Glyphosate in Collagen

FEBRUARY 1, 2017 BY STEPHANIE SENEFF, PHD
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Print post

Glyphosate in Collagen: Widespread Consequences

Last year, I received a phone call from Anthony Samsel who wanted to share with me an important new insight on a potentially new toxic mechanism of glyphosate. Anthony and I had already collaborated on four long papers on glyphosate, each one adding new dimensions to the knowledge of toxic mechanisms of this diabolical molecule. But what Anthony was about to share with me about glyphosate was a game-changer, if it turned out to be true. It could easily explain the alarming correlations we were finding between the exponential rise in the use of glyphosate as an herbicide on core crops and the corresponding rise in the incidence of a long list of debilitating diseases and conditions. Nancy Swanson was the first to recognize these strong correlations, which she compiled together with colleagues into an open access paper published in 2014.[1]

Glyphosate is the active ingredient in the pervasive herbicide Roundup®. You are probably familiar with Roundup as a convenient way to control dandelions in your yard and weeds growing in the cracks of your walkways. Monsanto, Roundup's manufacturer, convinced the U.S. regulatory agencies over four decades ago that glyphosate, despite the fact that it kills all plants except those core crops that have been genetically engineered to resist it, is practically nontoxic to humans.

Because of its perceived nontoxicity, the government has put very little effort into testing residue levels in the foods that we put on our table. The crops that are engineered to resist glyphosate are highly contaminated, because they take up the glyphosate and incorporate it into their own tissues. These include corn, soy, canola, alfalfa and sugar beets. As well, many grains, legumes and other crops are sprayed with glyphosate right before harvest as a desiccant or ripener. These include sugar cane, wheat, barley and oats, among others.

So, what was it that Anthony shared with me when he called me that day? He suggested that glyphosate might be getting into proteins by mistake in place of glycine. To understand the significance of this statement, you need to know a little bit about proteins and protein synthesis.

Proteins are one of the three major macronutrient classes in foods, the other two being carbohydrates and fats. Proteins are also the “work horses” of the body. All of the enzymes, receptors, ion channels and transporters are proteins. Hemoglobin, insulin, serum albumin and immunogobulins (antibodies) are all proteins.

EVIDENCE OF GLYCINE SUBSTITUTION BY GLYPHOSATE

Glyphosate is a complete glycine molecule except that a hydrogen that normally attaches to the nitrogen atom has been displaced by a methyl phosphonyl group. Glyphosate’s ability to disrupt pathways where glycine is normally involved is believed to be part of its toxicity profile, acting as a glycine analogue.[2] The thought had crossed my mind that glyphosate might substitute for glycine during protein synthesis, but I had rejected the idea because I mistakenly believed that the presence of a side chain on the nitrogen atom would prevent glyphosate from joining hands in the paper-doll-like chain.

However, after Anthony insisted that it could happen, I looked into the matter more deeply, and that was when I realized that the coding amino acid proline also has a carbon substitution for the hydrogen atom normally attached to the nitrogen atom, but has no trouble linking up with the other amino acids. That’s when I got really interested in the idea and started to get serious about exploring the consequences.

What I quickly found out is that protein synthesis is a sloppy process. Lots of mistakes are made, and the approach a cell takes is to take a chance on the mistakes being relatively benign, and then only disassemble and reassemble those proteins that turn out to be flawed in a major way. Probably it is easier to detect protein functional failure or major misfolding than it is to detect and then undo every single mistake during the assembly process, and so this sloppy approach to manufacturing has survived the test of time.

A study on glyphosate's effects on protein expression in microbes living in the rhizosphere (the soil surrounding the roots of plants) showed that both proteins involved in protein assembly and those involved in protein disassembly were significantly over-expressed in the presence of glyphosate.[3] This strongly suggests that glyphosate was causing a lot more errors during protein synthesis than normal.

