Chapter 4

We All Soak in a Synthetic Chemical Soup

I begin with a horror story that could happen to any one of us at any time, hopefully with low probability – but it is likely that no one knows what those chances are.[1]

4.1 Thomas Latimer's Unfortunate Experience.

On July 20, 1985 Thomas Latimer, a petroleum engineer living in Dallas, went out to mow his lawn. Twice the previous month, Latimer had sprayed his lawn with a pesticide made by Chevron-Ortho that contained diazinon. (Diazinon was banned for residential use on December 31, 2004, but it is still allowed for agricultural uses. It is, however, legal for consumers to use products containing diazinon purchased before 12/31/04. It was found in hundreds of products, including such brand names as Spectracide, Bug-B-Gon and GardenTox.) Halfway through that July day, Latimer got tired, his head began to hurt, and he felt dizzy and nauseated. He rested for the remainder of the day. The next morning he tried to finish the job, but the symptoms returned. This time, he experienced impaired vision.

His symptoms persisted for a week, he went to the doctor and had several tests. The doctor suggested that Latimer stop taking Tagamet, an antacid he had been prescribed. Latimer's test came back: he had been poisoned. A specialist later identified the toxin: diazinon (which Latimer picked up via the air and his skin while mowing and handling grass clippings.) The Tagament was interfering with his liver function, which should have filtered the poison from his blood.

In testimony before the Senate Environment and Public Works Subcommittee on Toxic Substances, Environmental Oversight, Research, and Development, May 1991, Latimer said that when he first became ill he called Chevron-Ortho's emergency toll-free number and asked if the symptoms he was experiencing could be related in any way to the pesticide he sprayed on his lawn. "I told the representative on the phone that I was taking the medication Tagament and asked, 'Could this have resulted in an interaction poisoning?"'

"The Chevron-Ortho representative said it was not possible to have a problem with diazinon if I was on Tagament. The representative claimed to me that diazinon was so safe that I could drink an entire bottle and the only problem I would have is that I would be nauseated for a few days."

[1]For a more complete account of this story see, for example, the newsletter of the Center for Public Integrity, Vol. 4, No. 3, August 1998, Web site www.publicintegrity.org.

Latimer's professional training gave him enough knowledge to handle his lawn chemicals carefully. Latimer suffered permanent damage: "I live every waking moment in constant, unrelenting head pain," he explained to the Senate committee. "My eyesight damage has been verified by three neuro-ophthalmologists. My ability to read is limited to ten minutes at a time ... I suffer from brain seizures, panic and fear attacks both day and night, and nightmares ...I suffer a degree of physical retardation and motor-skill damage. I cannot run or swim. I have also suffered from viral growths on my vocal cords, which have required laser surgery three times. It is likely I will need vocal-chord surgery every year for the rest of my life...I cannot yell or talk loudly. I must talk softly and on a limited basis. Many days, I have to be virtually silent. The frustration and anger level due to my voice being restricted is very high ..."

Mr. Latimer was hit by a *synergistic* interaction of two readily available *synthetic chemicals*.[2] We will learn in Exercise 17.19 that given the many tens of thousands of such chemicals registered for use in the U.S., it is virtually impossible to pretest for all such interactions. Thus for those who care about such things, caution is advised.

Who Cares? I once took a trip to a country rather infamous for muggings and theft. In fact, one of my guide books was blunt: "Assume you will be robbed." While there I did an informal survey of several of the people I met, asking them if theft/mugging was a problem. About half the people said there was no problem. The other half said I should take great care, mugging was a serious problem – perhaps my life could be in danger.

For me the most interesting part of this informal survey was this: Those who saw a problem had been mugged; those who had not been mugged saw no problem. This type of response is primitive, devoid of mathematical perspective, and it is inadequate for dealing not only with mugging but with more subtle threats to well being posed by, for example, toxics and climate change. The position: "If it kills me I will take note, if it doesn't I won't;" needs to be replaced by a bigger picture containing a more nuanced understanding. To appreciate and understand a looming threat before it is obvious requires abstract thought, and this thought invariably contains some form of mathematics. This abstract understanding has to be deep enough to induce sufficient action to neutralize the threat.

