The Impacts Of Genetic Modification On Humans, Plants, Animals, and Microorganisms

Thesis

Genetic modification is a method to change the characteristics of an animal, plant, microorganism or human. Scientists transfer DNA from one organism to another when genetically modifying an organism.[1] Genetic modification is also known as genetic engineering.[10] This process is accomplished through targeted removal of desired genes from one being to another.[1] In plants, there are two types of genetic modification. One type is known as cisgenesis which is the transfer of genetic material gathered from a related plant. The other type of genetic modification in plants is known as transgenesis which is the transfer of genetic material gathered from a non-related species.[1] Based on my background research I have concluded that genetic modification/genetic engineering is the process in which scientists modify the characteristics of an organism.

Scientific Principle

Genetic engineering also known as genetic modification is the alteration of an organism's genotype. This is done using recombinant DNA technology to modify an organism's DNA and achieve its desirable traits.[10] Genetic modification is a technique used to modify the characteristics of a human, plant, animal or microorganism. It is when a piece of DNA is transferred from one organism to another. Genetic modification is done through the targeted removal of desired genes from one organism to another.[1]

Genetic Modification in Plants

	Cisgenesis	Transgenesis
Description	The transfer of genetic material obtained from a related plant.	The transfer of genetic material obtained from a non-related species.
Example	When cross-fertilizing heterozygous plants which propagate vegetatively. (ie. potatoes, apples, bananas)	When food crops are genetically modified for pest and herbicide resistance.

Pros and Cons of Genetic Modification In Plants

Pros	Cons
Smaller use of pesticides	Affect biodiversity (eg. existing species can be taken over by more dominant new species) Negative impacts on non-target organisms and on soil and water ecosystems
Disease and drought-resistant plants which require fewer environmental resources (ie. water, fertilizer, etc.)	Increased herbicide use From 1994-2020 herbicide sales in Canada have increased by 234% since GM crops (herbicide-tolerant crops) have been introduced
Faster growing plants	Weeds that can not be killed by herbicides because of the use of GM herbicide-tolerant crops (Superweeds)
More nutritious, tastier food	Some insects have resistance to toxins in GM insect-resistant crops (Superpests)
Increased supply of food, reduced cost and longer shelf life	Contamination (serious ecological, economic and social impacts) GM contamination poses a threat to organic certification and the future of organic food and farming
Food with more desirable traits (ex. potatoes produce less of a cancer-causing substance when fried)	Gene flow from GM crops is a threat to weedy and wild crop relatives, non-GM crops and foods and organic farming
Medicinal foods that could be used as vaccines or other medicines	

Pros Of Genetic Modification In Plants

- Smaller use of pesticides
- Disease and drought-resistant plants which require fewer environmental resources (ie. water, fertilizer, etc.)
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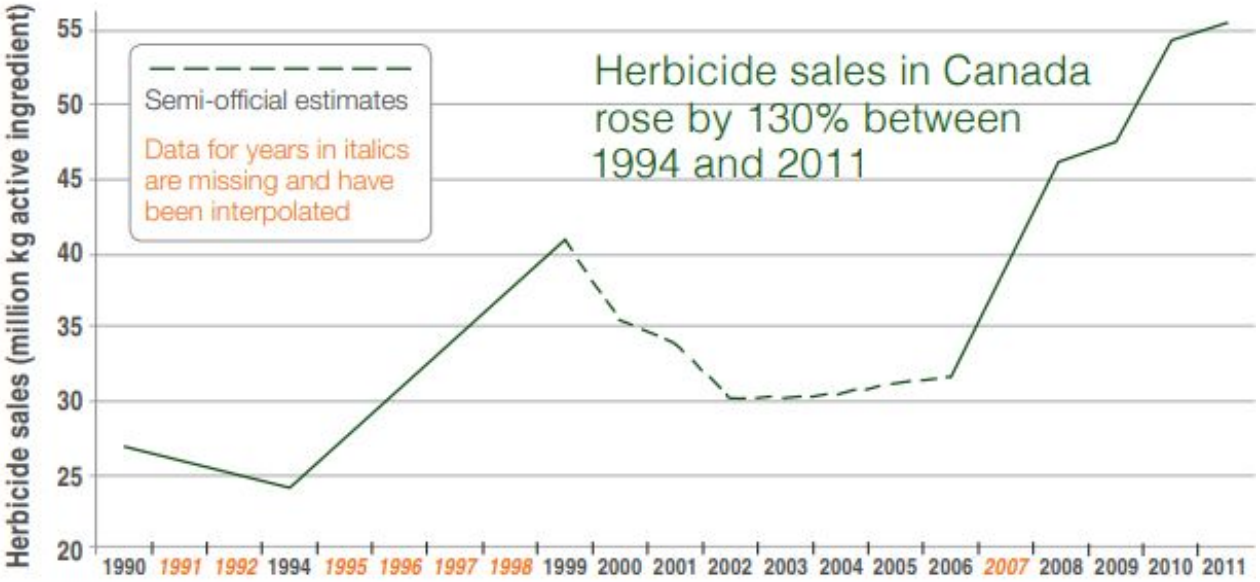
- More nutritious, tastier food
- Increased supply of food, reduced cost and longer shelf life
- Food with more desirable traits (ex. potatoes produce less of a cancer-causing substance when fried)
- Medicinal foods that could be used as vaccines or other medicines

Cons Of Genetic Modification In Plants

- Affect biodiversity (eg. existing species can be taken over by more dominant new species)
- Negative impacts on non-target organisms and on soil and water ecosystems
- Increased herbicide use (from 1994-2020 herbicide sales in Canada have increased by 234% since genetically modified crops/herbicide-tolerant crops have been introduced.)
- Weeds that can not be killed by herbicides because of the use of genetically modified (GM) herbicide-tolerant crops (Superweeds)
- Some insects have resistance to toxins in GM insect-resistant crops (Superpests)
- Contamination (serious ecological, economic and social impacts)
- GM contamination poses a threat to organic certification and the future of organic food and farming
- Gene flow from GM crops is a threat to weedy and wild crop relatives, non-GM crops and foods and organic farming

Herbicide Sales in Canada 1990-2011



Data for 1990-2006 is from the UN Food and Agriculture Organization and data for 2008-2011 from Health Canada

Pros and Cons of Genetic Modification In Animals

Pros	Cons
Better able to resist disease	Alteration of an animal's normal genetic homeostasis
Can grow faster	Lameness (the state of being unable to walk because of leg or foot pain)
More efficiently reproduce than current species of animals	Susceptibility to stress
	Reduced fertility

The Pros and Cons of Genetic Modification In Microorganisms

Pros
Medical benefits to the world’s growing population
Microorganisms produce enzymes extracellularly (simplifies the extraction method during the purification to produce food enzymes)
Specific MB strains can be selected to collect well-characterized enzymes with specific properties to produce food enzymes (FE)
Reduced production cost to produce FE because of shorter production times which means smaller production facilities are needed
Higher yields can be collected
Higher activity and stability (e.g. enzymes collected from thermophilic microorganisms will have a higher temperature tolerance)
Can easily be genetically modified to obtain optimized enzyme products, higher yields, and better characteristics
The ease of introducing genetic modifications in the production of microorganism strains to improve the industrial enzyme production
Production of food enzymes allows the production yield to increase which improves the characteristics of the produce enzyme and limits the production of unwanted metabolites. It also expresses enzymes in organisms that would not normally produce this enzyme.
Recombinant enzymes are used to improve an enzymes characteristics (activity, temperature optimum, and pH stability)

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The Pros and Cons of Genetic Modification In Humans

Pros (In the future)	Cons (Potential risks)
Prevent, treat or cure certain inherited disorders…	Damage to organs or tissues if an injection is involved
Cystic fibrosis	Allergic reactions
Alpha-1 antitrypsin deficiency	Certain types of cancers
Hemophilia	Targeting the wrong cells (cells may be damaged causing other illness or diseases like cancer)
Beta thalassemia	Infection caused by disease
Sickle cell disease	Possibility of causing a tumor
May be used to treat cancer or infections, including HIV	Unwanted immune system reaction (may cause inflammation, and in severe cases organ failure)

