1. Human Exposure to Pesticides

- During the past century, scientists have often been surprised to discover the persistence and mobility of pesticides. Government scientists had presumed that the compounds might degrade quickly and become non-toxic, or somehow simply disappear. Scientists now understand that this is not the case.

- Many pesticides are detectable far from their sites of application, and long after their release. They can be found in rainwater, oceans, polar ice caps, surface and ground water, soils, foods, drinking water, indoor environments and, eventually, in human tissues. Pesticide pathways are numerous and overlapping, resulting in broad dispersal and human exposures to ever-changing mixtures.

- To understand what happens to pesticides after their release requires testing for their residues in foods, surface and groundwaters, air, rain and snowfall, soils, and human tissues. The chronic Many pesticides are detectable far from their sites of application, and long after their release. They can be found in rainwater, oceans, polar ice caps, surface and ground water, soils, foods, drinking water, indoor environments and, eventually, in human tissues.
failure to test has been used to support claims that residues dissipate completely into non-toxic compounds.

- When food residue samples are taken and tested, sample sizes are normally small, and limited to relatively few foods. For example, the USDA’s annual food sampling program normally varies the crops tested from year to year, reducing scientists’ understanding of trends. Sampling is also limited by geographic region.

- Testing for pesticide residues in the U.S. Midwestern Corn Belt has demonstrated far different patterns of residues than are found in urban areas.

- Pesticide residues in water are normally caused by the application of herbicides and insecticides in agricultural areas, especially in the U.S. Midwest. These agricultural pesticide applications often result in pesticide residues being found in drinking water supplies.

- Many approved pesticides are allowed to be used on 50 or more crops, and individual crops may have as many as 100 different pesticides approved.

- The combinations of possible pesticide residues in a chef’s salad made with 10 different ingredients could conceivably include a different pesticide on each one of the ingredients in the salad. This is because the USDA and EPA have set tolerances one at a time, without regard to pesticide mixtures.

- Indoor pesticide applications can result in high levels of human exposure. When infants and small children crawl on floors, even higher levels of exposures can occur.

- Certain pesticides that are prohibited from residential uses are allowed to be used on food crops. Pesticide residue limits for food crops are established on a food-by-food tolerance basis.
The government’s logic for the differences in pesticide regulations is that indoor applications usually result in higher levels of exposure. Indoor pesticide residues are concentrated in less space, and are not dissipated by weather and mixing air. On average, people spend nearly 95% of their lives indoors.

Figure 6 demonstrates the various pathways that pesticides follow once they are released into the environment. Tracking pathways is expensive, scientifically complex, and difficult to understand for even a single chemical.

These issues discourage careful research to fully understand chemical releases, environmental movement, and routes of human exposure, as well as chemical absorption and fate within the human body.

Human tissue studies provide definitive proof of exposures, but do not identify the sources, contaminated media, or routes of exposure, whether via ingestion, inhalation, or dermal absorption.
Some pesticide formulations are sprayed by plane, while others are delivered via irrigation systems. Still others are encapsulated in microscopic plastic balls that break down at varying rates, similar in design to timed-release cold capsules.

Significant amounts of pesticides evaporate from agricultural fields, and together with fine sprays, can drift long distances from their target locations. Once airborne, these volatile chemicals flow with the winds before they eventually settle to the earth’s surface.

Insects in residential areas have even inspired a new application technique—fence-mounted sprayers wired to timers that trigger the periodic release of pesticides.

Some chemicals, such as glyphosate and the neonicotinoid insecticides, are systemic, which means that they are absorbed into most or all of a plant’s tissues. Other pesticides are superficial,
meaning that they tend to remain on the surface of food or plants until they wash off or evaporate.

- Some chemicals are injected into livestock or added to animal feed in order to promote growth. This produces chronic low-dose exposures to non-target species, including humans.

- Half-life is the amount of time it takes for the concentration of a substance to decrease to half its value. A chemical’s half-life strongly influences how long pesticide residues remain present on crops and in the environment.

- The assumption of pesticide disappearance has been a serious, long-standing, and continuing error in judgment made by the EPA, as well as by many other foreign governments.

- The disappearance myth is the underlying pillar of industry’s arguments about pesticide safety and environmental protection. It is born from the reluctance of manufacturers and governments to responsibly test both the environment and human tissues for the presence of pesticides, once released.

- This misunderstanding has resulted from inadequate pre-market testing. It has encouraged consumers to buy and apply more of the chemicals, without concern for how they will move through the environment, or where and how they will accumulate.

