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By Patrice Sutton, David Wallinga, Joanne Perron, Michelle Gottlieb, Lucia Sayre, and Tracey Woodruff

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Reproductive Health And The Industrialized Food System: A Point Of Intervention For Health Policy

Patrice Sutton (suttonp@obgyn.ucsf.edu) is a research scientist at the Program on Reproductive Health and the Environment, at the University of California, in Oakland, California.

David Wallinga is director of the Food and Health Institute for Agriculture and Trade Policy, in Minneapolis, Minnesota.

Joanne Perron is a post doctoral fellow at the Program on Reproductive Health and the Environment.

Michelle Gottlieb is codirector of Food Systems Health Care Without Harm, in Reston, Virginia.

Lucia Sayre is codirector of the San Francisco Bay Area Physicians for Social Responsibility, in Berkeley, California.

Tracey Woodruff is an associate professor and director of the Program on Reproductive Health and the Environment.

ABSTRACT What food is produced, and how, can have a critical impact on human nutrition and the environment, which in turn are key drivers of healthy human reproduction and development. The US food production system yields a large volume of food that is relatively low in cost for consumers but is often high in calories and low in nutritional value. In this article we examine the evidence that intensive use of pesticides, chemical fertilizers, hormones, antibiotics, and fossil fuel in food production, as well as chemicals in food packaging, are potentially harmful to human reproductive and developmental health. We conclude that policies to advance a healthy food system are necessary to prevent adverse reproductive health effects and avoid associated health costs among current and future generations. These policies include changes to the Farm Bill and the Toxic Substances Control Act, and greater involvement by the health care sector in supporting and sourcing food from urban agriculture programs, farmers' markets, and local food outlets, as well as increasing understanding by clinicians of the links between reproductive health and industrialized food production.

Public policies that have informed food production in the United States since the end of World War II have supported the growth of a highly concentrated and productive food production and distribution system.[1] Our "industrialized" food system is characterized by intensive application of petroleum-based pesticides and chemical fertilizers, which have taken the place of crop rotation, manure, and crop diversification to manage pests and maintain fertile soil. Another characteristic of post–World War II food production is the increase in processed food that is distributed over long distances and the decrease of locally produced, fresh food.[2] Although successful at producing high yields of certain foods offered at low prices, the US industrialized food system also yields (as will be discussed further below) potentially adverse health consequences that have yet to be scrutinized by government regulators in a manner comparable to other industries.[1]

The public, regulatory agencies, scientists, and health professionals have growing recognition of the need for a more complete accounting of the human and environmental health impact of an industrialized food system.[1–5] In this article, we first describe the relationship of the food system to reproductive health, which we define as encompassing all aspects of reproductive and developmental health throughout the course of life, including conception, fertility, pregnancy, child and adolescent development, and adult health. We then go on to describe opportunities for health professionals to advance food system-related policies in order to accelerate improvements in reproductive health.

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Reproductive Health, Nutrition, And The Environment

Our food system is inextricably linked to two key drivers of reproductive health: nutrition and the environment (Appendix Exhibit 1).[6] Humans are more susceptible to the benefits and harms of nutrition and the environment during periods extending from the time of conception through pregnancy, infancy, childhood, and puberty. This susceptibility can be attributed to the dynamic growth; high metabolic rate; immature liver detoxifying mechanisms; and underdeveloped nervous, respiratory, reproductive, and immune systems that characterize these developmental periods.[7]

A woman's nutrition before and during pregnancy can affect her child's health, including whether the child is born healthy and conditions that manifest later in life such as cardiovascular and metabolic disease.[8,9] The environment can also contribute to negative health outcomes. For example, the potential health consequences of prenatal exposure to toxic environmental contaminants include immediate effects, such as birth defects, preterm birth, and low birthweight; short-term effects, such as learning disabilities and childhood cancers; and long-term health effects, such as diabetes, cardiovascular disease, and cancers later in life.[7,10–12]

Every pregnant woman in the United States has measurable levels of multiple environmental chemicals in her body that can harm human reproduction and development; many of these chemicals are at levels associated with adverse health outcomes in human studies (Exhibit 1).[12] In general, toxic environmental chemicals end up in pregnant women primarily due to regular human activities, and the food system is an important pathway of exposure.