Monsanto claims that the main toxic effect of glyphosate on plants is disruption of an important biological pathway called the shikimate pathway. Specifically, glyphosate suppresses activity of an enzyme called 5-enolpyruvylshikimic-3-phosphate synthase (EPSPS). Remarkably, three different microbial species have developed resistance to glyphosate by swapping out a glycine residue at the site where the substrate phosphoenol pyruvate (PEP) is secured in place.[4,5] All three microbes have replaced this glycine residue with alanine (adding one extra methyl group). This results in a reduction in the efficiency of the protein, but, most remarkably, completely protects it from any suppression by glyphosate. One of these mutated microbial proteins is the basis of the genetic engineering that is done to afford resistance to glyphosate to all of the GMO Roundup Ready plants.[6]

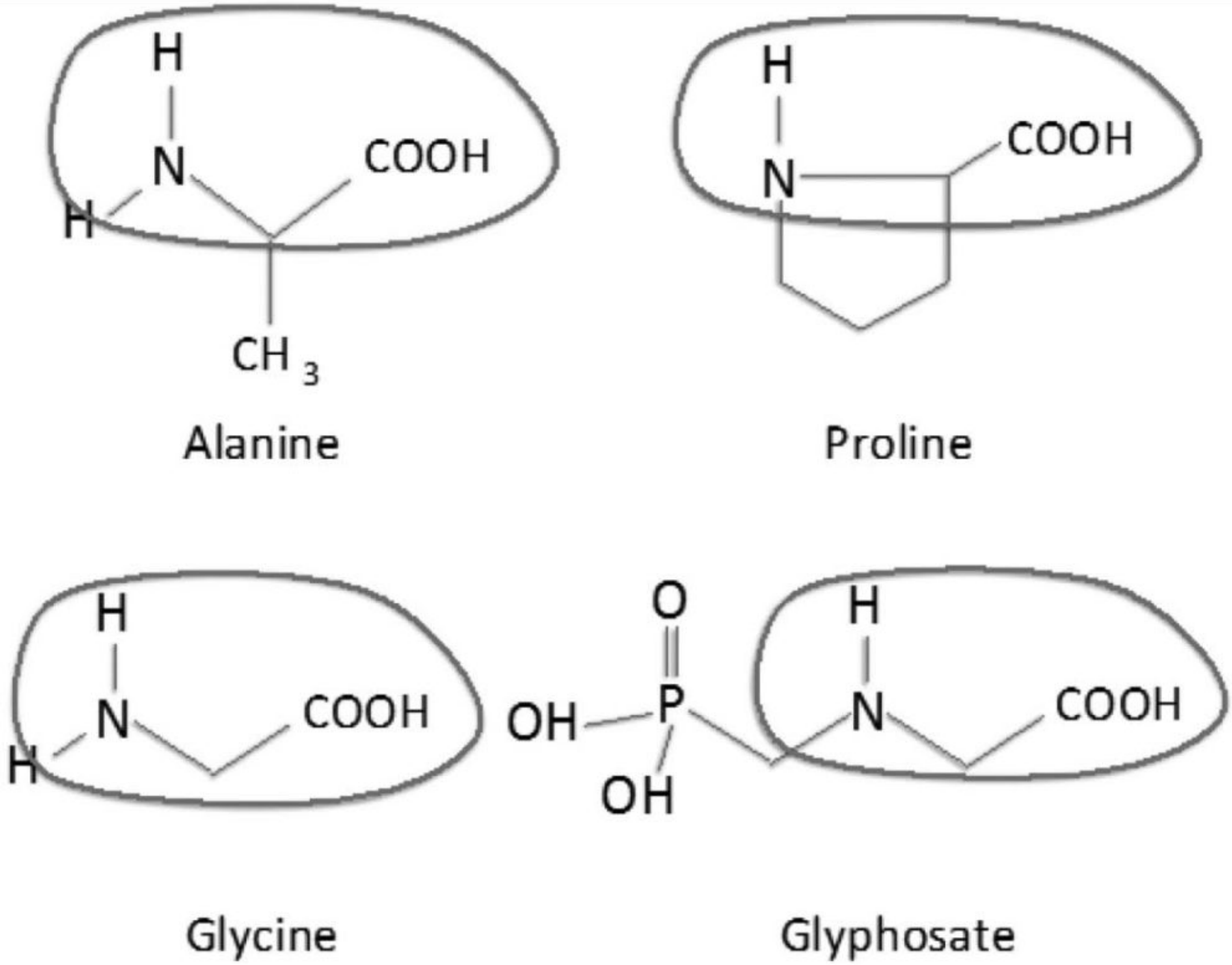