- The EPA has allowed the pesticide industry to be largely immune from producer responsibility by use of registrations and tolerances that give pesticides a government blessing.

- This even gives pesticides an image of health and safety. From manufacturers’ and farmers’ perspectives, chemicals have been designed to be persistent, meaning they need to be applied less often, given the longevity of their effectiveness.

The persistence of pesticides is precisely why the insecticide DDT was so effective, and still easily detected in the environment and wildlife nearly 50 years after it was banned in 1972.
The persistence of pesticides is precisely why the insecticide DDT was so effective, and still easily detected in the environment and wildlife nearly 50 years after it was banned in 1972. The assumption that pesticides disappear has been disproven over and over again by scientists when they collected and tested samples of food, water, soils, wildlife, and human tissues.

Chemical persistence has the benefit of prolonging effectiveness after application. The persistence of the insecticide DDT is largely responsible for its use on a global scale between 1950 and 1975.

During this period, insecticide use in agriculture was detectable in the air above the middle of the Pacific Ocean, even when applied thousands of miles away. The pesticides also concentrated in food chains, moving from small organisms to the larger predators.

The raptors at the top of food chain, such as eagles, hawks, and condors, accumulated the highest concentrations of DDT. The resulting loss of reproductive capacity reduced the number of offspring.

Humans lie at the pinnacle of these predatory chains, consuming a wide diversity of plant and animal species. This explains why most people in the world have carried pesticide residues in their fat tissues for decades.

Although DDT was banned in the U.S. in 1972, it remains one of the most detected pesticides in the U.S. food supply due to its persistence.

The lessons DDT taught about persistence and the need to understand chemical half-lives have been largely neglected by the public and manufacturers who promote images of immediate
Humans lie at the pinnacle of these predatory chains, consuming a wide diversity of plant and animal species. This explains why most people in the world have carried pesticide residues in their fat tissues for decades.

Pesticide persistence is well demonstrated by government’s failure to identify and contain the risks from those pesticides still intensively used in the U.S., including glyphosate and chlorpyrifos. These pesticides will be discussed in the following pages.

Different pesticides have different toxicities, mobilities, and persistences. This is shown by pesticide residues being found far from their intended targets.

This issue demonstrates two problems: (1) that the pesticides applied are excessive, mobile, and persistent; and (2) that the most stable chemicals have the capacity to move into global circulation.

By releasing these substances to the environment, the country has long accepted the fact that excessive applications cause overuse and environmental contamination. Excessive pesticide use damages non-targeted species such as bees, birds and mammals, including humans.
The Food and Drug Administration (FDA) is responsible for testing foods for pesticide residues. The U.S. Department of Agriculture (USDA) tests meat and poultry pesticide residues. This testing becomes the basis for determining if tolerances have been exceeded, and if they are, foods must be impounded and reexamined.

Food testing for pesticide residues

- The USDA conducts annual tests of pesticide residues in U.S. food supplies. Their special focus is on fresh fruits, vegetables, grains, milk, animal feed, and meats. Limited and inconsistent testing supports the USDA's conclusion that the food supply is free from dangerous pesticide residues.

- The USDA is responsible for estimating the benefits of pesticides that are not used in the production of food. The Environmental...
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Glyphosate and Modified Foods

- All three agencies, FDA, USDA and EPA, decide how best to coordinate the regulation of novel technologies such as genetically modified seeds designed to be resistant to insecticides, herbicides, or fungicides. Products subject to regulation include plants, animals, pesticides, drugs, and chemicals.

- The following questions should be asked: What chemicals have been administered to the food in question, and how persistent are they? Do they bind to water or fat? Are they used on food crops and livestock that are highly consumed as part of the American diet?

- Should raw foods be more sampled than processed foods? Which processed foods should be tested more often: flours, oils, sugars, or fats? Should plants be tested more often than animal products?

- To protect against dangerous exposures in food, the EPA sets maximum contamination limits or tolerances for each crop and its processed food forms. If residues exceed these legal limits, the food may be branded as adulterated and removed from the marketplace.

- Coffee and tea are allowed to be sprayed with glyphosate, and residues of 1 ppm are allowed to remain in products that are traded or sold to consumers. Shellfish may have glyphosate residues three times higher than the 1 ppm limit. Corn and quinoa are permitted to have residues five times higher, peas 8 times higher, beet sugar 25 times higher, and vegetable oilseeds 40 times higher.