Long-Term Effects of Genetic Modification

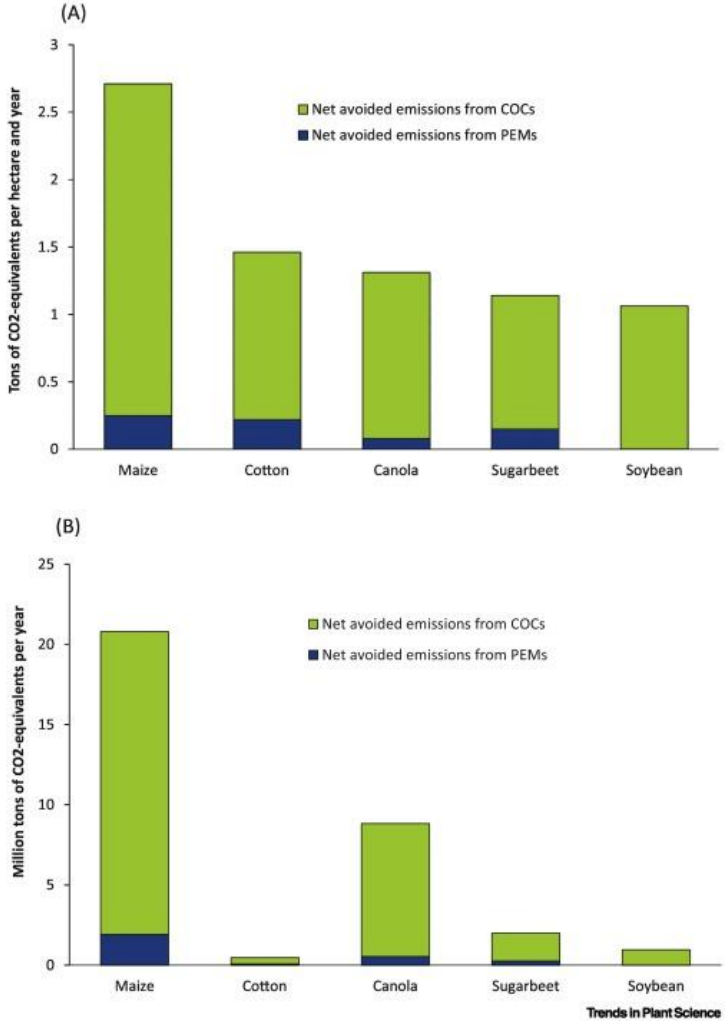
- GMOs can contribute to the development of cancer by raising levels of potentially carcinogenic substances in the body
- GMO supports climate change mitigation
- Increase in allergies
- Increase in antibiotic resistance
- Problems with the endocrine system
- Reproductive system disorders (congenital birth defects)
- Increased aging symptoms
- Cancerous tumor growth
- Autism prevalence
- Inflammatory bowel disease
- Intestinal infection

Long Term Effects of Genetic Modification

- Acute renal failure
- Hepatitis C
- ADHD
- Anxiety
- Schizophrenia
- Liver and intrahepatic bile duct cancer
- Kidney and renal pelvis cancer
- Urinary/bladder cancer
- Thyroid cancer
- Acute myeloid leukemia
- Diabetes
- Strokes

Long Term Effects of Genetic Modification

- Dementia
- Obesity
- Alzheimer’s
- Parkinson’s disease
- Hypertension
- Anemia
- Insomnia
- Vitamin D deficiency


(A)
Tons of CO2-equivalents per hectare and year
3
2.5
2
1.5
1
0.5
0
Net avoided emissions from COCs
Net avoided emissions from PEMs
Maize
Cotton
Canola
Sugarbeet
Soybean
(B)
Million tons of CO2-equivalents per year
25
20
15
10
5
0
Net avoided emissions from COCs
Net avoided emissions from PEMs
Maize
Cotton
Canola
Sugarbeet
Soybean
Trends in Plant Science

The potential avoided greenhouse gas emissions resulting from the yield increases of genetically modified crops (in the European Union). Graph (A) estimates per hectare and year and Graph (B) estimates for total European Union crop area per year.

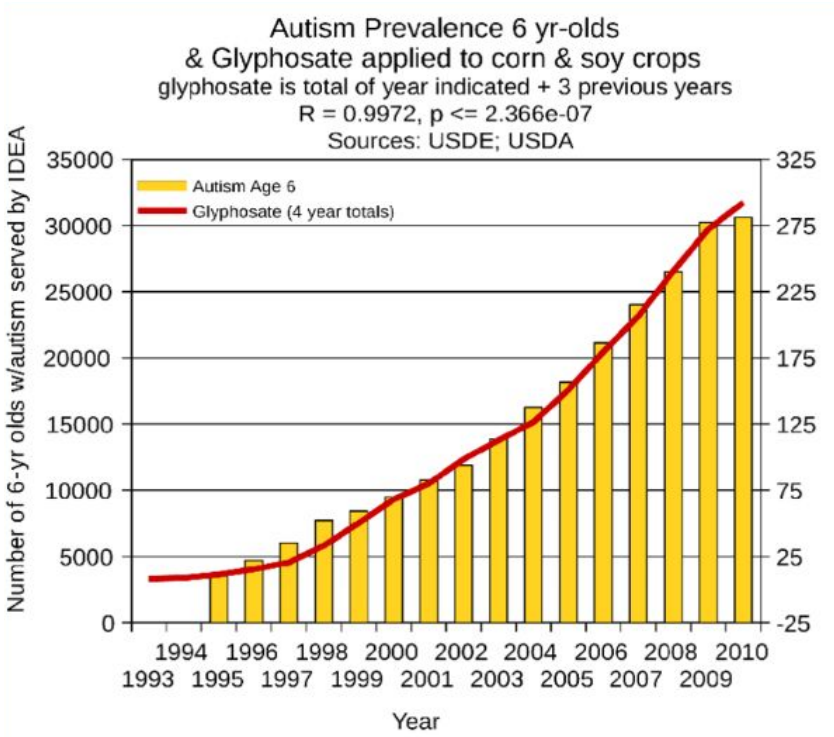
COCs: carbon opportunity costs of land use.