FIGURE 1: Four examples of amino acids. Glycine, the simplest amino acid, has no side chains. Alanine is the second simplest amino acid, which has a simple side chain consisting of a methyl group (CH3). Glyphosate is a glycine molecule with the side chain on the nitrogen atom instead of the traditional form with a side chain on the carbon atom. Proline is a unique amino acid with the side chain circling around so that it becomes attached to both the central carbon and the nitrogen molecule. The circles indicate the core structure of the molecule, which defines its membership in the "amino acid" class of molecules. Note that both glyphosate and proline have lost one hydrogen bound to the nitrogen atom, but this does not prevent them from linking up in the amino acid chain that makes up a peptide in a protein.

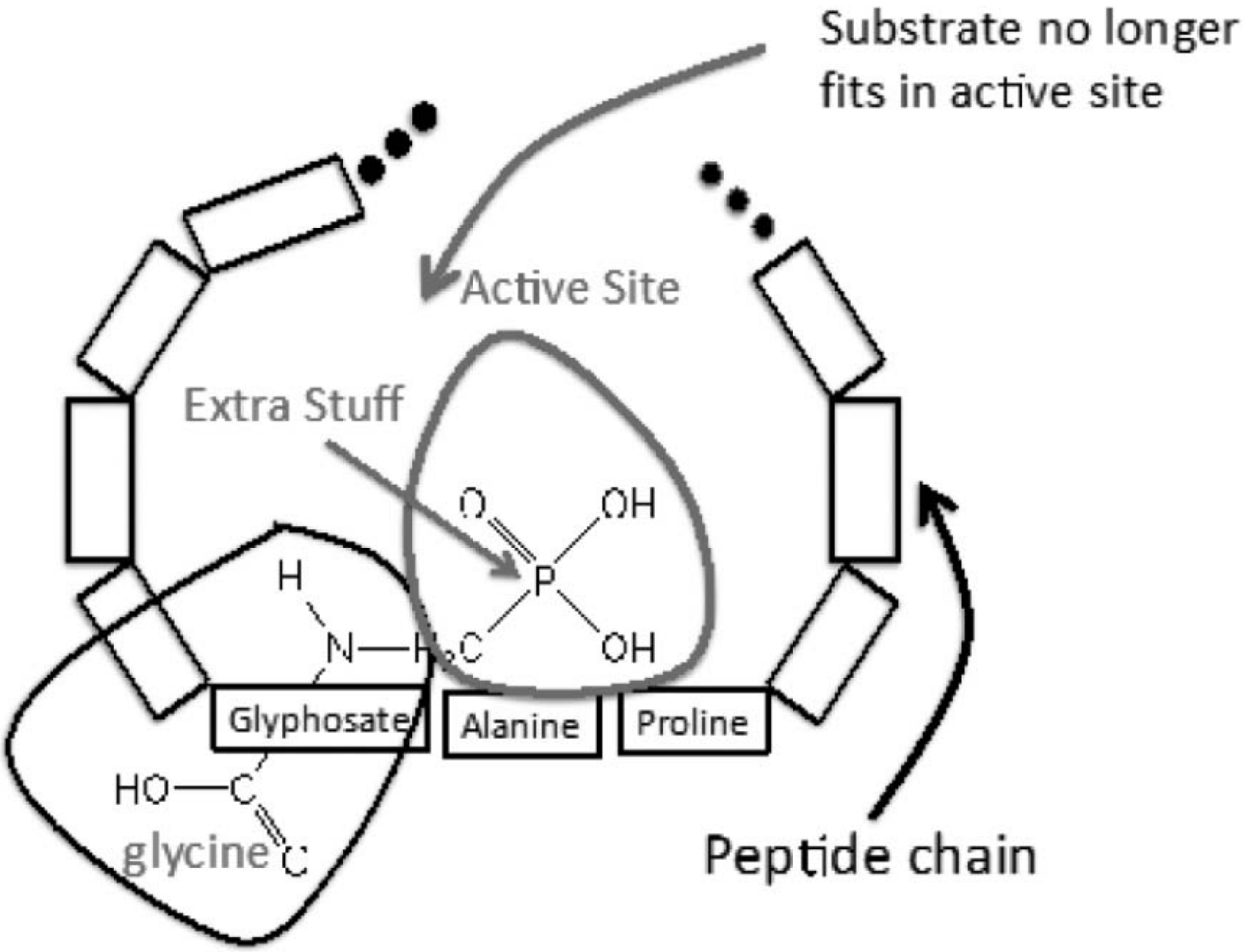

FIGURE 2: Schematic of how glyphosate substitution for glycine in a protein can totally disturb the shape of the pocket where the substrate for the enzymatic action would normally fit snugly.