The USDA conducts annual tests of pesticide residues in the U.S. food supplies. Their special focus is on fresh fruits, vegetables, grains, milk, animal feed, and meats. Limited and inconsistent testing supports the USDA’s conclusion that the food supply is free from dangerous pesticide residues.
Animal feeds are allowed to have glyphosate residues of 400 ppm, or 400 times higher than the 1 ppm limit. Glyphosate is licensed by the EPA for use on more than 160 different foods, including nearly all of the top 20 most consumed foods in the nation. The EPA, for example, has permitted glyphosate to be used to kill weeds that compete for soil nutrients.8

Receiving EPA approval for the use of a pesticide on crops destined for animal feeds is exceptionally valuable to manufacturers, given the diversity of crops used in feeds. These often include wheat, barley, alfalfa, millet, corn, soy, canola beans, and field hays. Collectively, these crops are planted on hundreds of millions of acres on farms in the U.S.

The allowance of 400 ppm glyphosate residues in feeds should raise questions about whether these concentrations are passed along to the meats and dairy products eaten by humans.

Species of sheep are assumed to consume dry feed with 530 ppm, dairy cattle 342 ppm, swine 123 ppm, and poultry 33 ppm. The European Food Safety Agency (EFSA) reports that residues in these meats and their processed products are not expected to exceed 18 ppm, which has become a norm of acceptability. In the U.S., as of the writing of this report, no tests of meat products have been publicly released.9

Why do the allowed residue levels vary so widely for different foods? Some crops may be susceptible to a diversity of pests that demand different intensities of pesticide applications.

Normally, as the concentration of biocides applied in the field increases, so does the concentration of residues on the food products. Thus, applying a chemical at a concentration that is effective in reducing or eliminating pests is often a more important driver of allowable residue levels than is the consideration of human health risks.
The residue levels allowed on a particular crop and the residue levels allowed in the processed forms of that same crop are different, and often much higher. This higher residue level has little to do with safe exposure limits, but is still allowed.

The higher levels could indicate the possibility that concentration during the conversion of the plant to other forms happens during processing. An example of such a conversion is when corn is processed into corn oil.

The most worrisome scenario is the one in which pesticide residues are high on foods that are heavily consumed by human populations, and the toxic potency of the pesticide is high. This becomes more serious for foods that are consumed by children.

The EPA’s judgment about dangerous levels of food pesticide residues is strongly influenced by the average national intake of a particular food and the average pesticide residue on that food.
Residue sampling designs tend to avoid the testing of infrequently consumed foods, with the EPA often allowing higher residues to remain on foods consumed only by a minority of consumers. As an example, when pesticides are found in citrus oil, consumption of citrus oil is so low that exposures would also be low.

On the other hand, if pesticide residues are found on highly consumed foods, such as milk, orange juice, apples, bananas, and meats, it should follow that allowable residue levels would be more limited.

Processed foods are often mixtures of foods from different sources. Oils are a good example. Palm oil is a blend derived from the fruits of many different smallholder producers in Southeast Asia. By the time the palm oil reaches international markets, the mixture can easily have been collected from hundreds of different farms, each having different pesticide practices and uses.

Figure 7. USDA Data from its Pesticide Data Program Sampling Program

<table>
<thead>
<tr>
<th>Kale Pesticides Detected in 2017 % Sample Positive Detects</th>
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<tbody>
<tr>
<td>Flonicamid</td>
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<tr>
<td>Difenoconazole</td>
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<tr>
<td>Fenamidone</td>
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<tr>
<td>Metalaxyl/Mefenoxam 3</td>
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<tr>
<td>Cytraniliprole</td>
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<tr>
<td>Cyhalothrin, Lambda*</td>
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<tr>
<td>Flupyradim</td>
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<td>Trifluralin</td>
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<td>Cypermethrin*</td>
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<td>Bifenthrin*</td>
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Percent of Sample Tested with Pesticide Residues
Since many pesticides banned in the EU and the U.S. are allowed to be used in other nations, residues in imported foods are a bigger concern for U.S. consumers than those produced domestically.

Testing showed that kale was found to have the most pesticides detected. Six pesticides were detected in 20+% of samples tested. In total, 30 separate pesticides were found on kale.

Tracking responsibly produced foods through international markets is both difficult and expensive to accomplish. This is especially important when considering the legitimacy of various food certification programs, especially when the products are derived from many different ingredients and sources.