Food system-related and other environmental chemicals are able to cross the placenta and enter the fetus. In 2010, the annual President's Cancer Panel Report concluded that "to a disturbing extent, babies are born 'prepolluted.'"[13]

Some environmental chemicals in our food like bisphenol A (BPA) break down quickly, but because we are constantly exposed to them through food storage and packaging materials, they are always present in our bodies. Other chemicals like the pesticide DDT, dioxins, and polychlorinated biphenyls (PCBs) do not break down but rather accumulate over time in the food system, and thus can be present in our bodies long after the chemicals have been banned and removed from production (see the Appendix).[6]

Although in some instances the effect of our daily exposure to individual chemicals has been studied, the cumulative health impact of concurrent exposure to many chemicals has not, primarily due to limitations in the current regulatory structure.[14] Our limited understanding of the potential harm is recognized by the National Academies of Sciences as a gap in current scientific methodologies that inform public policy.[15]

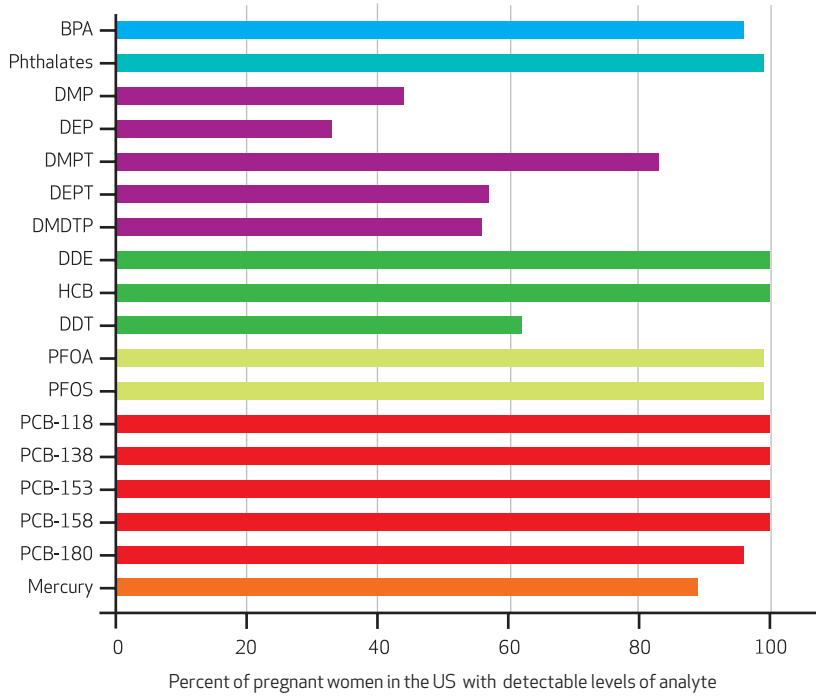
The Effect Of Food System Practices On Reproductive Health

PESTICIDES Millions of pounds of synthetic pesticides are applied annually in US conventional (nonorganic, resource-intensive) agriculture.[16] Pesticidess can spread beyond the crops and farms where they are applied to the wider environment, where they can contaminate air, water, and soil.[17,18] Pregnant women are exposed to agricultural pesticides primarily from food, water, air, and soil. This exposure is ubiquitous among pregnant women in the United States (Exhibit 1).

Pesticide exposure during pregnancy and early childhood can harm the developing brain and adversely impact child mental and behavioral

EXHIBIT 1

Food System-Related Environmental Chemicals Detectable In Pregnant Women In The United States, 2003–04



SOURCE See Note 12 in the text. **NOTES** These data show the results of chemical analysis of blood samples from 268 pregnant women included in the National Health and Nutritional Examination Survey (NHANES) 2003–04, a nationally representative sample of the US population, which may underrepresent highly exposed subpopulations. The food system is an important pathway of exposure to the analyzed chemicals; all are linked to adverse reproductive and developmental health outcomes. The cumulative health impact of all of these chemicals has not been studied. Full names of the chemicals in this analysis are provided in the Appendix (see Note 6 in the text).

