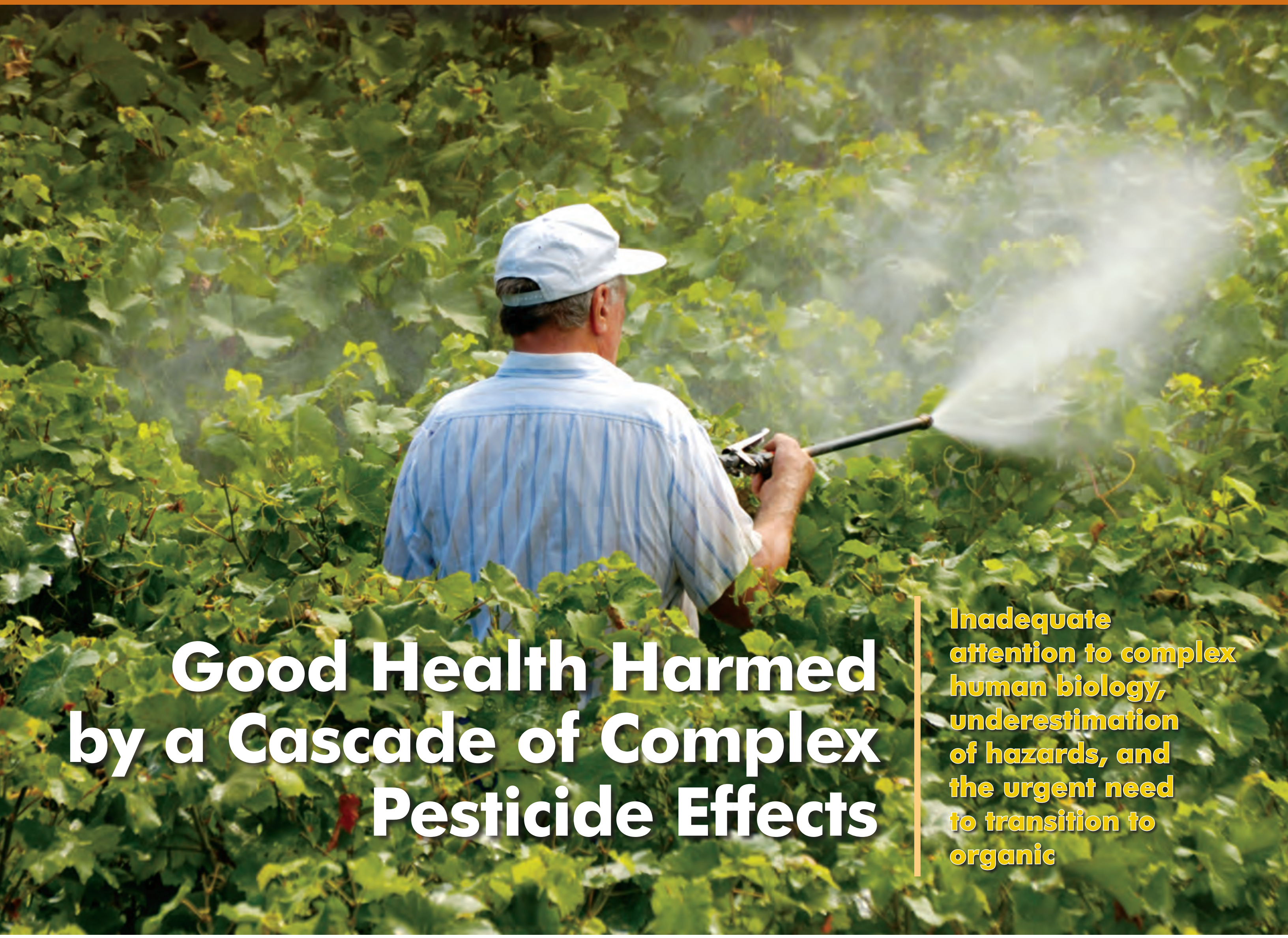

Good Health Harmed by a Cascade of Complex Pesticide Effects

Inadequate attention to complex human biology, underestimation of hazards, and the urgent need to transition to organic

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EDITOR'S NOTE: This article sets forth an approach to evaluating the health impacts of pesticides within the human body's ecosystem, with all its compexities. Consideration must be given to a broad range of effects in a holistic assessment for maintaining and enhancing good health. The current regulatory review and underlying standards governing the U.S. Environmental Protection Agency's allowance, or registration, of pesticide products used in agriculture, communities, homes, and gardens adopts a narrow, and therefore unrealistic, approach to the determination of safety thresholds for exposure—putting the public at risk for widespread diseases, from cancer to respiratory illness, Parkinson's, diabetes, reproductive problems, and learning disabilities, including autism. The approach called for in this piece builds on an earlier article in *Pesticides and You, Thinking Holistically When Making Land Management Decisions: Regulatory analyses that support pesticide use ignore complex ecological impacts*, which focuses on ecological impacts of chemical-intensive practices. (See *PAY*, 38:1, 2018.) Both assessments, ecological and human health, evaluate the dominant chemical-intensive approach to land management in the context of commercially available organic and sustainable approaches that eliminate pesticide exposure. In considering this approach, the question is whether it is reasonable for regulations to allow toxic pesticide use when nontoxic alternatives are available and economically viable. The need for a more realistic assessment of pesticides' impact on human health is being advanced at time when the urgency for the transition away for toxic chemical use has never been greater to ensure long-term human survival.