It is important for consumers to know that government claims about the absence of residues and the safety of the U.S. food supply can be politically manipulated simply by choosing which foods to test, and which chemicals to search for.

Figure 8. Percent of Food Samples Testing Positive and Pesticides Detected
Strawberries had the largest number of pesticides. Figure 9 above shows that many samples contained pesticide residues: 22% of the apples tested contained residues of four different pesticides, and 12% of pears contained residues of seven pesticides. Strawberries had the largest number of pesticides, including one sample that contained residues of 20 different chemicals.

Source: USDA’s Pesticide Data Program (2016) demonstrated the presence of numerous pesticides in the same samples of apples, pears, and strawberries.
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Figure 11. USDA Testing Detected Four or More Pesticide Residues on Oranges

Source: USDA’s Pesticide Data Program (2016) demonstrated the presence of numerous pesticides in the same samples of lemons, grapefruits, and oranges.

- When other ingredients are added to glyphosate, the formulations are often more toxic than glyphosate alone. The International Agency for Research on Cancer (IARC) considers the formulations that add other ingredients to glyphosate to be especially worrisome. The IARC highlighted concerns about formulations that combine glyphosate with other ingredients to enhance their weed-killing effectiveness.

- Monsanto and its rivals sell hundreds of these products around the world in a market valued at roughly nine billion dollars. The National Toxicology Program (NTP) has shown that glyphosate is more toxic when mixed with other chemicals. The acting chief of the NTP Laboratory noted that glyphosate formulations are much more toxic than glyphosate alone. These chemical formulations are capable of killing cells.10

- A 2019 study in the journal *Frontiers in Genetics* reports that glyphosate, when combined with other molecules, resulted in breast cancer development. Although exposing cells to glyphosate

Twenty or more tested foods had one or more pesticide residues over the legal limit. Another 109 contained residues that are illegal to use in the U.S. or above their legal limits. Residues were found on 20+ samples that have no allowable tolerance levels in the U.S. and are therefore prohibited.
The most striking finding from the organic produce analyses is the effectiveness of the national and California organic food standards.

 alone did not induce tumor growth, cancerous tumors did develop after glyphosate was combined with molecules that were linked to oxidative stress. Oxidative stress is a chemical reaction that occurs as the result of aging, diet, alcohol consumption, smoking, or other stressors, and it alters the organization and integrity of the genome of the breast, aiding cancer development.  

- The study showed that the breast tumor growth wasn’t the usual type of breast cancer we see in older women, but was a more aggressive form found in younger women, known as luminal B cancer. This study shows that glyphosate can trigger tumor growth, when combined with other frequently observed risks.


- The State of California annually tests for pesticide residues in food products, whether grown in the state or imported. In 2016-17, California tested 3,585 samples of food at the
Of the 3,585 conventional foods tested, 61% contained pesticide residues. Four percent of the residues were illegal, meaning that concentrations were above the allowable tolerance. No residues were detected on 39% of foods tested, as shown in Figure 12.

Twenty or more conventional foods tested had one or more pesticide residues over the legal limit. Another 109 contained residues that are illegal to use in the U.S. or above their legal limits. Residues were found on 20+ samples that have no allowable tolerance levels in the U.S. and are therefore prohibited.

On the other hand, the finding from the organic produce analyses shows how effective the national and California organic food standards have proven to be. They have now been adopted by the federal government, and further regulated by the State of California.
Testing showed that 61% of conventional produce contained pesticide residues. The organic produce tested had 8.8% of legal detectable pesticide residues acceptable under the CDFA Organic Program Guidelines.

Pesticides acceptable under this organic program are normally natural, and generally pose a far less significant threat to human health, non-target species, and environmental contamination.

The California Pesticide Residue Testing Program does not test all types of food products. The findings resulted from testing fresh produce. Testing excludes meats, dairy products, and many other processed foods derived from fresh crops, such as oils, sugars, flours, beverages, and an enormous number of ingredient combinations.

Dietary exposure is the source of many pesticide residues that have been detected in human tissues. A 2018 study of nearly 69,000 participants examined the association between organic food diets and cancer incidence. The authors found that those who consumed the most organic food were 25% less likely to develop cancer during the study period.

It is possible that people who consumed organic food also avoided intake of other types of foods associated with various cancers, including saturated animal fats, processed meats, and alcohol, further reducing their risk factors.

A 2019 study that tested human urinary concentrations of pesticide residues from dietary sources showed that the residues declined when the study participants switched from a conventionally produced diet to an organic diet.