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development.[19] It is estimated that 40 percent of US children have enough cumulative exposure to pesticides to potentially impact their brains and nervous systems.[20] Pesticide residues in the foods and beverages typically consumed by the US population—in terms of both type and quantity—can lead over time to exposures that are high enough to increase the chance of children developing cancer and other chronic diseases.[21]

Pesticide exposure can interfere with all developmental stages of reproductive function in adult females,[22] and is associated with adverse reproductive health outcomes across the life span of men and women, including birth defects,[23] sterility in males,[24] spontaneous abortion, diminished fetal growth and survival,[22] childhood leukemia, and adult breast and testicular cancers.[25–28]

CHEMICAL FERTILIZERS Farms today are very large and are increasingly likely to "monocrop"—that is, grow just one crop intensively, year after year, with the use of chemical fertilizers to maintain yield. In 2007, the majority (58 percent) of the nearly 23 million tons of chemical fertilizers used in US agriculture were nitrogen-based and the nitrogen was derived from natural gas.[29] Nitrogen-based chemical fertilizers contribute to groundwater contamination and impaired aquatic systems[30,31] and—because they are fossil fuel–derived—to climate change.

Groundwater is the source of drinking water for many Americans, especially those using wells. Nitrates in drinking water can cause "blue baby syndrome" (methemoglobinemia) in infants and have been associated with higher risks of reproductive health impacts and cancer.[32,33] Even when fertilizers derived from animal waste or treated sewage sludge are used in industrialized farming operations, the use of antimicrobials, heavy metals, and additives in food animal production may leave these fertilizers contaminated with pollutants that can find their way into drinking water.[34,35]

HORMONES IN BEEF CATTLE Three natural steroid hormones (estradiol, testosterone, and progesterone), and three synthetic surrogates (zeranol, trenbolone, and melengestrol) are currently in widespread use by US and Canadian beef cattle producers to increase meat production or yield.[36] Yet, no steroid hormones are approved for growth purposes in dairy cattle, veal calves, pigs, or poultry—an inconsistency in US policy governing hormone use in livestock.[37]

The use of natural and synthetic steroid hormones in cattle production has been restricted for more than twenty years in European countries. Residues from such hormone growth promoters can be measured in meat and in drinking water as a result of manure contamination and runoff from cattle feedlots.[38] Livestock also excrete naturally occurring steroidal estrogens.[39] It is estimated that 90 percent of the total estrogen in the environment is contributed by livestock manure.[40]

Definitive data are lacking on whether it is safe for humans to consume beef containing such hormones. However, many well-conducted human and animal studies have demonstrated that environmental exposure to hormones or chemicals that can interfere with hormone levels in the body can interfere with hormone function and may cause adverse reproductive and other health outcomes.[7,41] The proof of the principle that such exposures may cause reproductive harm is based on studies of the synthetic hormone diethylstilbestrol (DES), which was prescribed in up to ten million pregnancies from 1938 to 1971 to prevent miscarriages. DES was later found to cause cancer and other reproductive tract abnormalities in the children of women exposed to DES. These adverse health impacts manifested only decades after exposure.[7]

ANTIMICROBIALS IN BEEF CATTLE, SWINE, AND POULTRY As much as 80 percent of all antimicrobials—substances that kill or inhibit harmful microorganisms—used in the United States are found in food-animal production.[42] Antibiotic use for treating sick animals constitutes only a small fraction of the total.