Figure 1 shows the molecular structure of four amino acids—glycine, glyphosate, proline and alanine. It can be seen from the figure that both proline and glyphosate have something displacing the hydrogen atom that normally binds to the core nitrogen atom. Nonetheless, this does not prevent them from hooking up in the amino acid chain constituting a protein. Figure 2 schematizes how glyphosate substitution for glycine at the active site can cause extra material to bulge out into the pocket where the substrate normally fits snugly. This extra material interferes with the substrate and prevents it from entering the site, thus totally disrupting the enzyme's function.

Glyphosate is not the only non-coding amino acid that causes trouble by substituting for coding amino acids during protein synthesis. There are at least nine examples of non-coding amino acids that are naturally produced by certain organisms, mostly microbes, and are thought to be utilized as a defense mechanism against pathogens.[7] These unusual amino acids are analogues of the coding amino acids, including glutamic acid, leucine, L-arginine, serine, and proline. Note that glyphosate, however, is never synthesized by any life form—it is only a creation of the chemistry lab.

Some of the diseases linked to these other toxins include amyotrophic lateral sclerosis (ALS), Parkinson's disease, multiple sclerosis, and metabolic failure leading to death by starvation.[8] The book Into The Wild describes the experiences of Chris McCandless who tried to live off of nature in the wilds of Alaska, and met his death due to chronic poisoning by an analogue of L-arginine, which he ingested by eating seeds from a plant commonly called wild potato, known to botanists as Hedysarum alpinum. Jon Krakauer, the author of the book, later collaborated with scientific experts to write a paper about this.[9]

CONSEQUENCES OF GLYPHOSATE SUBSTITUTION TO HEALTH

Not every protein that gets a glyphosate substituted for glycine in its peptide chain is totally wrecked by this error. Probably in many cases it hardly matters that there's extra stuff stuck onto the nitrogen in the glycine residue. However, it turns out that there are hundreds if not thousands of proteins that strongly depend on glycine at certain spots in their chain in order to perform their job adequately. These are typically highly conserved, meaning that a glycine residue is always present in that spot in multiple variants of a particular protein that is expressed by many different species, even across different phyla in some cases. Researchers use alignment techniques to discover which residues are highly conserved across species in order to find residues that probably play an important role in the protein's function.

A good example is myosin—a molecular motor in muscle cells that is responsible for muscle contraction and therefore movement. Myosin's protein code specifies glycine at position 699 in the chain. If this glycine residue is replaced by alanine, myosin drops to only 1 percent of its original strength. In fact, if only one out of every fifty myosin molecules in a muscle fiber has glycine swapped out for alanine, the muscle loses half its strength, even though alanine has just one extra methyl group compared to glycine.

Substituting glyphosate for glycine 699 would be an even bigger deal. I strongly suspect that substitution of glyphosate for glycine in myosin and other molecular motors is a causative factor in chronic fatigue syndrome and ALS. In fact, we proposed this in a recent paper.8 In an earlier paper, the result of my phone conversation with Anthony Samsel, we showed systematically how various specific proteins would be adversely affected by glyphosate substitution, and how these could account for the steep rise that we are currently seeing in a number of diseases and conditions such as diabetes, obesity, autism, celiac disease, Alzheimer's disease and cancer.[10]

Two things to consider when thinking of proteins that might be most affected by this substitution error are the expression rate of the protein and the percentage of the protein that constitutes glycine residues. When you take these factors into consideration, one molecule stands out: collagen. Collagen is the most abundant protein in the body—one in every four protein molecules in our body is collagen. Collagen is what gives our joints, bones and skin strength and elasticity.