Residues of organophosphate (OP), neonicotinoid, and pyrethroid insecticides, as well as the herbicide 2,4-D, were reduced when the study participants changed from a conventional
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A 2019 study that tested human urinary concentrations of pesticide residues from dietary sources showed that the residues declined when the study group switched from a conventionally produced diet to an organic diet.15

An earlier study of chlorpyrifos supported this finding by showing that residues declined by four times when children switched from eating a conventional diet to consuming organic food.16

4. Drinking Water Safety

The Safe Drinking Water Act

- The Safe Drinking Water Act (SDWA) was passed in 1974. It is the principal federal law in the United States whose purpose is to ensure safe drinking water for the public.

- The SDWA does not apply to bottled water. Bottled water is regulated by the Food and Drug Administration (FDA), under the Federal Food, Drug, and Cosmetic Act.
The SDWA applies to every public water system in the United States. There are currently more than 170,000 public water systems providing water to almost all Americans at some time in their lives. However, the most direct oversight of water systems is conducted by state drinking water programs.

The SDWA was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources—rivers, lakes, reservoirs, springs, and groundwater wells. SDWA does not regulate private wells that serve fewer than 25 individuals.

The SDWA applies to every public water system in the United States. There are currently more than 170,000 public water systems providing water to almost all Americans at some time in their lives. However, the most direct oversight of water systems is conducted by state drinking water programs.

Pesticides in Drinking Water

Water is the most consumed food in the human diet, and it is intrinsic to all foods. Even beef consists of 70-80% water, depending on the cut and proportion of fat.

Poultry and fish are often pressure-infused with a salt water solution to increase purchase weight and enhance the flavor.
Water is commonly added to foods during processing and meal preparation, besides being consumed as a beverage.

Water is vulnerable to contamination by pesticides and other industrial chemicals. Microbes that contaminate water produce more than 38 million cases of food poisoning each year.17

Four problems contribute to the nation’s continuing pesticide contamination:

- Few pesticides are monitored;
- Sample sizes and frequencies are insufficient to understand dangers to health with reasonable accuracy;
- Many public and private water suppliers are exempted from testing requirements based upon past results; and
- Monitoring failures cripple any possibility of effective protection against water-borne hazards to human health.

Because many pesticides volatilize, they end up in rainwater, snow, and ice, and they move long distances before returning to the earth’s terrestrial and aquatic environments.

The increased use and intensity of pesticides in American agriculture has caused pesticides to reach underground aquifers.

The USDA estimated nearly two decades ago that nearly 50 million people living in the U.S. were at risk from pesticide residues. Groundwater drinking supplies are often contaminated not only with pesticides, but also with other agricultural chemicals.18

Pesticide residues have been detected in the drinking water of most nations that have tested for them. More than 17,000 scientific articles report the presence of hundreds of different pesticides in drinking water.19

These findings demonstrate the absence of forethought about managing the lifecycle of the billions of pounds of pesticides applied each year.
Farmers have long assumed that government licenses and label requirements demonstrate the safety of the pesticides that they use. However, regulators rely on the pesticide manufacturers’ own data, and assurances from the manufacturers that the pesticide residues will be minimal.

- The widespread presence of herbicide contaminants in the world’s water supplies also reflect governments’ neglect of basic chemical ingredients that could have predicted contamination of soils, water, foods, rain, and air.

- These ingredients include the chemicals’ ability to be soluble in fats and water, to be mobile, to cause adverse effects on non-target species, and and to cause human toxicity.

- All these effects should have been fully examined before the U.S. and over 100 other governments provided corporations with licenses to sell and use pesticides in their nations.

- Farmers have long assumed that government licenses and label requirements demonstrate the safety of the pesticides that they use. However, regulators rely on the pesticide manufacturers’ own data, and assurances from the manufacturers that the pesticide residues will be minimal.
The absence of glyphosate from the list of detected pesticides does not imply its absence. Instead, it reflects government testing avoidance.

The pesticides most commonly detected as residues in surface, ground, and well water are shown in Figure 14 above. Although the U.S. Geological Survey (USGS) has known about these findings since 2007, few consumers realize that residues are present in drinking water, or that they may pose health hazards.20

Figure 13 shows the pesticides most often found in both agricultural and urban water. The pesticides predominantly used are herbicides. Atrazine, an herbicide, has been detected in 80% of the water samples tested in agricultural areas.

The insecticides most often detected, chlorpyrifos and diazinon, are well-recognized neurotoxins. Although banned in the E.U. and many other nations, the U.S. still allows their use in agriculture.