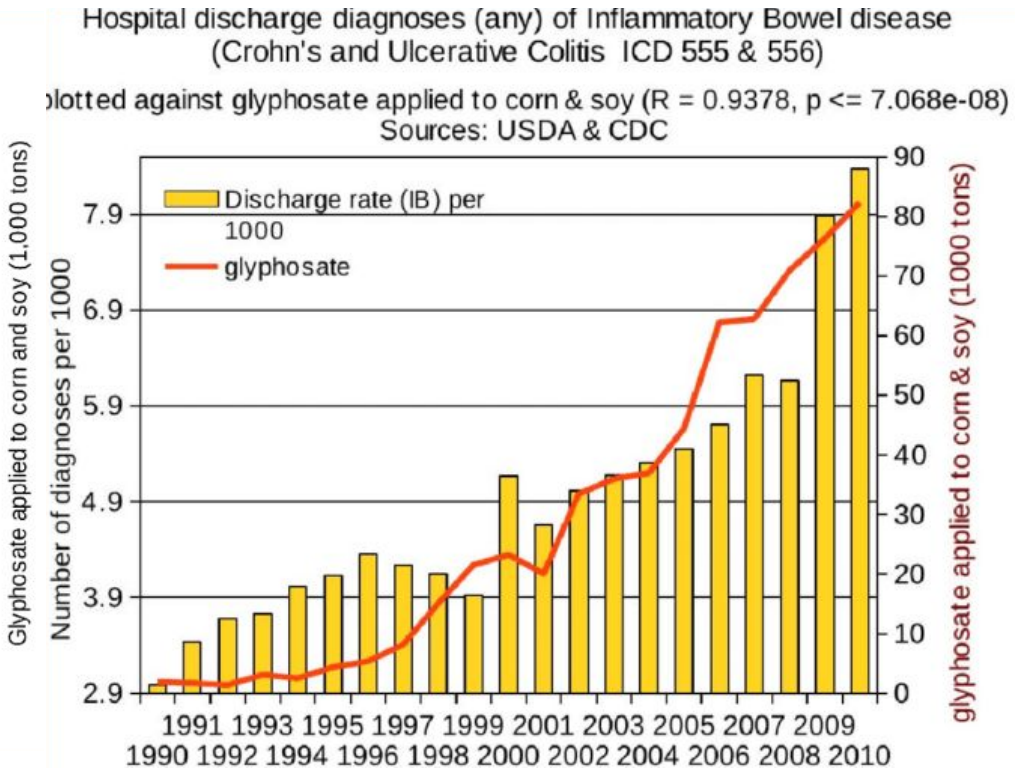
PEMs: production emissions

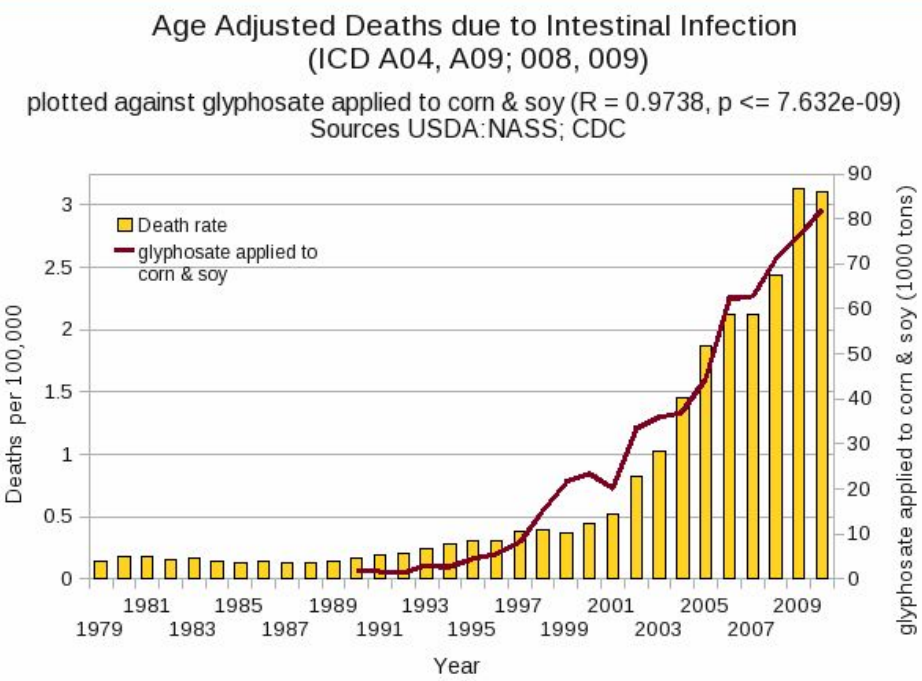
What Is Glyphosate

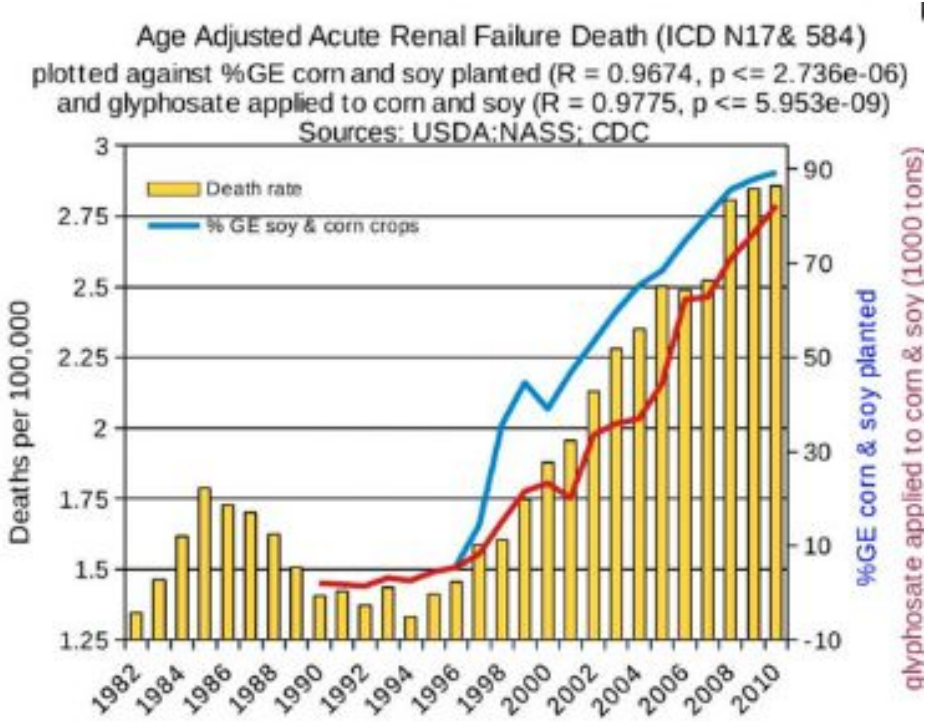
- Is a herbicide that is most widely used in Canada today
- Plays an important weed management role in agriculture and in non-agricultural land management
- Used to control weeds including invasive weeds, and toxic plants like poison ivy

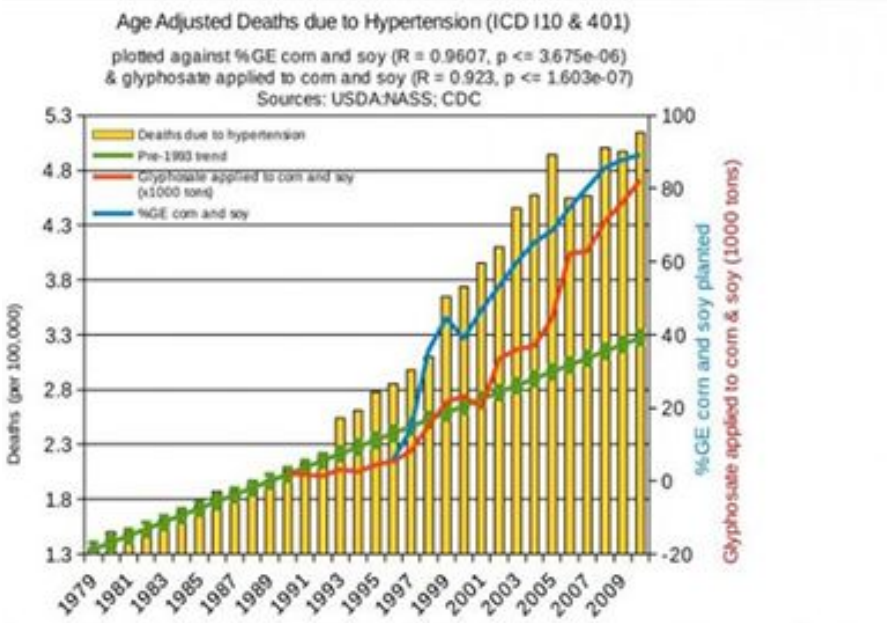
The graphs below further illustrate the long-term effects of genetic modification. They display a similar trend of an increase in various medical conditions.


