicans*
- *Pneumocystis carinii.*

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antibiotics in agriculture can contribute to resistance to antibiotics in human pathogens. The human pathogenic organisms themselves do not need to be sprayed by the antibiotic because movement of genes in bacteria is not solely "vertical"—that is from parent to progeny—but can be "horizontal"—from one bacterial species to another. Thus, a pool of resistant soil bacteria or commensal gut bacteria can provide the genetic material for resistance in human pathogens.

The use of glyphosate has an impact on the pool of antibiotic-resistant bacteria. Furthermore, residues of glyphosate in the soil may be taken up by treated or untreated plants and affect bacteria.[35]

The gut of humans and other animals provides an efficient incubator for antibiotic resistance. Antibiotic resistance increases first in commensal bacteria and may then be transferred to pathogens. Thus, the absence of human pathogens in fields sprayed with glyphosate is irrelevant to the actual development and spread of resistant bacteria. The number of bacteria in the gut is large—often more than 10^{14} bacteria of several hundred species—with a large gene pool offering many mechanisms of resistance, and every exposure to antibiotics providing new opportunities for selection for resistance.[36]

Glyphosate used on crops is also washed into waterways, where it finds another environment perfect for encouraging the growth of antibiotic-resistant bacteria. Aquatic environments are rich in bacteria, and provide opportunities for pathogens to obtain genes for resistance.

The Monsanto patent for glyphosate as an antibiotic claims efficacy against the malaria plasmodium and other protozoan parasites.[37] Other research supports this claim and identifies the shikimate pathway as a target for *Mycobacterium tuberculosis,* the cause of tuberculosis.[38] 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. In addition, glyphosate (along with some other herbicides) at environmentally relevant levels facilitates the development of resistance to antibiotics.[39] Broadcasting this antibiotic on grain crops—and spreading genes for resistance through genetically engineered crops dependent on glyphosate—contributes to the problem of antibiotic resistance.

As EPA stated for another antibiotic, if "bacterial resistance to oxytetracycline from pesticidal use occurs, it is most likely that it would be caused by development of resistance from non-pathogenic bacteria in orchards, which later transferred their resistance to human bacterial pathogens."[40] Therefore, EPA risk assessments based on toxic effects in animal and human models is inadequate for determining and managing the risk of antibiotic resistance promoted by glyphosate use.

MICRONUTRIENT IMBALANCE

Some researchers have dived more deeply into the mechanisms by which glyphosate achieves its toxic effects. A recent review article questions whether disruption of the shikimate pathway is sufficient to kill plants and suggests, "As a metal chelator, glyphosate could deprive plants of important nutrients which have major roles as enzymatic co-factors and biomolecular constituents."[42] 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 AMPA as a food source.[43] The impacts of glyphosate's interactions with the microbiota of the root zone are various. For example, soybeans are legumes and hence harbor nitrogen-fixing bacteria in root nodules. There are reports that glyphosate interferes with nitrogen fixation in glyphosate-resistant soybeans.[44] 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. The mechanisms observed for these increases in plant diseases include reduction in plant defensive compounds and reduced plant nutrition.[45] The reduced nutrition reaching

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.

Glyphosate: A Selected Bibliography

It is not easy to conduct or publish research that is critical of glyphosate, especially in the United States. One need only consider the 2012 paper by Giles Séralini et al., and the subsequent forced retraction, controversy in journals, and finally, republication.[51] The furor over the IARC classification of glyphosate as a Group 2A carcinogen, "probably carcinogenic to humans" followed by attacks on IARC and the principal author of the IARC monograph, Aaron Blair PhD, is another example.[52] The following bibliography presents only research from independent scientists.

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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.[46]

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,[47] an important finding is that glyphosate-tolerant 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 to the rhizosphere of non-target plants."[48] 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.[49] However, the potentially much greater impact of glyphosate through its effects on soil microbiota is unknown and require long-term studies.[50]

Glyphosate has been shown to have health and environmental effects that threaten the lives of myriad species, including our own.

CONCLUSION

The recent science on glyphosate—and this review 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 look at the effects of the complete product—and more importantly, the effects as mediated by microbiota in the soil and the human gut—it has been shown to have health and environmental effects that threaten the lives of myriad species.

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