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Human health depends on the proper functioning of interacting parts of the body. Weakening the body increases and/or changes the effect of toxic substance exposures. These impacts are not easily captured in current health risk assessments used by regulators because they may result from interactions among pesticides and cumulative impacts of single or multiple stressors. In order to assess the reasonableness of toxic chemical exposures associated with chemical-intensive agriculture and land management, it is necessary to evaluate the effects of that entire management system and compare its effects with those of organic management systems that eliminate toxic chemical exposures.

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PART ONE

Holistic Assessment of Health Effects

THE CONTEXT OF PESTICIDE USE

When determining the acceptability of pesticide use from a human health perspective, two issues emerge as particularly inadequate in the regulatory assessment: (i) the dramatic deficiency of evaluations that ignore the complex biological systems and exposure realities that must be considered to ensure good health, and (ii) the failure to consider the availability of less or nontoxic management systems for achieving pest management goals. The legal standard for registering a pesticide in the U.S. under the *Federal Insecticide, Fungicide and Rodenticide Act* (FIFRA) requires a determination of "no unreasonable adverse effects, taking into account the risks and benefits of pesticide use." However, the chemical-by-chemical approach used by the U.S. Environmental Protection Agency (EPA) to assess the acceptability of a pesticide's hazards and its assumed benefits to society or pesticide users belies the critical scientific need to assess pesticide use in a broader context of both exposure and pest management and prevention. Key to an adequate assessment is always the question of whether there is an alternative to using the chemical that does not involve merely substituting a different chemical into the same management system. To perform an accurate evaluation of the hazards of using a pesticide, it must be considered in the context of the chemical-intensive management system in which it is judged to be needed or essential—and the pesticide *in that system* must be compared to a system in which the pesticide is not used because it is unnecessary.

DETERMINING HUMAN HEALTH HAZARDS FROM PESTICIDES

Human health depends on many factors that may or may not be under the control of the individual. External threats to health go beyond toxicity to factors that affect the environment in which people live, the functioning of the body, and the importance of uncontaminated air, water, and food in supporting life. Thus, it is important to consider factors like human nutrition, gut microbiology, and the endocrine system, in addition to, and in conjunction with, the toxicity of pesticides.

IMPROVING THE STANDARD FOR MEASURING HEALTH EFFECTS OF PESTICIDES

Distinct from risk assessments undertaken by EPA, which measure risks of individual chemicals (see Box 1), a holistic health assessment approach is needed that evaluates individual chemical hazards in combination with the impacts of a chemical-intensive land management system, contrasted with a regenerative organic systems approach and an uncontaminated environment. With this method, regenerative organic agriculture and land management is understood to be a valid baseline because it is based on natural ecological systems and seeks to restore soil health, sequester carbon, improve animal welfare, and provide economic stability, fairness, and health protection for farmers, ranchers, and farmworkers.

A HOLISTIC LOOK AT HEALTH EFFECTS OF PESTICIDES

Health effects need to be evaluated in the context in which they occur—and the co-occurring threats presented by other aspects of chemical-intensive land management and pest management. The reasonableness of these impacts must be considered in the context of viable organic systems and least-toxic management systems. Compared to this approach, EPA's risk assessment is a one-dimensional view of a multi-dimensional system, in which the outcome is a single reference dose or cancer risk number.

Just as the needs of human biology are complex, so are the patterns of exposures to pesticides and other toxic chemicals. People are rarely exposed to just one chemical—they may be exposed to several chemicals at the same time, one or more chemicals sequentially, or inherit a transgenerational effect. In addition, timing of exposure can be very important, as well, as is the case with minute doses of endocrine disrupting pesticides.

EPA's risk assessment mostly ignores multiple chemical exposures. The exception is the cumulative assessment mandated by the *Food Quality Protection Act* (FQPA) (see Box 2) of chemicals with a "common mechanism of toxicity." However, to address more broadly the basic requirements for good health, a holistic evaluation looks at the many ways in which varied pesticide exposures interact and interfere with the normal and healthy functioning of the human body. To do this, the evaluation considers a range of exposures discussed below.

Clean Air. Key to the human need to breathe air is the oxygen that is required for cellular respiration—to break down food used for energy—and the exhaling of the waste

BOX 1

EPA's Health Risk Assessment

Toxicity tests required for EPA pesticide registration are performed on laboratory animals and assessed in relation to a number of standardized endpoints. These endpoints may or may not correspond directly to effects seen as a result of actual human exposure.