Collagen is loaded with glycine. Twenty to 25 percent of the residues in collagen are glycines. Collagen forms a triple helix (see Figure 3) in long segments of the molecule through a repeat pattern of GXX, where G stands for glycine and X is usually either proline or hydroxyproline. If you start randomly inserting glyphosate in place of glycines in this triple helix, you will disturb the crystalline structure and wreck the collagen properties of elasticity, strength and the ability to retain water. This will almost certainly result in joint pain, a major contributor to the opioid epidemic we're currently witnessing in the U.S.[11] Rheumatoid arthritis, osteoporosis and various skin disorders can all be anticipated.

Once you think of glyphosate insinuating itself into collagen, it's an easy step to imagine that glyphosate would be a major contaminant in gelatin, a very common food additive and the main constituent of gelatin-based deserts. Gelatin is routinely added to marshmallows, pudding, gummy bears, yogurts, margarine, frosting, cream cheese, sour cream, non-dairy creamers and fat-reduced foods. Gelatin is typically derived from the bones joints and skin of pigs and cows. These animals are fed high doses of glyphosate in their GMO Roundup Ready corn and soy feed. The glyphosate that makes its way into their joints ends up in your gelatin dessert.

Gelatin is also the main constituent of gel caps, which have become a standard way of packaging both pharmaceutical drugs and nutritional supplements such as fish oil. I would predict that any nutritional supplement housed in a gel capsule is going to cause you much more harm than good, because whatever benefit the contents provides is more than offset by the damaging effects of the glyphosate. This also means, of course, that bone broth, a highly nutritious food, must be made from grass-fed beef rather than from the large confined animal feeding operations (CAFOs). One solution is to be sure that your supplements use vegan gel caps, which are made from cellulose, a plant-derived polysaccharide that would probably be much less at risk of glyphosate contamination.

GLYPHOSATE, MMR AND AUTISM

The most serious consequence of glyphosate in collagen is likely to be glyphosate contamination in vaccines. Gelatin is an additive in many vaccines, and the measles, mumps and rubella (MMR) vaccine contains an especially high level of gelatin compared to other vaccines. Both Anthony Samsel and Zen Honeycutt of Moms Across America have tested various vaccines for glyphosate. Many of them tested positive, but MMR stood out as having more glyphosate by an order of magnitude than any of the others. The live measles virus is grown on gelatin, and this provides the virus with the opportunity to incorporate glyphosate into its own proteins.

In particular, the measles virus produces a protein called haemagglutinin, and this is the protein that the human immune system is supposed to react to, producing specific antibodies, in order for the vaccine to "take." Professor Singh of Utah State University has been studying autism since the early 1990s, and, in a series of papers, his team has shown that autistic children tend to produce an extremely high antibody response to measles haemagglutinin. Nearly all of those autistic children who have a high antibody response also have autoantibodies to myelin basic protein, an important protein in the myelin sheath surrounding nerve fibers in the brain.[12] The autoantibodies are a result of a phenomenon called “molecular mimicry,” whereby a foreign protein happens to have a peptide sequence that closely resembles a peptide sequence in a native protein. The immune cells get confused and mistake the native protein as foreign due to its resemblance to the foreign protein (in this case, haemagglutinin). The result is an autoimmune attack on the nerve fibers in the brain.

The FDA maintains a database called the Vaccine Adverse Event Reporting System (VAERS), and this database contains hundreds of thousands of reports of adverse reactions to vaccines since 1990. In a study that was conducted before I even knew the word glyphosate, my colleagues and I had reported the surprising result that events where MMR was one of the vaccines were highly over-represented with mentions of “autism” (p = 0.007).[13] At the time, we struggled to explain this observation, since MMR contains neither mercury nor aluminum, two toxic metals that have been implicated in autism, and we hypothesized that it might be due to acetaminophen prescribed to curb the fever from the vaccine.

Once I realized that MMR might be contaminated with glyphosate, it made sense that the MMR vaccine administered today might be much more toxic than the vaccine was in the early years when glyphosate usage on core crops was more modest. To test this hypothesis, I divided up the VAERS database into two subsets spanning equal time spans—events before 2003 and events after 2002, that is, early versus late. As expected, we found that there were significantly more instances of severe adverse reactions after 2002, including anaphylactic shock, hospitalization, seizures and autism, as shown in Table 1.

Table 1: Statistical analysis of frequency of various adverse reactions to MMR before and after January 2003. The p-values are computed according to a chi-square goodness of fit test.