Autism Prevalence 6 yr-olds
& Glyphosate applied to corn & soy crops
glyphosate is total of year indicated + 3 previous years
R = 0.9972, p <= 2.366e-07
Sources: USDE; USDA
Autism Age 6
Glyphosate (4 year totals)
Number of 6-yr olds w/autism served by IDEA
35000
30000
25000
20000
15000
10000
5000
0
325
275
225
175
125
75
25
-25
1994 1996 1998 2000 2002 2004 2006 2008 2010
1993 1995 1997 1999 2001 2003 2005 2007 2009
Year

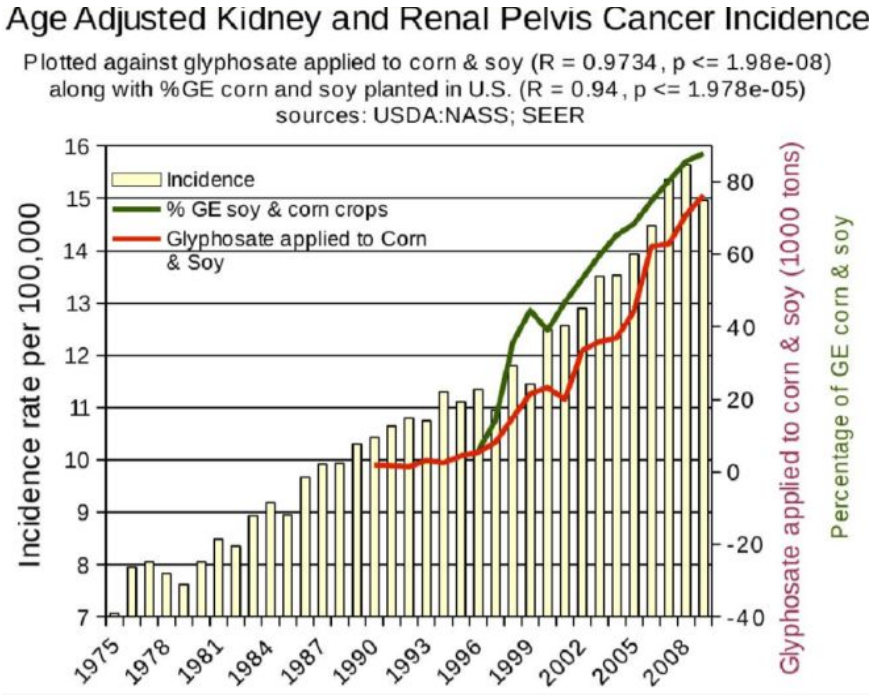

Hospital discharge diagnoses (any) of Inflammatory Bowel disease
(Crohn's and Ulcerative Colitis ICD 555 & 556)
lotted against glyphosate applied to corn & soy (R = 0.9378, p <= 7.068e-08)
Sources: USDA & CDC
Discharge rate (IB) per 1000
glyphosate
Glyphosate applied to corn and soy (1,000 tons)
Number of diagnoses per 1000
7.9
6.9
5.9
4.9
3.9
2.9
90
80
70
60
50
40
30
20
10
0
glyphosate applied to corn & soy (1000 tons)
1991 1993 1995 1997 1999 2001 2003 2005 2007 2009
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010

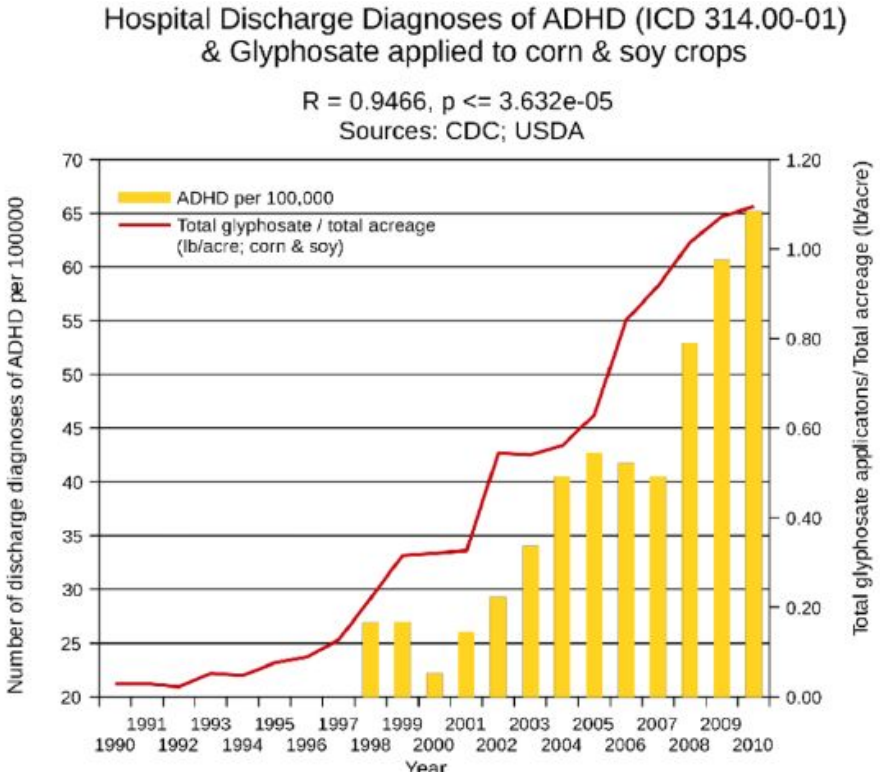

Age Adjusted Deaths due to Intestinal Infection
(ICD A04, A09; 008, 009)
plotted against glyphosate applied to corn & soy (R = 0.9738, p <= 7.632e-09)
Sources USDA:NASS; CDC
Death rate
glyphosate applied to corn & soy
Deaths per 100,000
glyphosate applied to corn & soy (1000 tons)
Year

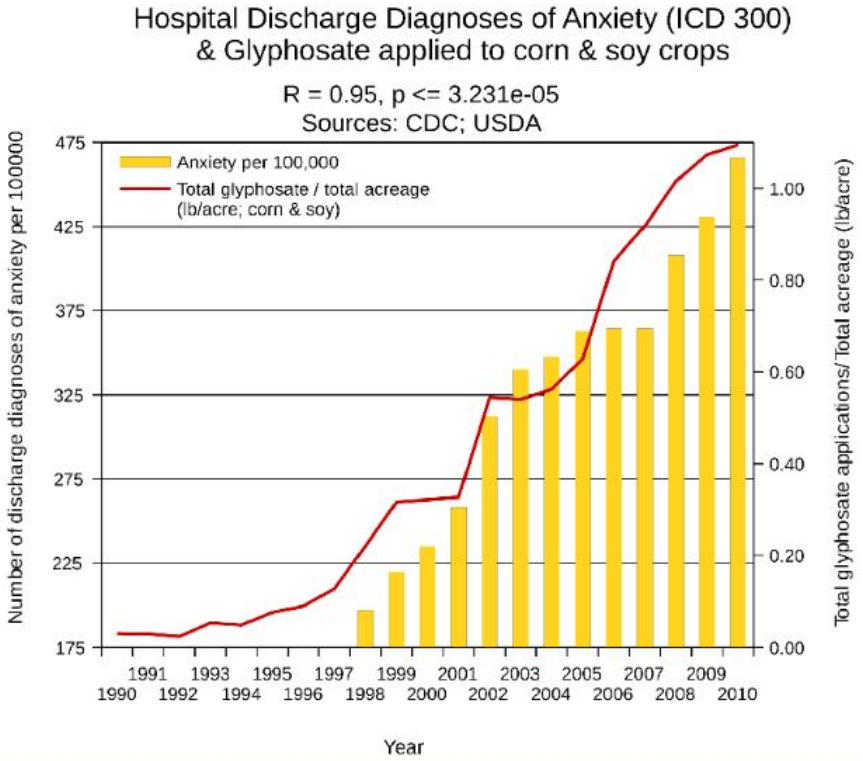

Age Adjusted Acute Renal Failure Death (ICD N17& 584)
plotted against %GE corn and soy planted (R = 0.9674, p <= 2.736e-06)
and glyphosate applied to corn and soy (R = 0.9775, p <= 5.953e-09)
Sources: USDA:NASS; CDC
Death rate
% GE soy & corn crops
Deaths per 100,000
%GE corn & soy planted
glyphosate applied to corn & soy (1000 tons)