Up to 70 percent of total antimicrobial use is given at nontherapeutic doses to otherwise healthy beef cattle, swine, and poultry to promote more rapid growth, or to offset the risk of infection among animals raised in large concentrated animal feeding operations. Most of these antimicrobials are from drug classes important to human medicine.[43] This practice is recognized as a significant contributor to the increased prevalence of antibiotic resistance among human pathogens.[43,44]

The practice of giving antimicrobials to healthy animals is prohibited in many industrialized countries including those in the European Union. No such prohibition exists in the United States, although legislation to reduce the prophylactic use of antimicrobials in healthy animals was reintroduced in the US House of Representatives in March 2011.[42]

In the United States, arsenic compounds are also used extensively in poultry and swine feed for disease prevention, meat pigmentation, and growth promotion.[35] This practice results in arsenic residues in our food and the introduction of large volumes of arsenic-bearing wastes into the environment, including through the common use of this manure as cropland fertilizer.[35,45] Emerging data suggest that early-life exposure to arsenic in drinking water is linked to liver, lung,

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and kidney cancer in adult humans.[46] Arsenic has also been linked to spontaneous abortion in animal studies.[47]

In February 2011, two Maryland state senators introduced a bill to ban the sale and use of chicken feed containing arsenic within the state.[48] Arsenical feed additives have not been approved as safe in the European Union, and are not allowed in Department of Agriculture–certified organic meat production.

FOSSIL FUEL CONSUMPTION AND CLIMATE CHANGE The average US farm relies heavily on fossil fuels and is not energy efficient.[49] Fossil fuels are consumed by the production of natural gas-derived fertilizers and petroleum-based pesticides, by farm machinery, and by transporting food to distant markets.

Overall, agricultural emissions are important contributors to reduced air quality.[1] Agricultural use of fossil fuels produces a number of air pollutants associated with adverse pregnancy and child health outcomes, including carbon dioxide, particulates, and nitrogen and sulfur oxides.[1,50,51]

Food-animal production is also a major source of greenhouse gas emissions in the form of carbon dioxide, nitrous oxide, and methane. The relative contribution of industrialized livestock production has been estimated to be 18 percent of all global greenhouse gas emissions that originate in human activity.[52] The climate effects of industrialized livestock production are largely due to the use of fossil fuel-intensive grain to feed the animals, and to deforestation for feed production and pasture.

It is anticipated that climate change will affect nutrition and the environment, and thus reproductive health. For example, climate change may produce malnutrition and disruption of the global ecosystem that is central to food production and human health.[53] Climate change may also lead to social disruption,[54] which, based on the experience of women living in areas affected by Hurricane Katrina, can lead to increased infant mortality rates, and increased likelihood of giving birth to low-birthweight or very-low-birthweight infants.[55]

Similarly, preterm births in California between 1999 and 2006 were positively associated with high ambient temperatures,[56] a condition expected to increase in some areas of the United States under predicted climate change scenarios.

Packaging And Human Health

Packaging and cookware widely used to store, heat, and serve food and beverages are sources of exposure to chemicals that can disrupt the normal functioning of hormones critical to human reproduction and development. Examples of these "endocrine disrupting" chemicals include bisphenol A (BPA), found in many everyday products, including polycarbonate plastic containers and the linings of canned foods and beverages; phthalates, which migrate from food packaging materials and from the ambient environment into food; and perfluorochemicals (PFCs) used in the manufacture of nonstick cookware and to make packaging that comes in contact with food resistant to oil and water.

These chemicals represent a reproductive health concern for several reasons: (1) because widespread exposure is documented among pregnant women in the United States[12] (Exhibit 1); (2) the placenta does not protect the fetus from exposure; and (3) exposure to each of these chemicals is associated with adverse female and male reproductive, developmental, and health effects.[15,57–59] The widespread use of plastic packaging also creates large volumes of waste, and waste disposal in landfills or by incineration (which produces dioxin, described in the Appendix)[6] transfers environmental contaminants back into the air, water, soil, and, ultimately, the food system.