EFFECTS OF ACUTE EXPOSURE TO PESTICIDES

"Acute toxicity" refers to the effects of a single exposure to the chemical. EPA requires chemical manufacturers, or registrants, to submit results of tests of acute toxicity through oral, dermal, and inhalation routes of exposure; primary eye irritation; primary dermal irritation; and dermal sensitization. All of these tests must be performed, under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), using both the technical grade active ingredient and the end-use product that people buy and use (which includes "inert"—not disclosed to the public—ingredients). In addition, acute neurotoxicity and delayed neurotoxicity tests are required for the active (that part of the formulation that the manufacturer claims attacks the target pest) ingredient only.

EPA uses the acute toxicity tests to set an acute reference dose (aRfD), which is the highest dose at which no adverse effect is found in the animal testing (also known as the no-observed-adverse-effect-level or NOAEL) divided by safety factors that EPA deems appropriate. The aRfD is used in establishing requirements for personal protective equipment (PPE) for applicators, reentry periods for farmworkers (time before returning to treated fields), classification as general or restricted use, and application rates. The data is also used to set allowable residues in food (tolerances) under federal food law.

CHRONIC EFFECTS OF EXPOSURE TO PESTICIDES

Chronic effects may be persistent effects that linger after acute exposure to pesticides, or they may result from chronic, low-level exposure over time. Chronic, low-level exposures can result from food residues, environmental contaminants, repeated use of home and garden products, or a body burden of persistent chemicals. EPA chronic risk assessments measure the impacts of repeated doses of chemicals over the lifetime of an experimental animal.

EPA's cancer risk assessment contains four steps: hazard identification, dose-response estimation, exposure evaluation, and risk characterization. In hazard identification, human data, animal data, and supporting evidence are combined to characterize the weight-of-evidence regarding the agent's potential as a human carcinogen. The current guidelines, as finalized in 2005, assign categories separately for the oral and inhalation routes: Carcinogenic to Humans, Likely to be Carcinogenic to Humans, Suggestive Evidence of Carcinogenic Potential, Inadequate Information to Assess Carcinogenic Potential, and Not Likely to be Carcinogenic to Humans. Dose-response estimation uses data from animal studies to develop a mathematical relationship between the dose and the likelihood of developing cancer. Exposure assessment assumes the amount of chemical to which a person will be exposed—with a high degree of uncertainty and without any thought to pre-existing medical conditions, genetic predisposition, exposure history (including workplace exposure), community exposure from toxic waste sites, and unique diets. Risk characterization combines the results of the earlier steps into a statement of risk.

All experiments on chronic effects used in pesticide registration decisions are performed on the technical active ingredient, not the product, including so-called "inert" ingredients. EPA also requires some intermediate-length subchronic tests. Of those, only the dermal tests must be performed on the end-use product as well as the active ingredient.

product carbon dioxide created in cellular respiration. The unimpeded exchange of gases requires healthy lungs. Polluted air can carry fine particles deep into the lungs and prevent efficient breathing.

Chemical fertilizers are used in chemical-intensive land management and animal agriculture, resulting in fine particulate pollution (nitrate and ammonia) that is carried deep into the lungs. Fine particulates have been identified as the most dangerous particles because they penetrate most deeply, affecting gas exchange within the lungs.

Asthma. Asthma is a leading chronic childhood disease—a serious inflammatory disease characterized by recurrent breathlessness, coughing, chest tightness, shortness of breath, and wheezing. It is the third leading cause of hospitalization among children under the age of 15 years, leading to an annual cost of treatment of $27 billion—and the incidence continues to increase. Experts agree that causation involves the interplay of different factors. "[A]t the exposure to relatively low concentration levels of air pollution, synergism of the inhaled pollutants is one of the basic phenomena and absolutely cannot be ignored," according to researcher and author Jozef Pastuszka, PhD (2015).

The linkages between pesticide exposure and asthma have been investigated by mechanistic, toxicological, and epidemiological studies. Some pesticides appear to be allergic sensitizing agents. Others are associated with airway hyperreactivity, oxidative stress, and immunological sensitization. Some epidemiological studies have found an association between organophosphate pesticides and asthma. These studies have all, to the extent possible, addressed pesticide exposure in isolation from other possible causes. However, agricultural pesticide use occurs within a system in which other factors associated with asthma are also present.

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Health effects need to be evaluated in the context in which they occur—and the co-occurring threats presented by other aspects of chemical-intensive land management and pest management.

There is an established association between obesity and asthma. While obesity increases the incidence of asthma, the class of endocrine disruptors known as obesogens—chemicals that increase fat mass in a living animal—includes a number of pesticides.

Clean Water. Water is the most essential human nutrient. It is recommended that an adult male consumes at least 12 cups of non-alcoholic, non-caffeinated fluids per day (9 cups for a female) to maintain a healthy level of hydration. Although much of that liquid is consumed in forms other than pure water, consumption of water that is contaminated with toxic chemicals is counterproductive because water is the medium for the safe elimination of toxins and waste products.