The absence of glyphosate from the list of detected pesticides does not imply its absence. Instead, it reflects government testing avoidance.
The U.S. Food and Drug Administration (FDA) has similarly avoided testing for glyphosate residues. The presence of residues in water means that exposures are occurring from both food and water sources. When Canada tested foods for glyphosate residues, manufacturers pressured the government not to release the details to the public, including both sampling protocols and detected concentrations.

As shown in Figure 15, pesticides were detected in 97% of the stream waters in both agricultural and urban areas that were tested. Surprisingly, these chemicals were also commonly found in surface and groundwaters in all types of land use.

Even in undeveloped areas, pesticides were detected in 65% of the stream waters and 29% of the shallow groundwater tested. This shows that the pesticides used were persistent and mobile. Pesticides were more likely found in stream waters than in shallow groundwater and major aquifers.
Persistent pesticides in the sediments of rivers, streams, and lake beds can be mobilized by floods and storms, making them available for absorption by plants and aquatic life.

Organochlorine pesticides include DDT, dieldrin, lindane, heptachlor, chlordane, endosulfan and dicofol. The use of these pesticides was widespread from the 1940s through the 1970s and 1980s. Because of the toxicity and the persistence of this class of pesticides, most of them were finally restricted or banned by the 1980s.

Organochlorine pesticides are extremely persistent in the environment. They break down slowly and accumulate in the fatty tissues of animals. They stay in the environment and food chain long after they had been applied.

The presence of organochlorine residues in fish and sediments shows the chemicals’ persistence and their ability to magnify in concentration as they move up the food chain.

The organochlorine pesticides' ability to kill many different and non-targeted species, as well as to accumulate in the environment and in human tissues, were all discovered well after the chemicals
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Relying on stream and river water for irrigation when it contains multiple pesticide residues can cause the chemicals to be spread over fields and crops. There is little understanding of the long-term effects of such practices on pesticide exposures from the food crops.

had become staples in global agriculture, forestry, vector-borne disease control, and residential uses.

- Persistent pesticides in the sediments of rivers, streams, and lake beds can be mobilized by floods and storms, making them available for absorption by plants and aquatic life.

- The U.S. Geological Survey (USGS) study of 1992 showed that pesticides were more commonly found in stream water than in groundwater. The presence of multiple pesticides in single water samples of stream water were quite high at 95%, while the stream samples in urban areas were lower at 90%.²¹

- The USGS study concluded that pesticides usually are found in mixtures, leading to questions of additive toxicity and synergistic health risks. For example, chlorpyrifos and diazinon are both organophosphate compounds that attack the nervous system. What is their effect when used together? They are not tested for their safety when used in combinations.

- The National Academy of Sciences concluded in 1993 that when two chemicals are found together, the risks of the combination should be tested. Although this regimen has been accepted when judging unacceptable concentrations of chemical mixtures in foods, it has not been applied during risk assessments of pesticides in drinking water within the U.S.

- Finally, relying on stream and river water for irrigation when it contains multiple pesticide residues can cause the chemicals to be spread over fields and crops. There is little understanding of the long-term effect of such practices on pesticide exposures from the food crops.

5. Health Effects of Pesticides

- Pesticides are designed to injure cells, cause disease, and induce death in many species. The single greatest error in governments’
collective judgment about their reflexive licensing of ever more pesticides is the simplistic assumption that humans would somehow be immune to their damage.

- Pesticides have been proven to cause many different human illnesses including: neurological disorders, cancers, cardiovascular events, reproductive impairment, immune system abnormalities, and disruption of normal hormonal actions. A single chemical may create many of these effects at the same time.

- This report focuses on many pesticides recognized as neurotoxins and hormone disruptors. The toxic effects of many of these pesticides are repeated across generations, meaning they can get passed on to future generations.

- It is important to consider how scientists reach conclusions concerning pesticides’ ability to damage health. Traditionally, experts have relied upon clinical evidence of disease associated with populations or individuals with known exposures.

- For example, farmworkers who enter fields that have been sprayed recently may suddenly and collectively experience dizziness, nausea, and skin rashes. Accidental poisonings also provide important understanding about human illnesses following intensive pesticide exposures. This evidence is invaluable, though less frequently available.

- An alternative way to better understand causation is pursued by epidemiologists who examine disease trends among large populations. Groups experiencing the same illnesses are then studied to search for patterns in pesticide exposure over long periods of time.