MORE COMMON BEFORE 2003			
Reaction	Count <2003	Count $\geq$ 2003	p-value
arthritis	52	18	0.045
joint pain	175	75	0.012

MORE COMMON AFTER 2002			
Reaction	Count <2003	Count $\geq$ 2003	p-value
hospitalization	132	423	0.00041
seizures	314	534	0.0055
dyspnea	139	279	0.0086
hives	444	654	0.011
anaphylactic shock	28	91	0.017
eczema	10	47	0.028
autism	105	184	0.031
hyperventilation	18	57	0.035
general infection	77	136	0.044
asthma	22	58	0.046
immunoglobulin G	0	17	0.048
ear infection	32	72	0.048
heart rate irregular	11	39	0.049

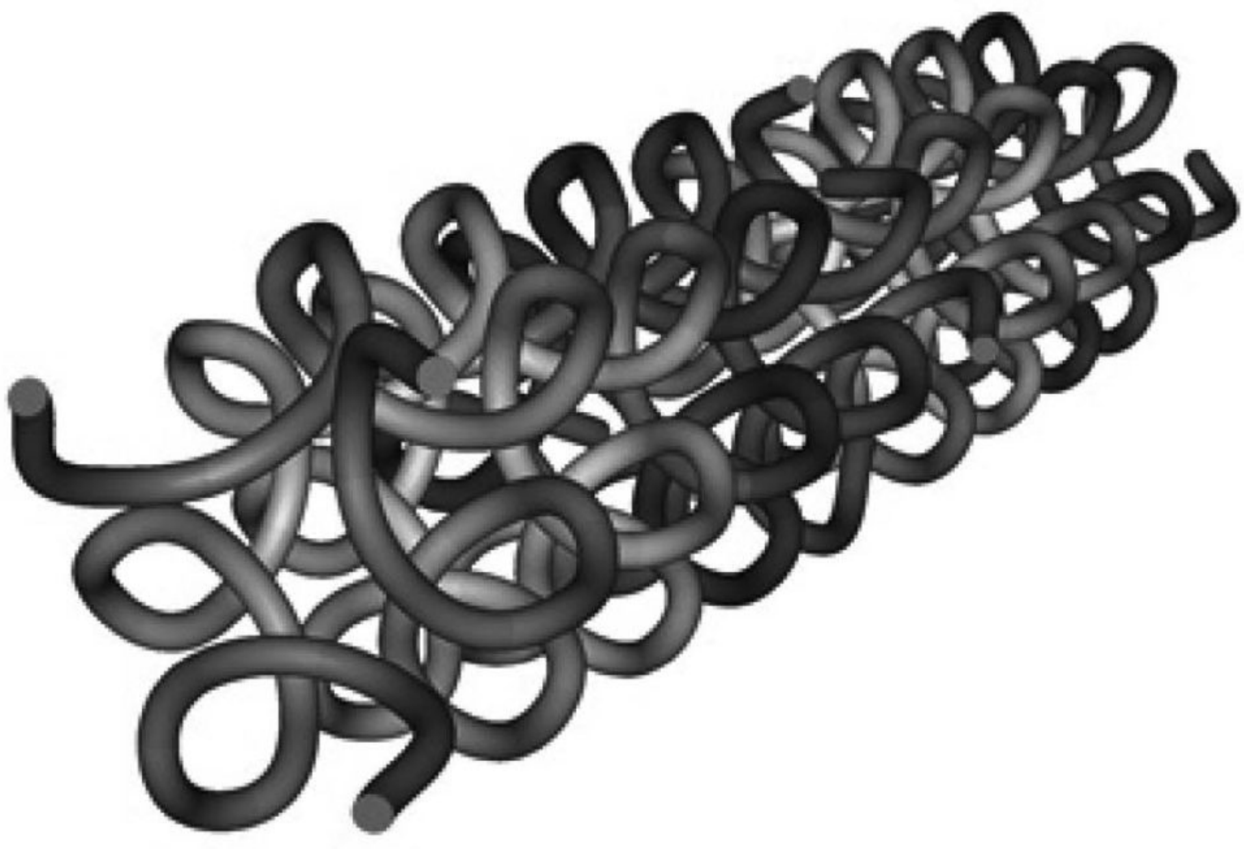

FIGURE 3: Collagen triple helix structure

SUMMARY
Glyphosate is the active ingredient in the herbicide Roundup, which is pervasive in our food supply. My recent research, inspired by Anthony Samsel's conjecture, leads me to strongly suspect that glyphosate is getting into proteins by mistake in place of glycine. This has huge consequences to our health, because the human proteins contaminated with glyphosate don't work properly in their function in the body, and the glyphosate-contaminated food proteins tend to resist proteolysis, sticking around and causing autoimmune disease through molecular mimicry. This feature easily explains the epidemic we're seeing in allergies to foods that are likely to contain high amounts of glyphosate contamination, such as gluten, casein and soy.

One molecule we can predict to be severely affected by glyphosate substitution for glycine is collagen, the most abundant protein in the body. Collagen is essential for cushioning the joints, and, when it is defective due to glyphosate contamination, it performs poorly in its job, leading to joint pain and tendonitis, among other things. This can explain why so many people today suffer from chronic pain conditions such as shoulder pain and back pain, and why we have an epidemic in opioid drug abuse. Foods that contain high amounts of gelatin can be expected to be highly contaminated with glyphosate, and this includes bone broth, which would ordinarily be very nutritious. One also has to consider the implications of glyphosate contamination in gel capsules.

Probably the most ominous consequence of glyphosate contamination in collagen is the implications it has for vaccines. Vaccines are injected directly into the body past all the normal barriers, and this makes any toxic ingredient in the vaccine very problematic. MMR vaccine in particular was found to have much higher levels of glyphosate than other vaccines, and this may well explain the association between MMR and autism that shows up in the VAERS database. This can also explain why adverse reactions to MMR are much more severe today than they were in the 1990s when much less glyphosate was used on core crops.

You can help reduce glyphosate exposure for your family by switching to a 100 percent certified organic diet. More generally, there is an urgent need for government action to ban glyphosate in order to protect our population from harm.