Pesticides and fertilizers are detected in the nation's drinking water resources—both surface water and groundwater. The U.S. Geological Survey (USGS) found pesticides in 97% of streams in urban and agricultural areas. Pesticides are detected in 61% of groundwater samples from agricultural areas and 55% of samples from urban areas. Samples from areas of mixed land uses or undeveloped areas are contaminated less frequently, but the majority of surface water samples from every land use pattern are contaminated. A significant number of the streams in agricultural and urban areas (9.6% and 6.7%, respectively) contain pesticides above human health benchmarks.

Related drinking water resources are contaminated by fertilizers. USGS found, "Concentrations of all five nutrients—nitrate, ammonia, total nitrogen, orthophosphate, and total phosphorus—exceed background levels at more than 90 percent of 190 streams draining agricultural and urban watersheds. Nitrate concentrations exceeded background levels in 64 percent of 86 shallow aquifer studies sampled in agricultural and urban areas." USGS also found that the maximum contaminant level (MCL) is exceeded in nearly 30% of agricultural streams, 7% of urban streams, 7% of domestic wells, 3% of public water supply wells, and 57% of all major aquifers.

Whether or not an individual pesticide or fertilizer exceeds the health-based standard is not as important as it could be because the standard is not based on exposure to multiple chemicals. USGS found that almost all urban and agricultural stream samples contain two or more pesticides—two or more pesticide compounds more than 90% of the time, and 10 or more compounds about 20% of the time. Similarly, the vast majority of wells in which pesticides are detected contain two or more pesticide chemicals. Fertilizer chemicals are also present in surface water and groundwater where pesticides are found.

A more recent USGS study of 100 Midwestern streams detected complex mixtures of pesticides and degradation products—a total of 94 pesticides and 89 degradation products, with a median of 25 chemicals per sample and 54 per site.

The toxicology community is taking note of the fact that mixtures of toxic chemicals often have serious effects at doses considered "safe" based on traditional toxicity testing. The new editor-in-chief of *Toxicology Reports,* for example, says he "has a special interest in low-dose, long-term effects from combined exposures." Of relevance to assessing the health impacts of pesticides are non-monotonic responses to low-dose mixtures of pesticides, pesticide products that exhibit different toxicological effects from their individual or combined active ingredients, synergistic effects of pesticides and heavy metals, synergistic and novel effects on the endocrine system, immunity, and behavior from multiple pesticide/fertilizer exposures at levels found in surface water and groundwater. Jaeger et al. (1999) point out six ways that testing of pesticides is deficient:

From: Rosi-Marshall EJ , et al. (2007). "Toxins in transgenic crop byproducts may affect headwater stream ecosystems." Proc Natl Acad Sci USA 104:16204–16208. © 2007 National Academy of Sciences, U.S.A.

1. Pulse doses (elevated levels during certain periods) at low concentrations are not considered;
2. Simultaneous exposure through multiple routes is not considered, and surfactants that increase entry through skin and other membranes are not included;
3. Immune, endocrine, nervous system, and developmental endpoints are not considered;
4. Contaminants, additives, and "inert" ingredients are excluded;
5. Commonly occurring mixtures are not tested; and
6. Naturally occurring stresses (such as nutrition, disease, and climate) are excluded.

BOX 2

Common Mechanism of Toxicity

The *Food Quality Protection Act* (FQPA) of 1996 requires that EPA base its assessment of the risk posed by a pesticide chemical on aggregate (i.e., total dietary, residential, and other non-occupational) exposure to the pesticide and available information concerning the cumulative effects to human health that may result from non-occupational exposure to other substances that have a "common mechanism of toxicity." EPA explains, "A person exposed to a pesticide at a level that is considered safe may in fact experience harm if that person is also exposed to other substances that cause a common toxic effect by a mechanism common with that of the subject pesticide, even if the individual exposure levels to the other substances are also considered safe."

EPA has applied the concept of "common mechanism of toxicity" very narrowly, to "two or more pesticide chemicals or other substances that cause a common toxic effect to human health by the same, or essentially the same, sequence of major biochemical events." It has identified five groups, or chemical families, that are assessed as having a common mechanism of toxicity: organophosphates, N-methyl carbamates, triazines, chloroacetanilides, and pyrethrins/pyrethroids.

The restriction of aggregate and cumulative assessments to those materials having a "common mechanism of toxicity" is another example of the one-dimensional view in EPA's risk assessment. From the perspective of the whole body, exposure to chemicals with varied mechanisms of toxicity may be much more hazardous. For example, an exposure to a substance that targets detoxification organs (e.g., liver) or the immune system sets the stage for much greater impacts from other toxic and pathogenic materials. In addition, synergistic effects (where the effect of two chemical exposures together is greater than each individual exposure alone) associated with chemical mixtures are not evaluated.