- These longitudinal studies are time-consuming and expensive, often including thousands of individuals, making possible comparison of illness rates among those exposed to pesticides compared to those unexposed.
Difficulties in Determining Health Effects

- It is difficult to control for the influence of many other potential causes of disease, since we all are exposed to carcinogens, neurotoxins, and endocrine disruptors in our daily lives that are not pesticides.

- Given these inherent problems in the availability of human evidence of toxicity, scientists turn to testing different animal species by exposing them to different concentrations of single chemicals and then examining them to understand any changes in physiology, growth and development, lifespan, and the onset of different abnormalities such as cancer, neurological deficits, reproductive failure, endocrine system disruption, and immunological impairments.

- Estimating human health risks by extrapolating them from animal evidence is fraught with uncertainties. This is because there are differences in lifespan, organ systems, functions from conception to maturity, and the ability to metabolize tested chemicals, often transforming them into non-toxic substances. The high doses that test animals receive compared to the exposures that humans are likely to experience are often very different.

- Most air, water, food, and consumer protection laws are designed to limit chemical releases. The goal is to ensure that human exposures remain below benchmark thresholds that would otherwise produce adverse effects.

- These laws assume a precision in scientists’ abilities to identify a threshold of dangerous health-threatening exposures that is rarely justified by available evidence.

- Regulators are routinely confounded by research-related problems, such as inconsistencies in findings among different studies, and the absence of clear standards to discern the degree of danger associated with common uses and typical exposures.
The study of chemicals that disrupt normal endocrine system action and outcomes has turned the presumption of dose-response upside down. One property of many endocrine-disrupting chemicals is their larger effects at smaller, rather than larger, doses.

The exceptionally low doses necessary for hormones to trigger cellular responses leads endocrinologists to conclude that no safe doses can be identified.

These compounds bind to a variety of hormone receptor sites, and can have the harmful effect of landing on a receptor site that blocks other natural or synthetic molecules from having a normal effect.

Because it is clear that some pesticides have harmful effects at low doses, this finding has very significant implications for regulations. The legal tradition sets residue limits based on high dose responses in air, water, food, and consumer products, and is therefore a hopeless strategy for creating health protective regulations.

Nearly 9,600 legal limits for pesticide residues in food have been set one by one, all with the public expectation that allowable doses are health protective.

The presence of pesticide residues in food, water, and air all demonstrate that pesticide residues surround us daily in complex and ever-changing mixture of exposures. Given the absence of health effect testing of pesticide combinations, any public belief in the health protective nature of U.S. or international law is unfounded.

Individual pesticides may cause many different types of health effects. Many of the pesticides intensively applied to food crops in the U.S. have been shown to be capable of affecting a number of different organ systems and functions that threaten human illness.

While individual pesticides may cause many different types of health effects, mixtures are a particular concern. The world’s legal
Human prenatal exposures to synthetic pyrethroids have been associated with reduced motor function, social adaptation, and intelligence among infants.

architecture examines chemical risks one by one, and sets residue limits one pesticide at a time, all while humans are exposed every day to ever-changing mixtures.

**Neurological Hazards of Pesticides**

- Pesticide researchers will hopefully guide their search for new types of pesticides using principles that extend well beyond achieving pest-control functionality. These principals should include concerns for persistence, mobility, toxicity, reactivity, solubility, and degradability into stable, non-toxic molecules.

- Oganochlorines are still in use today, but their neurotoxicity, discovered long after their use, motivated the search for a new class of pesticides to replace them in the 1980s.

- The harmful characteristics of organochlorines led to the design of two new classes of pesticides: (1) the *organophosphates*, including chlorpyrifos, diazinon, parathion, malathion, and 60 other variants; and (2) the *carbamates*, including aldicarb and carbofuran.

- Synthetic *pyrethroids* mimic the molecular structure of six natural pyrethrins esters derived from chrysanthemum flowers. After these synthetic pesticides became popular as replacements for organophosphates, they were discovered to have neurological effects, especially following gestational exposures and in very young animals.

- These pesticides are able to cross the blood-brain barrier, and can lead to changes in the blood vessels in the brain, causing deficiencies in coordination, learning, and memory among exposed animals.

- Fortunately, the synthetic pyrethroids tend to break down quickly, so they do not accumulate in the environment. Examples of the pyrethroids include allethrin, cyhalothrin, cypermethrin, deltamethrin, fenpropatrin, fenvalerate, permethrin, resmethrin, and tralomethrin.
Neonicotinoids have a common mode of action that affects the nervous system of insects, causing paralysis and death. These pesticides are persistent in the environment, and when used to treat seeds they become part of the pollen and nectar of the resulting plants. This effect has proven dangerous to both bees and birds.