In this section I will be dealing primarily with the flow of known and suspected toxins from our surroundings into our bodies. I will give evidence that such flows actually exist and that some harm has resulted. Whether a given person cares or not, or how deeply that concern goes, seems to depend in part on whether that person thinks he/she has been assaulted by toxins or not –

[2] *Synergy*, a phenomenon wherein the combined effect of two or more entities is more than the aggregation of the effects of each entity taken separately. Said another way: The whole is more than the "sum" of its parts. This can be a very positive experience, as when several people work together to accomplish much more than they ever could have working individually. It can also be a negative experience. We define *synthetic chemicals* to be those which did not exist until created by humans.

and if that person believes he/she or a loved one has suffered illness or worse because of the exposure. I am hoping that with a mathematical assist, the number of people who are concerned increases beyond those who are clearly and immediately impacted.

In this and subsequent chapters I will be thinking of humans as biological beings, i.e., boxes, with various flows involving toxins, food, water, energy and so on. As we will see, to understand these flows at even the most elementary level requires a little mathematics. The total amount of synthetic substances in your body is called your *body burden*, especially chemicals known to be toxic and uninvited.

4.2 What's in the Synthetic Chemical Soup?

Are We All Polluted? In 1996 Theo Colburn, et al., [103, page 106], wrote: "Virtually anyone willing to put up the $2,000 for the tests will find at least 250 chemical contaminants in his or her body fat, regardless of whether he or she lives in Gary, Indiana, or on a remote island in the South Pacific. You cannot escape them."

Unfortunately Colburn is being repeatedly proven correct; we are soaking in a synthetic soup. From the Web site for the nonprofit Environmental Working Group (EWG), http://www.ewg.org/reports/bodyburden/, we once read:

"In a study led by Mount Sinai School of Medicine in New York, in collaboration with the Environmental Working Group and Commonweal, researchers at two major laboratories found an average of 91 industrial compounds, pollutants, and other chemicals in the blood and urine of nine volunteers, with a total of 167 chemicals found in the group. Like most of us, the people tested do not work with chemicals on the job and do not live near an industrial facility. Scientists refer to this contamination as a person's *body burden*. Of the 167 chemicals found, 76 cause cancer in humans or animals, 94 are toxic to the brain and nervous system, and 79 cause birth defects or abnormal development. The dangers of exposure to these chemicals in combination has never been studied."

The EWG/Mt. Sinai/Commonweal study tested the blood and urine of the nine volunteers for 210 chemicals – the largest collection of industrial chemicals ever surveyed at that point in time. Of the 91 compounds found on average, most did not exist 75 years ago. As mentioned, in aggregate, 76 chemicals that cause cancer were found. They found a total of 48 PCBs, which were banned in the U.S. in 1976 (but are used in other countries) and persist in the environment. The list of participants, together with their test results, are at the EWG Web site mentioned above.

The Centers for Disease Control and Prevention (CDC) tested the blood and urine of a statistically representative sample of some 2,500 (noninstitutionalized) volunteers in the U.S. population for the years 1999 and 2000, cf., http://www.cdc.gov/exposurereport/. The CDC looked for 116 chemicals to

which people in the U.S. are exposed via pollution or consumer products. The report (referred to as the 2nd report) found positive results for 89 chemicals, including PCBs (polychlorinatedbiphenyls), dioxins, phthalates, selected organophosphate pesticides, herbicides, pest repellents, disinfectants, and so on. The complete report is available in hardcopy or on the Web site noted above for the CDC. It is over 250 pages long. The CDC plans to issue a new report every two years, expanding the number of chemicals tested for.

The CDC released its 3rd National Report on Chemical Body Burden July 21, 2005. Look it up and compare it with the second report. As soon as the 4th report comes out, repeat, and so on. For those interested in this subject from the point of view of trying to minimize their body burden: http://www.beyondpesticides.org and the Web site of Pesticide Action Network North America, http://www.panna.org are helpful.

The tests done by the EWG and CDC mentioned above, imply that you likely have a large number of synthetic chemicals in your body known to be correlated with cancer and/or endocrine disruption and/or reduced intelligence and/or teratogenic effects and/or other maladies. Let me make this less abstract by pointing out one long-term development.