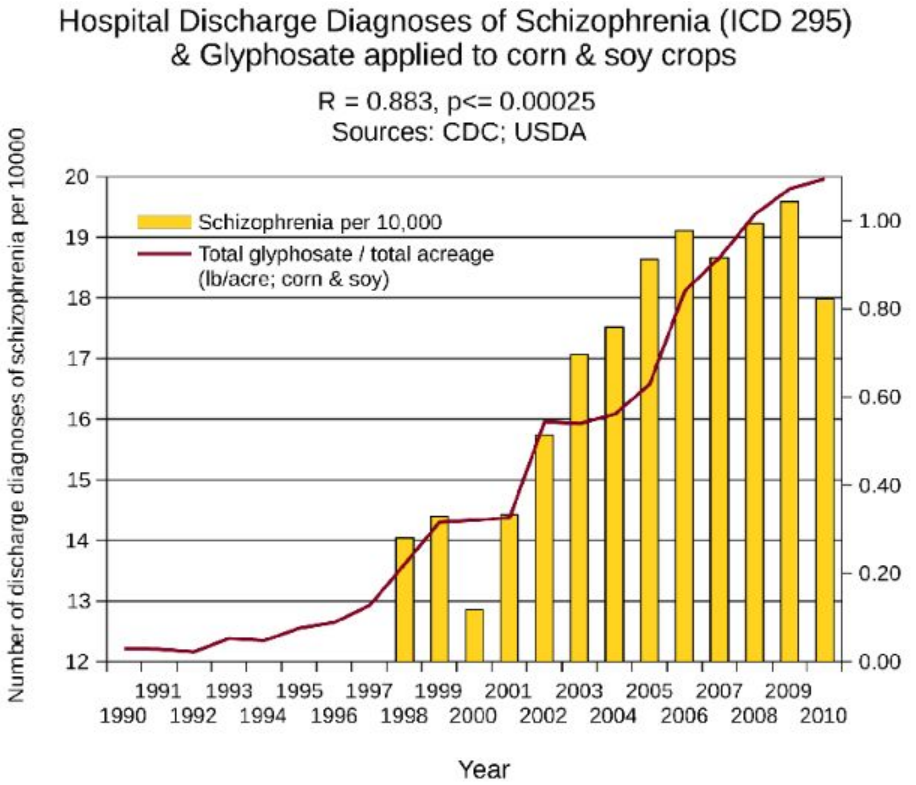


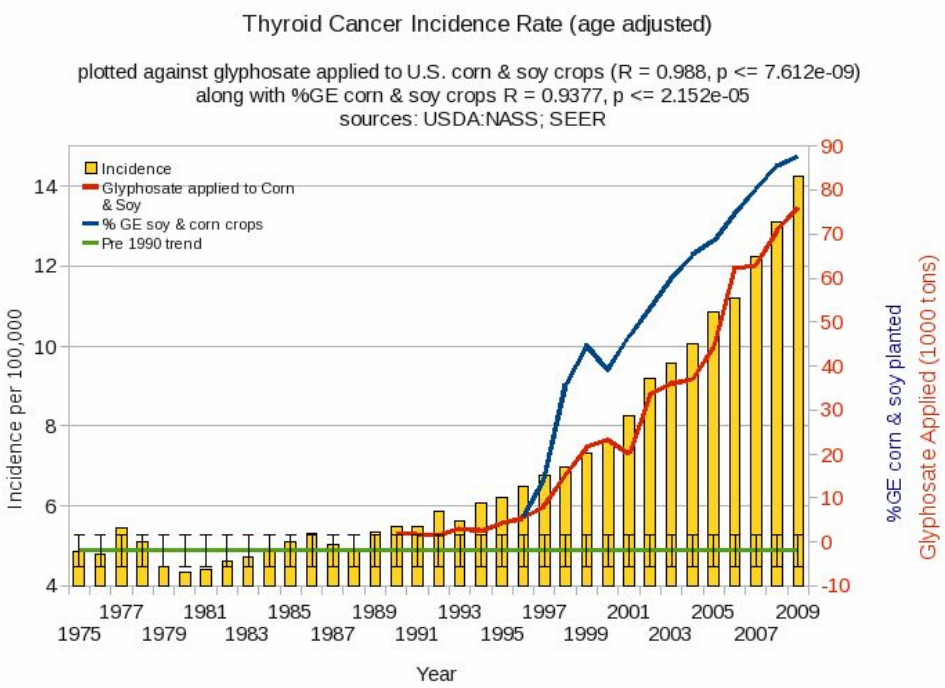
igure 11. Correlation between age-adjusted hypertension deaths and glyphosate applications nd percentage of US corn and soy crops that are GE.

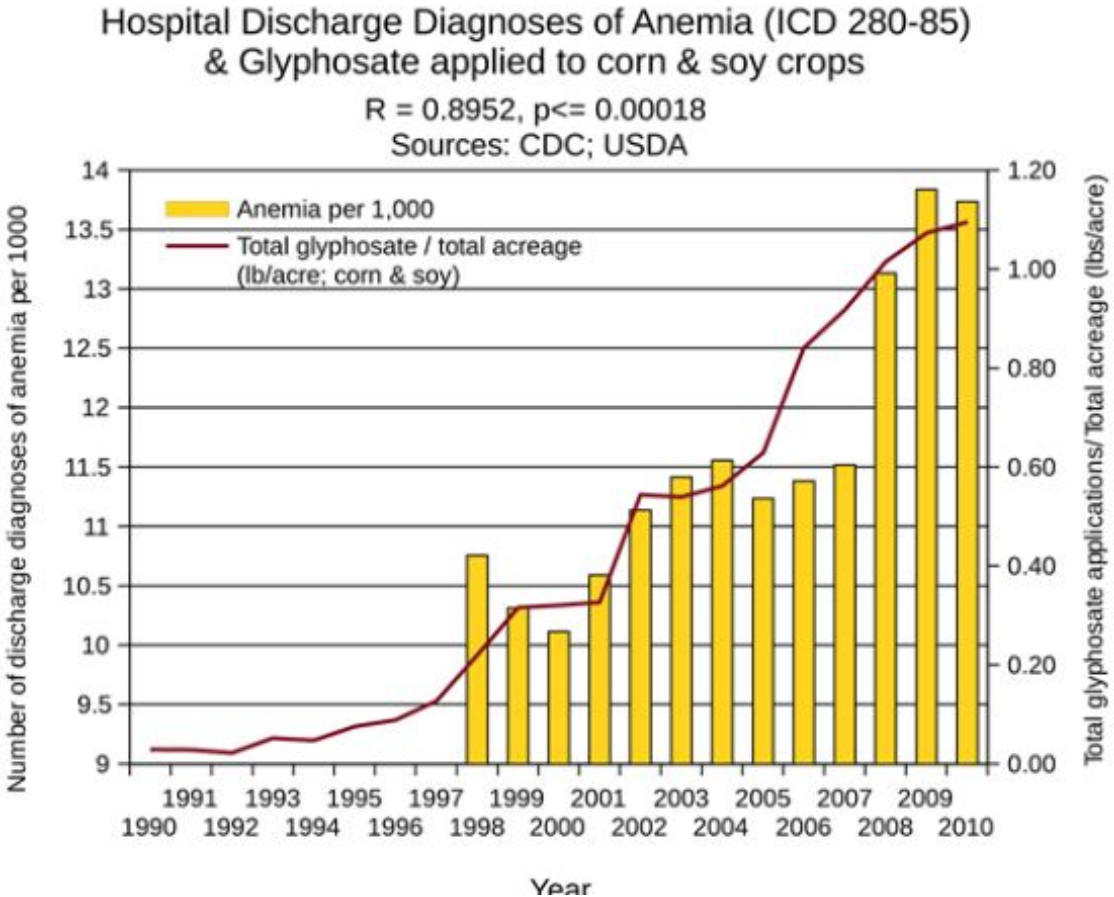



Hospital Discharge Diagnoses of ADHD (ICD 314.00-01)
& Glyphosate applied to corn & soy crops
R = 0.9466, p <= 3.632e-05
Sources: CDC; USDA
ADHD per 100,000
Total glyphosate / total acreage
(lb/acre; corn & soy)
Number of discharge diagnoses of ADHD per 100000
Total glyphosate applications/Total acreage (lb/acre)
Year


Hospital Discharge Diagnoses of Anxiety (ICD 300)
& Glyphosate applied to corn & soy crops
R = 0.95, p <= 3.231e-05
Sources: CDC; USDA
Anxiety per 100,000
Total glyphosate / total acreage
(lb/acre; corn & soy)
Number of discharge diagnoses of anxiety per 100000
Total glyphosate applications/Total acreage (lb/acre)
Year


Hospital Discharge Diagnoses of Schizophrenia (ICD 295)
& Glyphosate applied to corn & soy crops
R = 0.883, p<= 0.00025
Sources: CDC; USDA
Schizophrenia per 10,000
Total glyphosate / total acreage
(lb/acre; corn & soy)
Number of discharge diagnoses of schizophrenia per 10000
Year