Neonicotinoids are used in over 120 countries. There is some controversy over how much harm neonicotinoids are actually causing bird populations to decline and honey-bee colonies to
Bumblebees are more sensitive than honey bees to neonicotinoid insecticides. Researchers have been sounding the alarm for years about the declining numbers of bee populations, and they continue to do so.  

- In 2013, the European Union restricted the use of certain neonicotinoids, and in 2018 the EU banned the three main neonicotinoids, clothianidin, imidacloprid, and thiamethoxam, for all outdoor uses. The Canadian federal government is taking steps to phase out the use of neonicotinoid-based pesticides starting in 2021.

- In summary, each generation of insecticides has spread quickly in international markets before independent tests to predict their neurotoxic risks have been fully conducted.

- Avoiding the late-recognized neurological hazards of former generations has normally occurred without sufficient environmental and health testing to understand and predict hazards for future generations.

- This cycle of regret for past ignorance and faith in the safety of unproven replacements has occurred roughly every 25 years. It is curious that the patent life for new generations of pesticides is 20 years, after which generic brands may be produced, and profitability declines for original patent holders.

- The neurotoxicity of organophosphate pesticides is a special case. They were introduced in the U.S. in the 1940s to 1960s, before there were any significant government pesticide regulations.

- In 1947, the USDA became responsible for pesticide registration, but that agency had little, if any, expertise in neurotoxicity.

- The expectation then was that serious health loss could be avoided simply by reducing human exposures during chemical mixing and application.
The neurotoxicity of organophosphate pesticides works by causing the enzyme that regulates the central nervous system to malfunction. In humans, organophosphates inhibit the production of the enzyme acetylcholinesterase that breaks down acetylcholine, a key neurotransmitter in nerve synapses.

Tests for various types of developmental neurotoxicity should go beyond cholinesterase inhibition. Effects on the human central nervous system (CNS) range from confusion, dizziness, and convulsions to coma and death.

Government regulators know that avoiding acute effects is important, but they also need to know and pay attention to the chronic health effects of pesticides, especially when exposures occur during fetal development and early childhood.

During the 1990s, the organophosphate pesticides were discovered to be capable of disrupting the normal neurological development of fetuses, infants, and young children when they were exposed.

Brain cell replication is reduced in relation to the intensity of pregnant women’s and children’s exposures, resulting in altered cognitive, memory, and learning capacity.

Governments have long over-simplified health threats associated with pesticide exposures during the different stages of the human lifecycle. Now it is well understood that windows of vulnerability open and shut for exposures to cause various harmful health effects.

Most human epidemiological studies on threats from pesticide exposures have focused on the period of gestation. A study by Whyatt et al. in 2004 and 2005 found that as organophosphate exposures increased, birth weight and body length among minority children declined.\(^{31}\)

These physiological metrics led to the discovery that the same cohort of children, especially those that were more heavily exposed...
to organophosphates, experienced some attention deficits and motor skill deficiencies that were dependent on neurological functions.

- The most important implication of these findings is that government regulation focused on cholinesterase inhibition, only one neurological effect among many, and even then only in adults.

- Given the high level of pesticide exposures necessary to produce adverse effects, pesticide residues on food were permitted to be high for decades.

- Government studies found that nearly everyone examined carried residues of organophosphate metabolites in their urine at levels capable of inducing the developmental effects that government had long neglected.

- For nearly 50 years, the USDA and EPA failed to test for other health effects, such as issues of memory, learning, motor skills connected to brain functions, and attention deficits, among those exposed to residue levels commonly found in the U.S. food supply.

- The failure of governments to recognize the vulnerability of fetuses and children is difficult to understand, given physicians’ historical hesitancy to prescribe pharmaceuticals to pregnant women precisely because of concerns over susceptibility during gestation and early childhood.

- Since many of the firms producing pesticides also manufacture drugs, this neglect seems more deliberate than just an oversight.

- The neurological risks to children have diminished somewhat, due to the EU and U.S. cancellations of several dozen organophosphate insecticides. However, the U.S. government has responded slowly to the serious threat to children’s health posed by a large group of remaining neurotoxic pesticides. The European Union, by contrast, has moved with much greater speed to ban most of these chemicals.