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PART TWO

Organic Supports Healthy Management Systems

CLEAN DRINKING WATER

Organic practices reduce or eliminate pesticide runoff. Organic farming and land management reduce or eliminate water pollution and help conserve water and soil. According to the Food and Agriculture Organization (FAO), several countries in Europe compel or subsidize organic farmers to use organic techniques specifically to combat water pollution problems.

Organic production reduces nutrient runoff. Organic standards stipulate that soil fertility and crop nutrients can be managed through tillage and other cultivation practices, such as crop rotation, which preserve and maintain the fertility of the soil so that synthetic inputs become unnecessary. Organic therefore eliminates the need for and use of synthetic nitrogen/phosphorus-based fertilizers. Organic standards require that manure be managed in a way that avoids nutrient pollution of water. Thus, organic practices significantly reduce the threats that nitrogen and phosphorus runoff pose to aquatic ecosystems and drinking water sources.

Organic standards prohibit the use of sewage sludge/biosolids. Sewage sludge, which is often contaminated with a host of chemicals, including heavy metals, pharmaceuticals, and pesticides, is not allowed in organic production. These can all reenter the aquatic environment once the sludge is recycled on land.

Genetic engineering (GE) is prohibited. Genetic engineering that incorporates the popular herbicide-tolerant, Roundup Ready corn and soybeans, or insecticidal genes into plants, is prohibited in organic management. GE crops have led to a dramatic increase in herbicide use, as farmers are able to apply these chemicals without killing their crop. Weed and insect resistance develop in response to GE methods, ultimately leading to increased use of herbicides and insecticides.

FREEDOM FROM CANCER

Eliminating the use of cancer causing pesticides is important to fighting a disease that is debilitating to both patients and their families. Cancer, like other diseases caused by environmental contaminants, places a huge personal and financial strain on sufferers. The National Cancer Institute says, "In 2018, an estimated 1,735,350 new cases of cancer will be diagnosed in the United States and 609,640 people will die from the disease." The number of cancers continues to increase, especially among children.

The link between pesticides and cancer has long been a concern. In addition to agriculture-related cancers from pesticides, 19 of 30 commonly used lawn pesticides and 28 of 40 commonly used school pesticides are linked to cancer. Even with the growing body of evidence linking environmental exposures to cancer in recent years, a 2010 report by the President's Cancer Panel finds that the true burden of environmentally-induced cancer is greatly underestimated. The Panel's report, *Reducing Environmental Cancer Risk: What We Can Do Now,* concludes that while environmental exposure is not a new front on the war on cancer, the grievous harm from carcinogenic chemical use has not been addressed adequately by the nation's cancer program. As of this writing, the Beyond Pesticides Pesticide-Induced Diseases Database contains 430 epidemiological studies linking pesticides to 31 types of cancer. Many of these studies involve more than one pesticide, emphasizing the message that the pesticide-dependent agricultural system must be considered as a whole.

The controversy over glyphosate makes another point. The World Health Organization's International Agency for Research on Cancer (IARC) finds sufficient evidence of carcinogenicity in experimental organisms to classify glyphosate as "probably carcinogenic to humans," while EPA concludes that glyphosate is "not likely to be carcinogenic to humans." The main difference between the IARC and EPA findings (and others, including EFSA (the European Food Safety Authority), is that IARC considers glyphosate-based formulations in its assessment, whereas EPA does not. Glyphosate is never used alone in any pesticide product, but is always formulated with "other" or "inert" ingredients (co-formulants). It is notable that in EPA's ecological assessment for glyphosate the agency highlights the differences in toxicity to nontarget organisms between glyphosate and its formulated products, and determined that formulated glyphosate products are more toxic than the active ingredient alone. EPA states, "[T]he ecological effects of the pesticide-surfactant combination may differ from that of the single pesticide or the single surfactant," and, "One class of surfactants used in glyphosate formulations are the polyethoxylated tallow amines (POEA) and this class has been shown to be more toxic to aquatic animals than glyphosate alone." In evaluating the potential risk to non-target organisms, the agency states it estimated exposure risks from (1) glyphosate only, (2) glyphosate formulations, and (3) surfactant only (POEA). However, this same due diligence was not afforded to the human health assessment—even though formulated glyphosate products are known to be more toxic to human cells than glyphosate alone.

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NUTRITIOUS FOOD

Because nutrition is essential to good health, it is of note, that in addition to lacking the toxic residues of conventional foods, organic food is more nutritious. In particular, vegetables grown in a chemical-intensive system are higher in nitrates, pesticides, and cadmium, and lower in antioxidants; milk produced in a chemical-intensive system has a less desirable fatty acid composition, is lower in tocopherol and iron, and higher in iodine and selenium; and meat produced in a chemical-intensive system has a less desirable fatty acid composition.