Thyroid Cancer Incidence Rate (age adjusted)
plotted against glyphosate applied to U.S. corn & soy crops (R = 0.988, p <= 7.612e-09)
along with %GE corn & soy crops R = 0.9377, p <= 2.152e-05
sources: USDA:NASS; SEER
Incidence
Glyphosate applied to Corn & Soy
% GE soy & corn crops
Pre 1990 trend
Incidence per 100,000
%GE corn & soy planted
Glyphosate Applied (1000 tons)
Year


Hospital Discharge Diagnoses of Anemia (ICD 280-85)
& Glyphosate applied to corn & soy crops
R = 0.8952, p<= 0.00018
Sources: CDC; USDA
Anemia per 1,000
Total glyphosate / total acreage
(lb/acre; corn & soy)
Number of discharge diagnoses of anemia per 1000
Total glyphosate applications/Total acreage (lbs/acre)
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1990
1991
1992
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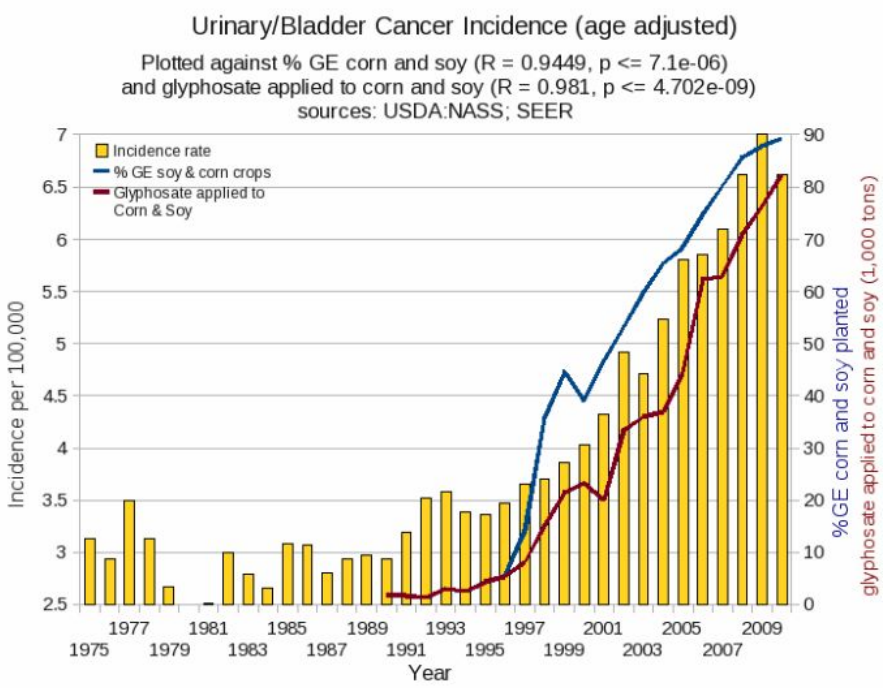
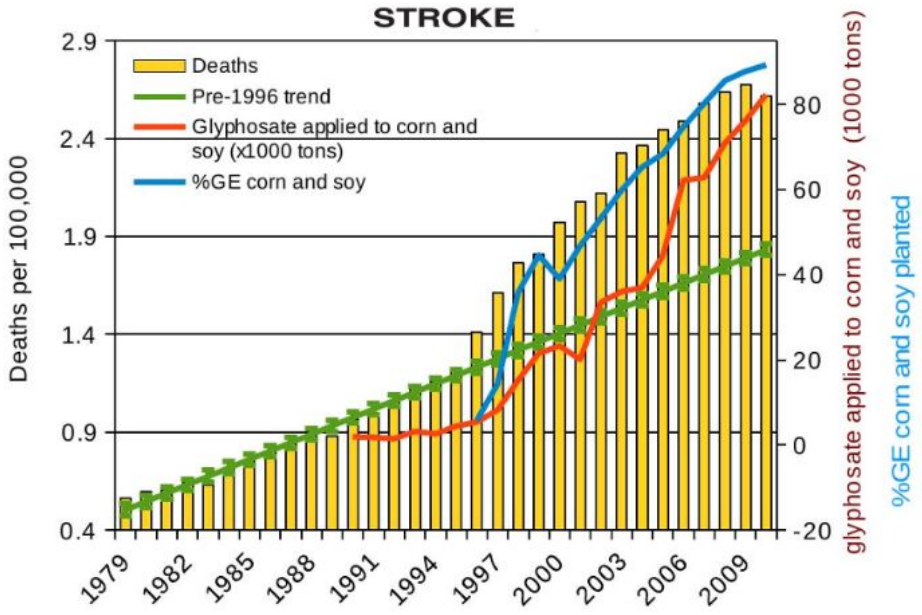
2008
2009
2010
Year


Urinary/Bladder Cancer Incidence (age adjusted)
Plotted against % GE corn and soy (R = 0.9449, p <= 7.1e-06)
and glyphosate applied to corn and soy (R = 0.981, p <= 4.702e-09)
sources: USDA:NASS; SEER
Incidence rate
% GE soy & corn crops
Glyphosate applied to Corn & Soy
Incidence per 100,000
%GE corn and soy planted
glyphosate applied to corn and soy (1,000 tons)
Year


STROKE
Deaths
Pre-1996 trend
Glyphosate applied to corn and soy (x1000 tons)
%GE corn and soy
Deaths per 100,000
glyphosate applied to corn and soy (1000 tons)
%GE corn and soy planted

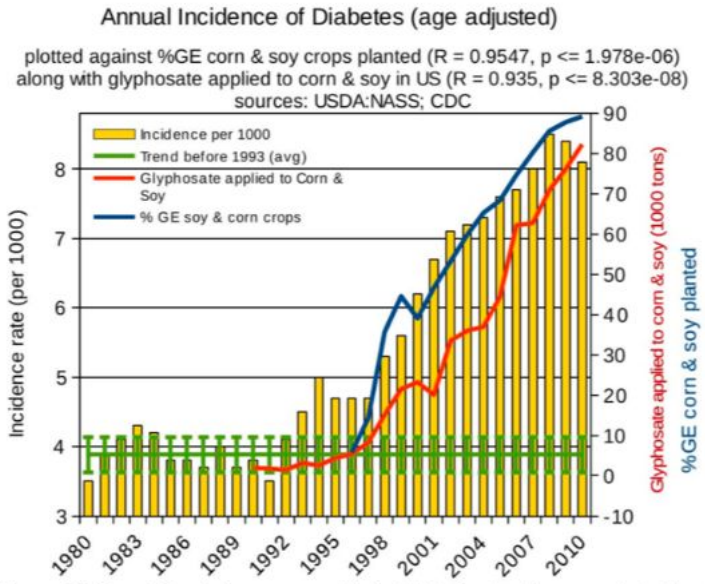
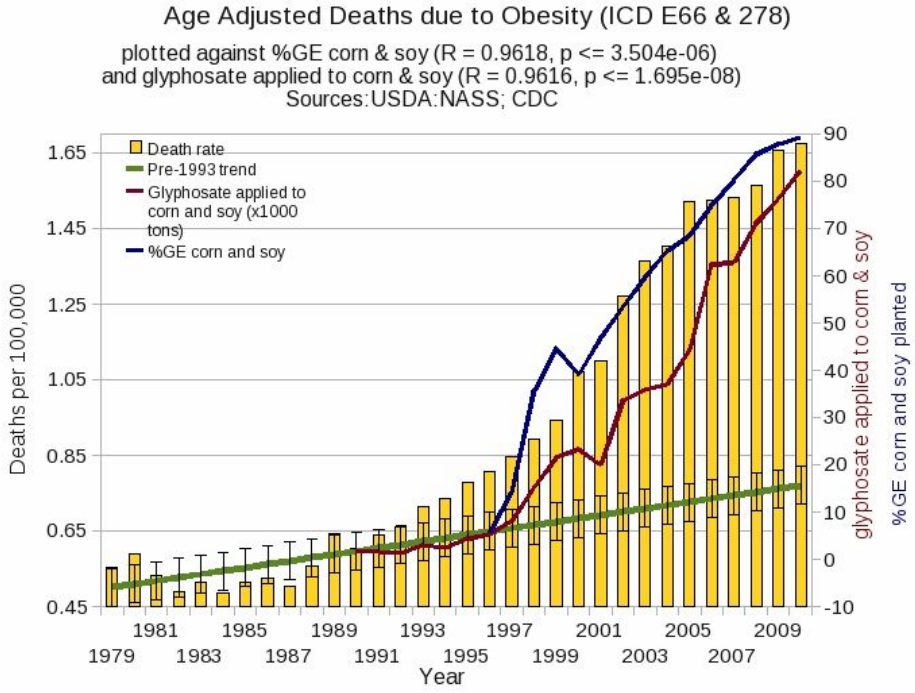
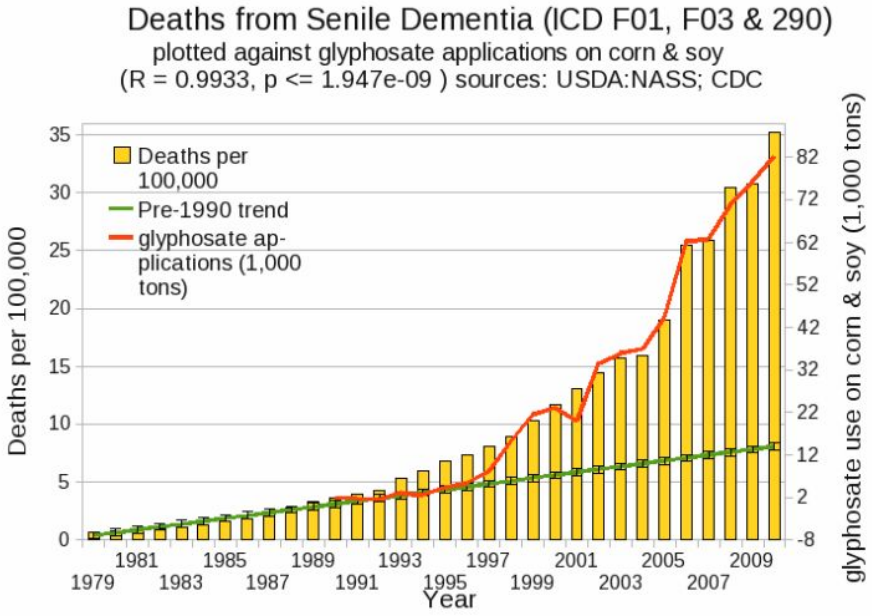