Products Lean Toward Unhealthy Choices

Policies, practices, and marketing all drive what ends up on US dinner plates.[60] And US policies, practices, and marketing tend to favor foods that are unhealthy for pregnant women, children, and adolescents. These include large volumes of processed food that is cheap, convenient, attractively packaged, and tasty, but high in calories and low in nutritional quality. On average, Americans currently consume about 600 more calories each day than they did in 1970,[61] and they eat excessive amounts of animal protein—nearly twice the global average.[62]

Widespread exposure to processed, prepared, and sweetened foods and beverages contribute to the US obesity epidemic and the concomitant increased risk for many diseases, including diabetes, heart disease, some forms of arthritis, and several cancers.[63] The prevalence of diets that are relatively high in fructose and low in fiber may also adversely influence children's metabolism and the related capacity to regulate their weight.[64]

High consumption of animal fats and processed meats also contributes to an increased risk of obesity, cardiovascular disease, diabetes, metabolic syndrome, dementia, and some kinds of cancer.[65] Consuming animal fat is also an important pathway of exposure to reproductive toxicants such as dioxin that persist in the envi-

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ronment and the food chain (see the Appendix).[6]

Approximately one in three women in the United States ages 20–49 are overweight or obese.[66] Being overweight or obese during pregnancy is linked to adverse maternal and child health consequences that can span generations,[67] and to increased use of health care services.[68]

Environmental chemicals may exacerbate the influence of inactivity and dietary contributors to obesity and related disorders. It is hypothesized that environmental endocrine disrupting chemicals can permanently disturb developing regulatory systems required for maintaining a normal body weight.[69] Paradoxically, our food production system contributes to most of the fetal and developmental chemical exposures linked to obesity cited in the May 2010 White House Task Force on Childhood Obesity Report to the President,[63] including BPA, perfluorooctanate, phthalates, fructose, and certain organophosphate pesticides.

Combining Farm Policy With Health Policy

"Farm policy is health policy," and the health care sector is uniquely poised to advance policies in support of a healthy food system as a primary prevention strategy to ensure healthy pregnancies, children, and future generations.[3]

Societywide policy actions are essential to creating a healthy food system for several reasons. Individuals operating alone cannot control the environmental impact of the current food production system that stems from the healthfulness of the food produced or from air and water pollution. Federal policy will influence whether and how research is undertaken to help shape the future food production system. And environmental justice issues related to our food system cannot be sufficiently redressed by individual action.

The Environmental Protection Agency (EPA) defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." Further, "fair treatment means that no group of people should bear a disproportionate share of the negative environmental consequences resulting from industrial, governmental, and commercial operations or policies."[70]

Food system–related environmental justice issues are exemplified by disparities in access to healthy foods and policy is needed to create opportunities to increase fruit and vegetable consumption in underserved areas.[71,72] There are also disparities in exposure to food system–related environmental pollution. For example, both women and men exposed to pesticides at work and in agricultural communities incur substantively higher exposures than the US population overall.[73,74]

NATIONAL POLICY OPPORTUNITIES The Farm Bill, a complex piece of legislation that Congress passes every five to seven years, is responsible for some $60 billion in annual spending. The bill is also a key driver of the US food system. As such, the Farm Bill presents a relevant point of policy intervention for health care professionals and institutions, since it promotes food production practices, described above, that have adverse impacts on human and environmental health.[3]

The purpose of the Farm Bill is to supplement and secure farm incomes, ensure a stable food supply, support the American farm economy, and help ensure that the poor have enough food to eat. More than two-thirds of the appropriations under the Farm Bill are for the Supplemental Nutrition Assistance Program (formerly known as the food stamp program).

The policies inherent in the Farm Bill encourage high production and lower prices for commodities like corn, soybeans, and wheat, which then become the principal feed stocks for low-price sugars, hydrogenated oils, and highly refined starches. These in turn play a big role in America's processed food supply and are linked to the obesity epidemic.

The Farm Bill also has an impact on the environment by encouraging the concentrated, resource-intensive production that predominates in conventional agriculture.

In anticipation of the renewal of the Farm Bill in 2012, leading physicians and other health practitioners are collaborating on a Charter for a Healthy Farm Bill[75] to focus attention on the health impact of how food is produced, processed, marketed, and disposed. Similarly, a collaboration of health, professional, and other organizations recently promulgated a set of Principles for a Healthy, Sustainable Food System to accelerate these efforts. Research documents that when children's diets change from conventional to organic food, the levels of pesticides in their bodies decline.[76] The decrease indicates that the food supply is a primary source of exposure, and thus amenable to policy interventions to reduce harm.