Detoxification Pathways. Nutrients from food support detoxification pathways in the body. Nutrients that have been identified as important in detoxification include a wide variety of antioxidants, amino acids, vitamins, and minerals. Their deficiency leads to increased toxicity from drugs, carcinogens, allergens, and environmental pollutants. This may manifest itself as cancer, Parkinson's disease, fibromyalgia, and chronic fatigue/immune dysfunction syndrome. Consumers eating food grown in a chemical-intensive system require a healthy body to detoxify the resulting pesticide residues because the food produced in this system is deficient—in comparison to organic food—in certain key elements supporting detoxification, such as total antioxidant capacity, total polyphenols, quercetin, and kaempferol. This means that any assessment that does not take into account the total system will grossly underestimate pesticide risks.

Omega 3's. Studies have also shown that dairy products from organically raised animals are more beneficial than dairy products from chemical-intensive systems. One large-scale, nationwide study of fatty acids in U.S. organic and non-organic milk found that, averaged over 12 months, non-organic milk contains a 2.5-fold higher omega-6 (linked to higher blood pressure) to omega-3 (linked to improved cardiovascular health) ratio compared to organic milk. All individual omega-3 fatty acid concentrations are higher in organic milk—linolenic acid, eicosapentaenoic acid, and docosapentaenoic acid—as is the concentration of conjugated linoleic acid.

No Antibiotics. Animals raised organically are not given antibiotics and are required to be grazed on organically managed pastureland or fed organically grown feed. Antibiotics used in chemical-intensive animal production systems can exacerbate the problem of antibiotic resistance, which the Centers for Disease Control and Prevention (CDC) calls "one of the world's most pressing public health problems." Antibiotics used in agriculture contribute to antibiotic resistance not only through antibiotic residues on food, but also by antibiotics released into the environment. Perhaps most importantly, antibiotic resistant microorganisms proliferate in the environment—particularly waterways—where their genes for resistance can be passed on to pathogenic microorganisms.

Protecting Microbiota. A human being contains more cells in and on the body that belong to microbes—and contains more microbial DNA than that originating from human genes. In fact, only 10% of human cells are genetically human, and only 1% of the DNA in the human is "human." The 90% 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 that help the body function as it should. The human body, rather than being a distinct organism, should be thought of as a biological community, or "superorganism," truly the product of coevolution.

In addition to interfering with digestion, exposure to antibiotics can disturb the microbiota, contributing 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. Of particular interest in the current context, the human immune system is largely composed of microbiota.

Preventing Autism and 21st Century Diseases. Autism spectrum disorder (ASD) arises from a complex interaction between genetic and environmental factors. ASD severely affects social functioning and self-sufficiency. The dramatic rise in the incidence of ASD in recent decades points to the importance of environmental factors, and there is strong evidence for the role of pesticides in causing autism. In addition, nutrition and gut microbiota can play a role in both causing and managing ASD. Since chemical-intensive agriculture is implicated in a loss of nutrient density and dysbiosis of gut microbiota, the autism epidemic is strongly linked to the use of pesticides.

There are, therefore, other ways—in addition to toxicity—that pesticide use within the context of the chemical-intensive food production system, interferes with human health. It interferes with detoxification, hinders digestion, disrupts the immune system, contributes to antibiotic resistance, and (through its impact on gut microbiota) contributes to the list of 21st century diseases above. Food produced in this system does not promote health; it destroys health.

The human body, rather than being a distinct organism, should be thought of as a biological community, or "superorganism," truly the product of coevolution.

HEALTHY LIVING AND WORKING ENVIRONMENT

In contrast to the risk assessments that allow pesticides to be used, acute effects in the real world are seen by those doctors who treat pesticide poisonings. The EPA manual, *Recognition and Management of Pesticide Poisonings,* catalogs signs and symptoms that would not be reported by rats and mice. Agricultural poisonings are a direct effect of the agricultural system in which they occur—without a system dependent on toxic chemical inputs, there would be no poisoning. The EPA manual notes that replacement of one pesticide by a "less toxic" one does not solve the problem:

> "The relative frequency of cases generally reflects how widely a product is used in the environment. Organophosphate (OP) insecticides have historically topped the list of most commonly reported exposures. . . . In the United States, pyrethroids have largely replaced the OPs in terms of widespread usage. As such, they now account for the most human case reports in the United States."

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BOX 3

Antibiotics Prohibited in Organic Production

About 80% of all antibiotics, and 70% of antibiotics of medical importance to humans are used in animal agriculture—including cows, poultry, hogs, and fish. Antibiotic residues are carried over into manure, which is then applied to crops that would otherwise not be exposed to antibiotics, in some cases organic crops. Such residues may be taken up by crops. While conventional agriculture has no restriction on the use of manure, organic standards require that, if used on crops for human consumption, it must be either composted or incorporated into the soil 90–120 days before harvest, which may reduce concentrations of some antibiotics and populations of antibiotic-resistant microbes. Organic producers must also "manage manure in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, heavy metals, or pathogenic organisms and optimizes recycling of nutrients and must manage pastures and other outdoor access areas in a manner that does not put soil or water quality at risk."