A survey of the scientific literature done in [103, 93] indicated that over the last half-century (in much of the world, including the U.S. and Europe) human sperm counts have been falling, breast and testicular cancer have been rising and human breast milk is contaminated.[3] At the time these books were published a spin/propaganda campaign denounced as "junk science" the research upon which [103, 93] are based. Little noticed in the major media was (is) the story that the corporation Zeneca manufactures organochlorines (possible causes of breast and other cancers) and leading anticancer drugs, while being a controlling sponsor of Breast Cancer Awareness Month, which emphasizes detection and treatment – which everyone supports – but *not* prevention – which goes unmentioned. As said in [533]: "Cancer prevention would clearly conflict with Zeneca's business plan." [4]

One might think that in a country raised on Ben Franklin's adage: An ounce of prevention is worth a pound of cure; that people would be asking: When are we going to march for the *prevention* of breast cancer (as well as the cure)?

Mark Schapiro points out in [601], among many things, that everyday products in the United States contain toxics that have been banned for some time

[3]From [93, page 54], in October 1993 testimony before the House Committee on Energy and Commerce, we read: "... The breast milk of many American women has higher levels of DDT and its metabolites than allowed in cow's milk by the FDA; cow's milk contaminated at similar levels would be seized as adulterated and banned from interstate commerce." Despite such contamination doctors still recommend breast feeding.

[4]Project censored, in [533], rated the Zeneca conflict of interest story covered in [93] (and subsequently in *Rachel's Environment and Health Weekly* and [307]) as the number two censored story of 1999. See [533, p. 34]. You might want to trace the geneology of AstraZeneca, Novartis, Syngenta, possibly others, such as it might be when you read this.

in the European Union. Among those everyday products are cosmetics. Cosmetic industry critic, Stacy Malkan asks, in [439]: Why do companies market themselves as pink ribbon leaders in the fight against breast cancer, yet use hormone-disrupting and carcinogenic chemicals that may contribute to that very disease? (For those who use cosmetics and personal care products the following Web site of the Environmental Working Group should be of interest: www.cosmeticsdatabase.com.) Why do products marketed to men and women of childbearing age contain chemicals linked to birth defects and infertility?

Finally, I call your attention to [178]; the dark side of the politics of cancer involves some of the groups dedicated to fighting it.[5]

Exercise 4.1 Sperm Counts are Dropping. Breast and Testicular Cancer Rates are Rising One of several relevant references is [603].

(i) A report[6] found that sperm counts have fallen an average of 1.5% per year since the 1930s in the United States. Twice this rate of decline was found in Europe. What would be the total percentage drop from 1930 to 2000 in the U.S.? In Europe?[7]

(ii) Saying that the average rate of decline of sperm counts is 1.5% per year is different from actually listing the rate of decline for each year. Take a five year period, for simplicity. Find a list of five rates of decline not all equal to 1.5% (one for each of five years) whose average is 1.5%. Compute the total decline over five years given your list of annual declines. Compute the total decline over five years if the decline in each of the five years was exactly 1.5%. Are these two totals different? Can they be? The point of this exercise is to find out how the cumulative decline in sperm counts depends on the actual list of yearly declines, as opposed to the average rate of decline.[8]

(iii) From [93, page 12] we read: "From 1940 to 1980, breast cancer rates increased by an average of only 1.2% each year. But more recently, rates have skyrocketed, according to the ACS[9]. Since 1980, the rate of diagnosis in women has increased about 2 percent a year, reaching a level of about 108 per 100,000 (*Cancer Facts and Figures, ACS, 1994*).

[5]On August 26, 2000, an Associated Press article by Charley Gillespie pointed out that former American Cancer Society executive, Daniel Wiant, 35, pleaded guilty to embezzling nearly $8 million from the charity.