The health impacts of our food system are also influenced by federal policy decisions that may not at first glance appear to be germane to food. Regulation of toxic releases from nonagricultural processes under the Clean Air Act, such as mercury emissions from coal-fired power

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plants, are one example. Such toxic emissions ultimately end up in the water where they can concentrate in fish consumed by children and pregnant women (see the Appendix).[6] Similarly, toxic chemicals used in commerce and that are regulated under the Toxic Substances Control Act can enter the food supply.

Under the Toxic Substances Control Act, the vast majority of more than 80,000 chemicals in commerce have entered the marketplace without comprehensive and standardized information about their reproductive, developmental, and other toxicities. As noted, these include chemicals that enter the food system directly via packaging and cookware, and indirectly from the ambient environment. The shortcomings of the US regulatory framework for chemicals in commerce is receiving increased attention by the EPA;[14] the American Medical Association;[77] as well as broad coalitions of nongovernmental organizations, including the Safer Chemical Healthy Families Coalition and the American Chemistry Council.

HEALTH CARE INSTITUTIONAL POLICY INTERVENTIONS Health care institutions can support the development of urban agriculture programs, farmer's markets, and local food sourcing outlets to increase accessibility to healthier foods. Community-based obesity prevention interventions, such as increasing availability of healthier foods in schools, neighborhoods, and corner stores, are being implemented by Kaiser Permanente and others and are currently being evaluated. These results will help provide the evidence base for more widespread adoption of effective environmental-based approaches to obesity.[5,78]

Health care systems have also undertaken procurement policies to create a sustainable and healthy food service model for their employees and patients. Nearly 350 hospitals support the Healthy Food in Healthcare Pledge, which commits health care facilities to take steps such as procuring food that is produced in systems that eliminate the use of toxic pesticides, prohibit the use of hormones and nontherapeutic antibiotics, support farmer and farmworker health and welfare, and use ecologically protective and restorative agriculture.[79] The returns on such efforts are measurable for hospital systems and even affect their operating budgets. For example, data from four institutions demonstrate that implementation of "Balanced Menus," which reduce meat purchasing in hospitals, can yield substantial savings in outlays for food and in greenhouse gas emissions (since livestock production is an energy-intensive activity).[80] Because the purchasing power of the US health care system is so large—about $12 billion devoted to food purchasing annually[81]—changes to procurement patterns can spark food system change in multiple sectors.

At another level, clinician education is a key gap. Health care institutions and professional societies can organize and participate in continuing medical educational activities and in other forums to increase clinician understanding of the links between reproductive health and the industrialized food production system.

PATIENT-LEVEL POLICY INTERVENTIONS To the extent that individuals can choose what they eat, the ease, ready availability, and intensive marketing of highly processed foods that have low nutritional value—in excess of $4.2 billion was spent on marketing fast food in 2009 alone—can make it difficult to choose wisely.[64,82,83] Decisions on the individual level about what to eat are inextricably wedded to societal responsibility to provide equal opportunities to make healthier choices.[84] Healthier foods—those that are not highly processed—are fresh; low in fat, salt, and sugars; are more difficult to procure; and frequently more expensive to purchase.[60] Although decisions about what to eat are influenced in a myriad ways, people do make choices about what to eat. Improving those decisions can make a difference to a person's health and, by sending a signal to the market, can influence the food system.

For example, to combine behavioral and societal responsibility, clinicians can advise a new mother about eating more fruits and vegetables; provide her with information about how the food system affects health; tell her what she can do to make changes in her food choices; and offer her a coupon to the hospital-hosted farmer's market. Such a policy supports individuals in making healthier food choices; educates consumers about the policies that underlie their food options and how they can participate in societywide decision making; and encourages the development of a local, sustainable food system.