While the use of antibiotics in animal agriculture is widely acknowledged as harmful, the use of antibiotics in chemical-intensive crop production also poses unnecessary risks. Glyphosate, while marketed as a weed killer, is also patented by its manufacturer, Bayer (Monsanto), as an antibiotic. It is the most widely used antibiotic in agriculture—attacking the shikimate pathway, part of the mechanism for producing certain amino acids in both plants and microbes. The use statistics cited above do not include glyphosate. When use of glyphosate is included, it accounts for 87.6% of all antibiotic use, animal agriculture accounts for 10.0 percent, and use for human illness accounts for 2.6%.

Protecting Vulernable Population Groups. Three groups of people face higher risks from pesticide exposure because of occupation and/or developmental susceptibility—farmworkers, children, and women of reproductive age. The one million to 2.5 million hired farmworkers—especially Latinos—are the workers most often affected by pesticides.

Children represent another population of concern as they may be at greater risk from pesticide exposures because they are growing and developing. Women of reproductive age and pregnant and nursing women may also be more vulnerable because of the effects of pesticide exposures on fetuses and infants.

In the case of farmworkers, all of these groups converge because, "Farmworkers often reside in agricultural communities where they and their family members may be further exposed in their homes because of pesticide drift from spraying of nearby fields or orchards and drinking contaminated water. Para-occupational exposure factors, such as pesticide residue on workers and their clothing, shoes and vehicles and lack of adequate facilities to clean pesticide-contaminated work clothes may increase the risk of pesticide exposure for other household members as well." (EPA, 2013)

Looking only at pesticide residues in food as a measure of pesticide exposure ignores the fact that many foods that do not end up with high pesticide residues nonetheless involve toxic chemicals in production that put workers' health at risk. Pesticide use in production and farmworker exposure is a necessary consideration in looking at the whole pesticide problem. A shift to organic agriculture is the only way to eliminate toxic pesticide exposure for everyone.

Although other labor practices may not be uniformly protective on organic farms, workers are not exposed to nearly all toxic chemicals if the farm is certified organic. Thus, this dangerous working and living environment must be factored into any assessment of pesticide hazards.

HEALTHY ENDOCRINE SYSTEM

The endocrine system consists of all the glands in the in the body that produce hormones, including adrenal glands, parathyroid gland, pituitary gland, thyroid gland, ovaries, pancreas, and testes. The endocrine system controls the functions of organs, tissues, and cells in the body. The proper functioning of the endocrine system is essential to maintaining homeostasis and is therefore important to health. An endocrine disrupting chemical (EDC) is a xenobiotic chemical that mimics or interferes with the natural functioning of hormones.

LEARNING AND DEVELOPMENT

Developmental disabilities affect roughly one in six children in the U.S., ranging from a learning disability to a serious behavioral or emotional disorder. Science shows that toxic chemicals in the environment contribute to the rise of physical and mental effects in children. Children's developing organs create "early windows of great vulnerability" during which exposure to pesticides can cause great damage. Requirements for testing pesticides and other chemicals in the U.S. for potential developmental and learning disorders are minimal.

Children at Risk. During development, the brain undergoes a highly complex series of processes at different stages that makes the developing brain much more susceptible to the effects of toxic chemicals than an adult brain. Interference from toxic substances that disrupt these processes can have permanent consequences. The higher level of vulnerability extends from fetal development through infancy and childhood to adolescence. Research has shown that low levels of exposure to environmental toxicants, such as pesticides, can have important adverse effects, such as decreases in intelligence or changes in behavior, that may not be clinically apparent.

Children may be exposed to pesticides at any time from conception onward. Children of farmworkers and those who live or play where chemical-intensive management of indoor or outdoor spaces is used are likely to be exposed during a window of developmental vulnerability because pesticides are nearly always present in those environments. It is therefore not surprising that the most significant results come from the CHAMOCOS study in the Salinas Valley of California, which links pesticide exposure with attention deficit and hyperactivity disorder (ADHD), decreased Mental Development Index scores, reduced IQ, and other developmental and cognitive effects.

A STABLE CLIMATE

Climate affects many factors that have an impact on human health. As climate changes, the distribution of plants and animals changes, leading to exposure to different allergens, disease vectors, and the chemicals used to control them. There are many influences on climate, and not all can be blamed on chemical-intensive agriculture. However, the climate is affected by the loss of carbon sequestration in fields that lay bare half the year and contain minimal plant and microbial diversity during the growing season. In addition, nitrous oxide is both a long-lived greenhouse gas with a global warming potential of about 300 times that of carbon dioxide and an ozone depleter. It is now known that the recent rise in atmospheric nitrous oxide levels is largely the result of an increased reliance on nitrogen-based fertilizers. Costs associated with the multitude of health, environmental, and economic impacts of global climate change tied to chemcial-intensive agriculture must be assessed.