[6]On November 24, 1997, newspapers reported on the research findings of Dr. Shanna Swan, chief of the reproductive epidemiology section at the California Department of Health and the principle author of the sperm-count report in *Environmental Health Perspectives*, a monthly health journal of the National Institute of Environmental Health Sciences, a branch of the National Institutes of Health (NIH). The report found that sperm counts have fallen an average of 1.5% per year since the 1930s in the United States. Twice this rate of decline was found in Europe. Results were not conclusive in the rest of the world. Dr. Swan serves on the National Academy of Science's panel looking into hormonally active agents in the environment. She says that falling sperm counts in the last half-century are associated with higher rates of certain types of cancer of the male reproductive system and a growing number of unusual birth defects. Data on the decline in sperm counts can be found in *Vital Signs*, published by the WorldWatch Institute, 1999, pages 148-9.

[7]Hint: If you start with a quantity X in year one and it decreases 1.5% in one year, then in year two you have $X * (1 - .015) = X * .985$. In year three you have $X * .985 * .985$.

[8]What is the biggest possible difference between these two answers? This is a pure math question for extra credit.

[9]American Cancer Society.

From 1980 to 1987 alone, the number of breast cancer cases reported in the U.S. rose by 32 percent."[10]

In [103, page 182] we read: "Fifty years ago, a woman ran a one in twenty risk of getting breast cancer. One in eight women in the United States today will get breast cancer in her lifetime."

Are the two statements from [93, page 12] and [103, page 182] *consistent*?[11]

(iv) Perhaps more subtle than reproductive cancers is the topic of multiple chemical sensitivity (MCS), the existence of which is debated in the medical community. Some authorities say the MCS does not exist, other experts say that MCS sufferers are the "canary in the coal mine." What does the phrase "canary in the coal mine" mean, and do you think MCS really exists as a disability? Relevant references are [18], [566].

(v) Synergy is, mathematically speaking, a *nonlinear* phenomenon. Briefly, in a *linear* situation if you double an input you double the output; or if you halve the input you halve the output. In a nonlinear situation it can happen that a doubling, say, of a small input can have an enormous effect on the output. A list of a few known negative synergies to avoid among drugs and foods is in [251]. Can you find examples of synergy in your life or on the Web?

(vi) Does lipstick sold in the United States contain lead at the time you read this?

Scandal Revealed. I end this section with an update on Erin Brockovich, who fought a battle against chromium-6 water pollution in California similar to the battle of Lois Gibbs at Love Canal, [222, 223].[12] While it is to be expected that there are public relations efforts to carry out disinformation campaigns through the popular media, it is yet another level to tamper with academic and scientific literature. In [714, p. 4] I learned that an influential article downplaying the link between hexavalent chromium water pollution and stomach cancer was exposed as a fraud by the Environmental Working Group, EWG, resulting in the article's public retraction from a prestigious medical journal, *The Journal of Occupational and Environmental Medicine*, in July 2006. This now retracted article was used by the EPA and separately by California public health authorities to weaken pollution standards regarding chromium-6. By the way, do you think this scandal is unique?

4.3 Synthetic Flows and Assumptions

Now that it is established that our bodies are probably polluted, i.e., the box consisting of humans contains stocks of many different toxic, synthetic

[10] Could any of this dramatic increase be attributed to better diagnosis, detection, and/or reporting?

[11] Two statements are consistent if they can both be (simultaneously) true – without contradicting each other. Fuzzy (measured) logic allows a little more wiggle room here than sharp, Aristotelian logic. In this case, however, I am just asking if the two statements are saying roughly the same thing numerically in two different ways.

[12] If you are totally unfamiliar with the story of Erin Brockovich, there is documentary movie, *Erin Brockovich*, about the case available on DVD, (2000).

chemicals, what are the flows? Where did this stuff come from, and how did it get in my body? Who made the decisions that resulted in widespread human contamination? What criteria were (are) used in making these decisions?