Figure 14. Correlation between age-adjusted diabetes incidence and glyphosate applications and percentage of US corn and soy crops that are GE.





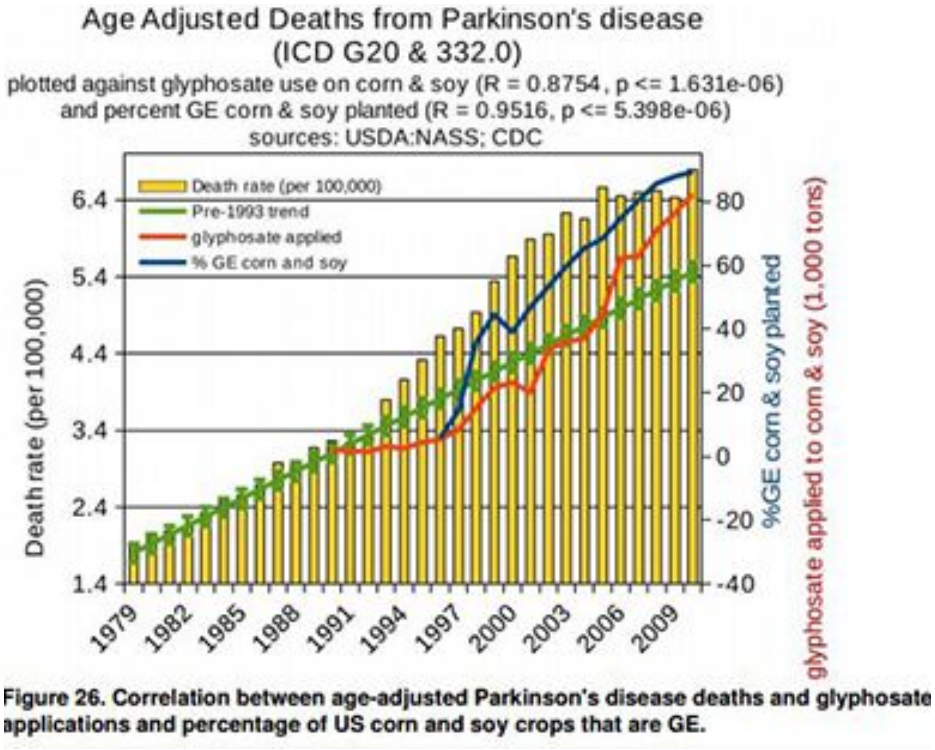


Figure 26. Correlation between age-adjusted Parkinson's disease deaths and glyphosate applications and percentage of US corn and soy crops that are GE.

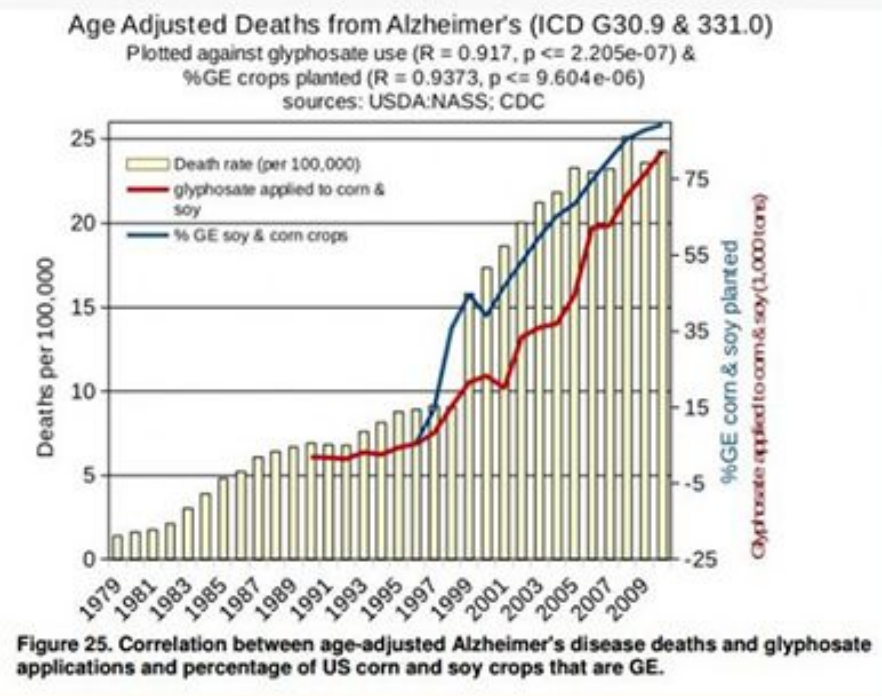
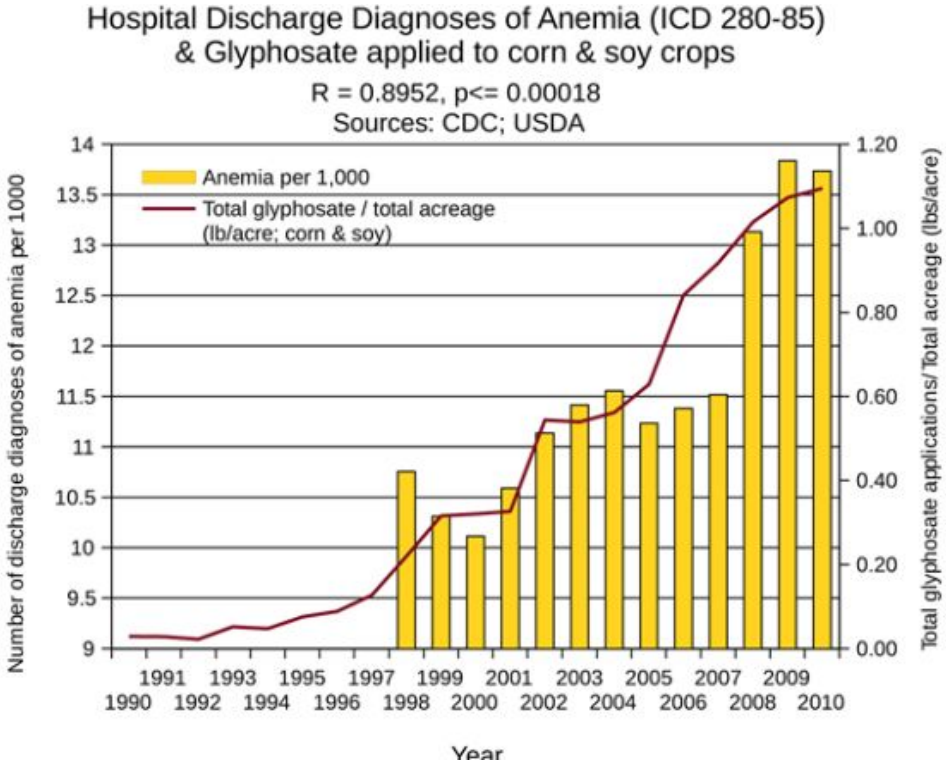