Conclusion

How and what food is produced affects nutrition and the environment. Pregnant women and children are highly susceptible to the benefits and harms of nutrition and the environment, and these influences can affect reproductive health outcomes in the short and long term. Our industrialized food system is highly productive and yields large volumes of food that is relatively low in cost for consumers; however, it also engenders substantive environmental impacts, and the food produced tends to be high in calories and low in nutritional value. Policy interventions by the health care sector at national, institutional, and patient levels offer mutually reinforc-

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ing opportunities for advancing a healthy food system as a strategy for preventing adverse reproductive health impacts among current and future generations. ■

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ABOUT THE AUTHORS: PATRICE SUTTON, DAVID WALLINGA, JOANNE PERRON, MICHELLE GOTTLIEB, LUCIA SAYRE & TRACEY WOODRUFF

Patrice Sutton is a research scientist at the Program on Reproductive Health and the Environment.

In their article in this month's issue, Patrice Sutton and a team of clinicians, scientists, and policy experts survey the many ways that industrialized food production compromises reproductive health through the use of pesticides, chemical fertilizers, hormones, antibiotics, fossil fuel, and chemicals in food packaging. Advancing the cause of a healthy food system, the authors say, is a way for health care professionals to serve their patients by preventing adverse reproductive health outcomes.

Sutton is a research scientist at the Program on Reproductive Health and the Environment at the University of California, San Francisco. She spearheads collaborative transdisciplinary efforts to synthesize and interpret the emerging science on reproductive environmental health in ways that will advance clinical practice and policy change.

Sutton has published widely, particularly in the area of adverse health effects among various populations as a result of certain environmental hazards. With Tracey Woodruff, she coauthored another paper in this issue that proposes a methodology enabling clinicians to make evidence-based recommendations for prevention regarding environmental hazards to health to their patients.

Sutton received her master of public health degree in environmental health sciences from the University of California, Berkeley.

David Wallinga is director of the Food and Health Institute for Agriculture and Trade Policy.

David Wallinga is director of the Food and Health program at the Minneapolis-based Institute for Agriculture and Trade Policy, a research and advocacy group that promotes sustainable food and farm systems and analyzes trade agreements on food safety issues. He also is a William T. Grant Foundation Distinguished Fellow in Food Systems and Public Health at the University of Minnesota, School of Public Health. His research focuses on health impacts of food and how it is produced, processed, packaged, and distributed. He received a master's degree in public and international affairs from Princeton University and a medical degree from the University of Minnesota Medical School.

Joanne Perron is a postdoctoral fellow at the Program on Reproductive Health and the Environment.

Joanne Perron is a postdoctoral fellow with the Program on Reproductive Health and the Environment at the University of California, San Francisco. She is also an obstetrician-gynecologist with more than twenty years of clinical experience serving a diverse population of women with a spectrum of reproductive disorders, many of which she attributes to environmental contamination. Her medical degree is from Chicago Medical School.

Michelle Gottlieb is codirector of food systems, Health Care Without Harm.

Michelle Gottlieb is co-coordinator of Health Care Without Harm's National Healthy Food and Healthcare Initiative, the coordinator for the New England region, and the co-coordinator of the Food Matters Clinical Education and Advocacy Program. She has a master's degree from the Yale University School of Forestry and Environmental Studies.

Lucia Sayre is codirector of the San Francisco Bay Area Physicians for Social Responsibility.

Lucia Sayre is codirector of the San Francisco Bay Area Chapter of Physicians for Social Responsibility and manages all aspects of its programs, including the Healthy Food in Health Care project, pediatric and reproductive environmental health projects, the clinical education and advocacy training program, and climate and health literacy efforts. She is also co-coordinator of both Health Care Without Harm's national Healthy Food in Health Care program and its Food Matters program. Sayre has a master's degree in community-based education from Prescott College.

Woodruff is director of the Program on Reproductive Health and the Environment at the University of California, San Francisco, an associate professor in the Department of Obstetrics, Gynecology, and Reproductive Sciences and Philip R. Lee Institute for Health Policy Studies. Woodruff was previously at the Environmental Protection Agency, where she was a senior scientist and policy adviser in the Office of Policy, Economics, and Innovation. She holds a master's degree in public health and a doctorate in environmental health sciences from the University of California, Berkeley.

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