Synthetic Flows. Pick any synthetic chemical: people created it; people marketed/advertised it; and people bought it – usually to do just one thing, most likely, thought to be beneficial. Kill some insects with DDT. Kill some dandelions in a lawn with 2,4-D. (Note 2,4-D is short for 2,4-dichlorophenoxyacetic acid.) Kill weeds on farms in much of the U.S. with glyphosate and/or atrazine (plus secret inert ingredients). Kill some fungus with a fungicide. Make a PVC pipe with vinyl chloride, or use vinyl chloride as a propellant in an aerosol can of hair spray (until this use was banned in 1974). Make a plastic water bottle with phthalates. Improve engine performance with tetraethyl lead, cf., Section 4.5. Make a safer more efficient refrigerator with Freon, cf., Section 4.5. Increase agricultural production with a chemical fertilizer like ammonium nitrate, cf., [81]. Cure an illness with .... This list could go on for thousands of pages. I could also introduce slightly involved mathematics (diffusion processes) that help(s) explain how pollutants ended up in isolated South Pacific islanders, Arctic Innuits, as well as you and me. (You will be able to understand some of the details of how this works after we have studied spreadsheets in V. But briefly for now, if something is put into the environment that lasts a long time, it is bound to end up everywhere.)

Recall the Principle of Unintended Consequences, page 48, which says that despite the intention to do just one thing, e.g., kill dandelions, one cannot. Since everything is connected to everything else, doing any one thing has a ripple effect throughout Nature. There are *unintended consequences* of any act.

Thus the introduction of a synthetic chemical into the environment to do one thing, will undoubtedly do other things. It would seem prudent to find out and understand what some of these other things are. For example, if a chemical is invented to kill one form of life, what is its effect on other forms of life – like you and me?!

According to [626], the children of baby boomers have higher rates of birth defects, asthma, cancer, autism and other serious illnesses than previous generations and [626] links these problems to various pollutants. A report in *onearth*, Volume 27, Number 4, Winter 2006, titled: "Hundreds of Man-Made Chemicals – In Our Air, Our Water, and Our Food – Could be Damaging the Most Basic Building Blocks of Human Development," states its thesis clearly in the title, cf., www.onearth.org. For example, humans' greatest advantage, intelligence, may be in the process of being lowered by our synthetic soup. The closest thing to a proof of this fact, with respect to agricultural pesticides, is the remarkable study of anthropologist Elizabeth A. Gillette comparing two groups of preschool children, one exposed the other not. The group exposed to pesticides over time showed lower mental and motor skills and increased agressiveness. See Gillette, Elizabeth A., Meza, Maria Mercedes, Aguilar, Maria

Guadalupe, "An anthropological approach to the evaluation of preschool children exposed to pesticides in Mexico," *Environmental Health Perspectives*, v. 106, no. 6, June 1998, pp. 347-53.

Of course, the theses of the these and other similar studies are not universally shared, the contrary view being that there really is no problem, or any problem of significance. Actually, given the *variability* of living systems, humans in particular, it is quite possible that what is a truly incapacitating problem for one person is (at least in the short-term) ignorable for another. Although some pollution is unavoidable, for those who would like to minimze their exposure the following references might be of interest, [728, 18, 382, 316, 471, 385, 481, 603, 701, 284, 143, 119, 120, 566, 565, 564].

Hidden Assumptions. The next two exercises might challenge some assumptions commonly held.

Exercise 4.2 Less Poison Can Be More Deadly than More, Endocrine Disruptors in the Rain. It is a common assumption, justified by more than one rigorous, scientific observation, that biocides are more deadly the larger the dose. However, it appears that there are cases where this assumption does not hold. (See *Science News*, July 10, 2004, Vol. 166, No. 2, page 20, for a report of experiments done by Sara Storrs, University of Missouri, Columbia, and Joseph Kiesecker, formerly of Pennsylvania State University, State College. Their experiment is written up in the July, 2004, issue of *Environmental Health Perspectives*.)

The most commonly used herbicide in the U.S., as I write, is atrazine (glyphosate may become number one). In fact, rain water has been shown to often contain atrazine; and atrazine occurs in some domestic drinking water. Somewhat surprisingly to many, an experiment showed that atrazine is more likely to kill developing amphibians (frogs and toads, for example) when it is highly diluted than when much more concentrated – at least in aquatic environments.

In the experiment more than 800 toad and frog embryos and tadpoles were left to grow for about a month in four aquatic environments: (1) no atrazine; (2) 3 ppb (parts per billion) atrazine; (3) 25 ppb atrazine; and (4) 65 ppb atrazine. In six of seven cases, premature death occurred more frequently among tadpoles exposed to 3 ppb atrazine than among those not exposed to the chemical. The death rates in the 25 and 65 ppb environments were less than the death rate in the 3 ppb environment, but greater than the death rate in pure water.