Figure 25. Correlation between age-adjusted Alzheimer's disease deaths and glyphosate applications and percentage of US corn and soy crops that are GE.



Alternate Opinion

The graphs below illustrate that there are negative human effects from glyphosate. However, there is controversy over this topic. Glyphosate is associated with its ability to block the shikimic acid pathway. This is involved in the synthesis of aromatic amino acids in plants, fungi, and some microorganisms. This blocks the metabolic pathway which eventually causes the death of the target organism within a few days. Animals do not have a shikimate pathway which led to the conclusion that glyphosate-based herbicides do not pose a health risk to animals and humans. Many investigations on glyphosate toxicity in animals have suggested the low toxicity of this compound. The adverse effects have only been found after exposure to relatively high doses. It is said that there are important discrepancies between the findings in this topic but it is unequivocal that exposure to glyphosate, alone or in commercial formulations, can produce important alterations in the structure and function of the nervous system. It can affect the nervous systems of humans, rodents, fish, and invertebrate animals.[59]

Ways In Which Humans Can Help Reduce Negative Effects of Genetic Modification on the Environment

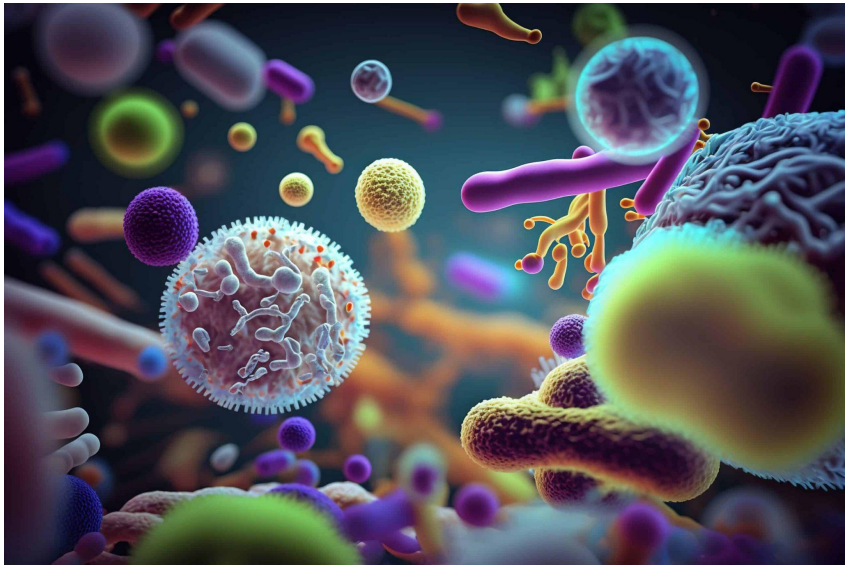
- Buying Organic
- Looking for “non-GMO” labels
- Avoiding at-risk ingredients

At risk ingredients (the “Big Five”):

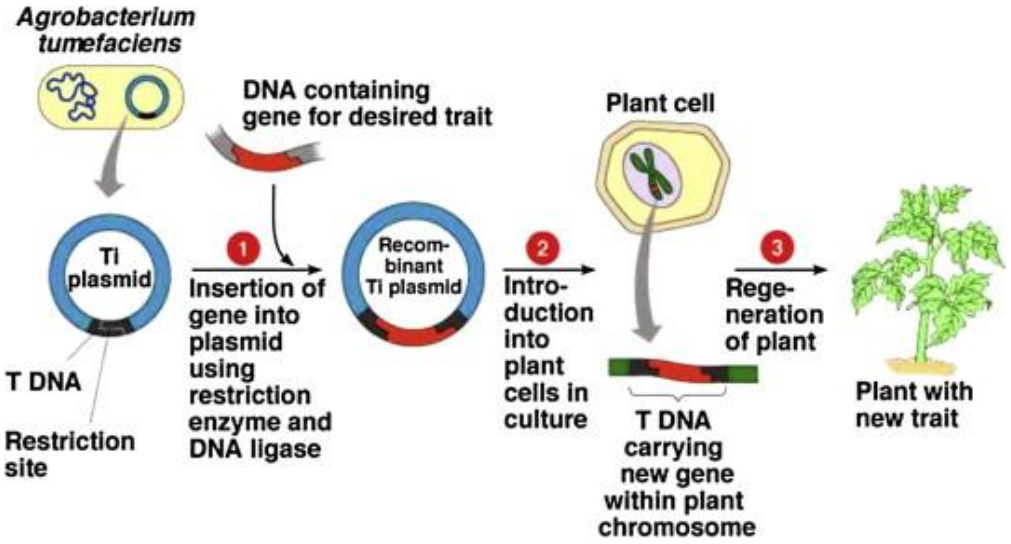
1. Corn: corn flour, meal, oil, starch, gluten, and syrup. Sweeteners such as fructose, dextrose, and glucose; Modified corn starch*
2. Beet Sugar: Sugar not specified as 100% cane sugar is likely from GE sugar beets
3. Soy: Soy flour, lecithin, protein, isolate, and isoflavone, Vegetable oil* and vegetable protein*
4. Canola: Canola oil (also called rapeseed oil)
5. Cotton: Cottonseed oil

Non-GMO Corn

GMO Corn



Transgenesis



References Available Upon Request

Conclusion

Genetic modification is the alteration of an organism's (living thing) genotype using recombinant DNA technology to modify an organism's DNA and to achieve its desirable traits. There are two types of genetic modification/genetic engineering in plants: cisgenesis and transgenesis.There are many merits and demerits of genetic modification in plants. One merit is that disease and drought-resistant plants require fewer environmental resources (ie. water, fertilizer, etc.) and one demerit is an increase in herbicide use. There are also pros and cons of genetic modification in animals. For example, they are better able to resist disease but they have a higher susceptibility to stress. In microorganisms, a positive effect is that there are medicinal benefits to the growing population. However, there is a possibility of creating new or worse viruses. Genetic modification in humans also has benefits and drawbacks. For example, in the future genetic modification may be able to prevent, treat, or cure inherited disorders like beta thalassemia. A drawback is that there is a risk of an unwanted immune system reaction. There are numerous long-term effects of genetic modification like cancerous tumor growth, climate change mitigation, schizophrenia, insomnia, etc. Some ways in which humans can help reduce the negative effects of genetic modification on the environment are by buying organic, looking for "non-GMO" labels and avoiding at-risk ingredients.

Citations

[1] “Genetic Modification.” *WUR*, www.wur.nl/en/dossiers/file/genetic-modification-1.htm. Accessed 2 Jan. 2024.

[2] Schouten, Henk J, et al. “CISGENIC Plants Are Similar to Traditionally Bred Plants: International Regulations for Genetically Modified Organisms Should Be Altered to Exempt Cisgenesis.” *EMBO Reports*, U.S. National Library of Medicine, Aug. 2006, www.ncbi.nlm.nih.gov/pmc/articles/PMC1525145/#:~:text=Cisgenesis%20is%20a%20particularly%20efficient,make%2Dup%20of%20the%20plant. Accessed 3 Jan. 2024.

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