SIDEBAR

PROTEINS AND THE DNA CODE

Proteins are the set of molecules that are specified through the DNA code, and they are made up of sequences of so-called coding amino acids, the building blocks of proteins. There are four DNA nucleotides that are arranged as beads on a string and that can be represented symbolically by the four letters, A, G, C and T. Each sequence of three of these letters codes for a specific amino acid.

There are sixty-four possible unique codes, but only around twenty coding amino acids, so the code is redundant. The amino acids also assemble like beads on a string, or more like paper dolls holding hands through chemical bonds between a nitrogen atom in one amino acid and a carbon atom in the next one in the chain. Any sequence that contains two guanines (GG) followed by any one of the four nucleotides (thus, GGA, GGG, GGC, and GGT), codes for glycine, the smallest amino acid, uniquely free of any side chains.

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This article appeared in *Wise Traditions in Food, Farming and the Healing Arts*, the quarterly magazine of the Weston A. Price Foundation, Winter 2016 (http://www.westonaprice.org/journal/journal-winter-2016-mens-health/).

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About Stephanie Seneff, PhD

Stephanie Seneff, PhD received her Bachelor’s degree in Biology with a minor in Food and Nutrition in 1968 from MIT. She received her Master's and PhD degrees in Electrical Engineering and Computer Science in 1979 and 1985, respectively, also from MIT. Since then, she has been a researcher at MIT, where she is currently a Senior Research Scientist in the Department of Electrical Engineering and Computer Science, and a Principal Investigator in the MIT Computer Science and Artificial Intelligence Laboratory. Throughout her career, Dr. Seneff has conducted research in diverse areas including human auditory modeling, spoken dialogue systems, natural language processing, human language acquisition, information retrieval and summarization, computational biology, and marine mammal socialization. She has published over one hundred fifty refereed articles on these subjects, and has been invited to give keynote speeches at several international conferences. She has also supervised numerous Master's and PhD theses at MIT. She has recently become interested in the effect of drugs and diet on health and nutrition, and she has written several essays on the web articulating her view on these topics. She is the first author of two recently published nutrition-related journal papers, one on the metabolic syndrome and one on Alzheimer's disease. Two papers on theories related to cholesterol sulfate are currently under review. Stephanie will give an all-day workshop on metabolism at Wise Traditions 2011.