In other experiments this effect was also observed for herbicides mecoprop and dicamba. (See *Science News*, October 12, 2002 page 228.)

(i) In [385, p. 227] it is stated that the maximum contaminant level of atrazine allowed in drinking water in the U.S. is .003 mg/liter. Recall: A liter of water is 1000 cc (cubic centimeters). One cc of pure water has a mass of 1 g (one gram). The symbol mg stands for one milligram, or one one-thousandth of a gram. The .003 mg/liter standard is from the EPA (Environmental Protection Agency) Region 5, Water Division, 1-30-90, and is still in effect as I write.) Is this the same concentration as the 3 ppb used in the experiment described above?

(ii) Can you give an explanation for this "less is more lethal" phenomenon? (For those interested in information on atrazine and its effects I highly recommend the research papers and presentations of Professor Tyrone Hayes at the University of California, Berkeley. In other work done by Hayes and reported in the October 21, 2006 issue of *Science News*, p.270, pesticide exposure, in the form of runoff from agriculture in Salinas Valley, Calif. in this particular study, compromised the immunity of frogs, making them highly susceptible to fungal infections, for example. His work and discoveries continue.)

(iii) Is atrazine an *endocrine* disruptor? (For a project expand this topic into a research paper, there is a great deal to be discovered.)

(iv) Research a list of endocrine disruptors, especially mimics of variants of the hormone estrogen, that you personally are exposed to routinely.

(v) While you are doing (iv) do not forget to check into whether the waste treatment plants that provide part (or all) of your drinking water are removing hormone mimics from the excretions of natural hormones and drugs that are flushed down toilets upstream from you. Has anyone checked the fish in your local water supply for gender modifications due to hormone exposures, for example? If you are drinking bottled water, are there endocrine disruptors in those bottles leaching into your water?

(vi) Find documentation that atrazine has been found in rain water. Can the atrazine in rain water originate from an atrazine application hundreds of miles away? A thousand?

In mathematics we are always on the lookout for the truth value of statements/assumptions, hidden or not.

Exercise 4.3 Popular Beliefs

In [385], the late Marc Lappé presents the following ten statements as popularly believed hypotheses. Note: An hypothesis is a special type of assumption. It is a statement *tentatively* offered for the purpose of investigation. It is in this context a guess why, an explanation of why, some phenomenon is thought to be observed. Before looking up Dr. Lappé's analysis of these hypotheses, assign a truth value between 0 and 1 to each of them.

(i) The body's defenses are adequate (regarding exposure to synthetic toxics).
(ii) Toxic effects not seen will not occur.
(iii) All effects of toxics disappear as doses diminish.
(iv) The fetus develops out of reach of toxic danger.
(v) "Nonreactive" chemicals, like silicone breast implants, lack adverse effects.
(vi) The body's own chemicals are safe.
(vii) Naturally occurring substances cause most cancer.
(viii) If it comes out of the water tap, it's safe to drink.
(ix) The environment is resilient.
(x) The problem of toxics is localized.

4.4 The Flow of Information About Synthetic Flows

When trying to understand anything in Nature, with or without mathematics, you need information/data about that which you are studying. The usefulness of any study is immensely impacted by the quality/accuracy/honesty of the information on which it is based. More often than not, given any particular set of data, it has been my experience that there is a constant struggle between those who wish to know the data and those who try to prevent "others" from knowing the data.

Thanks to the sustained efforts of environmental and labor activists we have to some extent "the right to know" about the toxics that have been and are being released in to our communities[13] and workplaces; the name Tony

[13]For example, the Emergency Planning and Community Right to Know Act (EPCRA) was enacted by Congress on October 17, 1986, in response to public concerns over the protection of the public from chemical emergencies and dangers.