BOX 4

Organic Practices Protect Farmworkers

The number of farmworkers injured each year is unknown because there is no national reporting system for farmworker pesticide poisonings and no system for tracking chronic illness related to pesticide exposure. Although 30 states require health professionals to report suspected pesticide poisoning, many incidents go unreported. In spite of factors leading to underreporting—such as rising health care costs that have heightened reluctance to seek medical attention, misdiagnosis from medical professionals, and the failure of insurance companies to forward reports to proper authorities—EPA estimates that 10,000-20,000 farmworkers are poisoned on the job due to pesticide exposure. This number does not include the many workers who suffer chronic health problems such as cancer, infertility, and neurological disorders, including Parkinson's disease, as a result of exposure to pesticides.

Pesticide exposure can have devastating effects on pregnant women and their children, who are at great risk of health effects because of their high susceptibility to pesticides. Pesticide exposure is linked to higher rates of birth defects, developmental delays, leukemia, and brain cancer among farmworker children. The severe developmental effects of pesticides on children are graphically demonstrated in a study by Elizabeth Guillette, PhD on children in an agricultural area of Mexico.

MISDIAGNOSIS OF POISONING

Farmworkers receive the highest pesticide exposures. The risks associated with those exposures are compounded by the difficulty of receiving adequate medical attention. EPA's manual, *Recognition and Management of Pesticide Poisonings* (6th edition), states,

> One important factor contributing to under-diagnosis occurs if the exposed person does not, or is unable to, seek medical attention. A pesticide applicator, for example, may not perceive the incident as significant enough to seek care, particularly if he or she has been accustomed to low-level exposure scenarios on the job. Some agricultural workers are unable to readily address a pesticide poisoning because of a complex set of socioeconomic factors including inability to take off from work, transportation problems, language and cultural barriers, lack of health insurance, scarcity of available community health services and fear of losing employment. Another scenario is the exposed person may simply not recognize his or her symptoms as pesticide related.

The same manual points out that, "Few healthcare providers are adequately trained in environmental medicine," and that the existing education system does little to address this need. It is not only farmworkers who experience these problems. Access to adequate affordable health care is a major public health issue. Minor impacts can become major when the body's defenses are under assault and adequate treatment is not available.

BIODIVERSITY

Biodiversity supports human health by maintaining ecosystem functions, including a balanced ecological community that eliminates the need to control "pests." It also provides potential sources of health-protective nutrients—some of which are yet undiscovered.

The requirement for organic farmers to "maintain or improve the natural resources of the operation, including soil and water quality" has been clarified by National Organic Program policy to mean that "the producer must initiate practices to support biodiversity and avoid, to the extent practicable, any activities that would diminish it." The guidance states,

> The conservation of natural resources and biodiversity is a primary tenet of organic production. For instance, native vegetation interspersed throughout a certified organic operation provides food, cover, and corridors for beneficial organisms such as pollinators, slows water down for erosion control and groundwater recharge, and filters pollution. Using practices that attract or introduce beneficial insects, provide habitat for birds and mammals, and provide conditions that increase soil biotic diversity serve to supply vital ecological services to organic production systems. Advantages to certified organic operations that implement these types of production practices include: 1) decreased dependence on outside fertility inputs; 2) reduced pest management costs; 3) more reliable sources of clean water; and 4) better pollination.

Chemical-intensive agriculture, which does not adhere to these tenets, not only threatens the environment, but also threatens human health. It is the elimination of biodiversity, which on organic farms delivers fertility and pest control, that results from the dissemination of toxic pesticides and fertilizers. Conservation of biodiversity is not only the basis of organic farming it is also a prerequisite for maintaining human health.

CONCLUSION

To protect human health, the effects of pesticides on complex human biology are currently not evaluated by EPA when permitting pesticide products on the market. At the same time, the agency ignores the viability of organic systems for land management that eliminate both the known adverse effects and the uncertainties that arise from inadequate evaluations and risk assessments. With the rise in serious health problems—from cancer to Parkinson's, diabetes, reproductive failures, to developmental disorders, including autism, as well as the steep decline in biodiversity and threat of global climate change—it is time to embrace an urgent transition to organic management systems.

Jay Feldman, executive director of Beyond Pesticides, contributed to this article. A fully cited version of this report is available at www.bp-dc.org/humanhealth.

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BOX 5

How Organic Reduces Climate Change

- Agricultural emissions of nitrogen fertilizers account for 80% of the growth in global air concentrations of nitrous oxide (NO_2), a greenhouse gas with global warming potential of 265-298 times that of carbon dioxide.
- Chemical-intensive agriculture promotes climate change by reducing (in comparison to undisturbed land or organic production) the sequestration of carbon in the soil.
- The climate is affected by the loss of carbon sequestration in fields that lay bare half the year and contain minimal plant and microbial diversity during the growing season.
- Industrial agriculture and subsistence agriculture account for 80% of the deforestation between 2000-2010, while the National Organic Standards Board has, in contrast, adopted a policy on "Eliminating the Incentive to Convert Native Ecosystems to Organic Production" to discourage such deforestation.
- Organic production relies less on fossil fuel inputs, including synthetic pesticides and fertilizers, leading to a reduction in greenhouse gas emissions.