Mazzocchi merits mention in this regard, cf., [391]. Thus if you do an internet search for "Toxic Release Inventory," (TRI), you will find Web sites such as http://www.epa/gov/TRI/tridata, where "epa" refers to the Environmental Protection Agency (EPA), which hopefully still maintains data bases on the releases of toxic chemicals in the United States. I say hopefully, because every such regulatory agency of the government is subject to the political climate at any given moment in time. For example, the so-called USA PATRIOT ACT of 2001 made it more difficult for citizens to get toxics information; and in late 2006 the U.S. President started the process of closing EPA's network of research libraries across the nation. To follow the current status of issues such as these involving government employees and environmental issues the Public Employees for Environmental Responsibility (PEER), www.peer.org, is an organization worth consulting. It's motto is "Protecting Employees Who Protect Our Environment."

A user friendly Web site for accessing TRI information is www.scorecard.org; all you need is your zip code to get started. It is useful to compare current data with a data set from the past, say, 1991, such as is found in [232], where you will find a wealth of data – county by county across the U.S. – on causes of death, levels of exposure to various toxins in the air, water and other information such as geographically correlated diseases. Mathematics plays an important role here.

Exercise 4.4 Toxic Releases Near Your Home

(i) For a project you might want to investigate the data available from the Toxic Release Inventory concerning the toxic exposure of people in the zip code(s) where you spend most of your time.

(ii) Investigate whether any of the toxins you are exposed to are correlated with any particular diseases or health problems. For a brief, intuitive explanation of *correlation* see Section 5.11.

(iii) How many sources of data are there on toxic releases in the zip code(s) of concern to you?

In the following exercise we look at two points of view of the widely used herbicide 2,4-D. After this exercise we look at one of the hurdles that a critic of 2,4-D had to deal with regarding the flow of information about 2,4-D.

Exercise 4.5 Kill Your Dandelions (and What Else?) with 2,4-D.

Synthesized for military purposes in 1942, the two phenoxy herbicides, 2,4-D and 2,4,5-T, (Note: 2,4,5-T is short for 2,4,5-trichlorophenoxyacetic acid. 2,4,5-T has been outlawed, [672, Chapter 2]; but 2,4-D is still a popular herbicide.) were mixed together and used as Agent Orange[14] between 1962 and 1970 by the U.S. to defoliate rainforests and destroy crops in Vietnam.[15]

[14]The barrels containing the mixture of 2,4-D and 2,4,5-T had orange paint identification to distinguish it from other chemicals, such as Agent White, Agent Blue, and so on.

[15]A long battle between Vietnam veterans and the U.S. government over "Agent Orange Syndrome," see [723], is being replayed with the "Gulf War Syndrome," see [302].

The herbicide 2,4-D has become one of the most popular weed killers in agricultural fields and forests, lawns, gardens, and golf courses. Regarding golf courses you may find the following story of interest.

"Two years ago, a new golf-related hazard made it into *The British Medical Journal*: 'golf ball liver.' In Ireland, a 65-year-old retired engineer who played golf every day experienced lethargy and abdominal discomfort, had dark urine and jaundice, and was finally diagnosed with acute hepatitis. The cause was a mystery, until it was discovered that he often licked his golf balls to clean them, a habit that exposed him to the weedkiller used on the greens (in this case 2,4-D). This is not an isolated event, given 'the propensity of golfers to lick their golf balls and the widespread use of weedkiller on golf courses,' in the words of researchers." ... "Also, if you take your shoes off while walking the green, it's probably a good idea to wash your feet and change your socks afterwards." This information is from the July, 1999 entry of the *Wellness Engagement Calendar* prepared by the Editors of the University of California, Berkeley Wellness Letter.

(i) It is not difficult to find respectable scientists, teachers and others minimizing the health threats of chemicals like 2,4-D. Can you find one?

Here is one that I found. In 1992 *The Restless Biosphere*, by Donald R. Eaton pages 145-6 says: "Herbicides are equally important economically, and have proved just as contentious in their usage as insecticides. The best known are the phenoxy herbicides, 2,4-D and 2,4,5-T, the structures of which are shown in .... This type of herbicide was the basis for the infamous Agent Orange used as a defoliant in the Vietnam war. These particular compounds are *not* particularly poisonous, they are about comparable to aspirin in this respect, but the earlier products contained dioxin as an impurity which is *very* poisonous and the reputation of these herbicides has never recovered. There are a number of alternatives on the market these days, a couple of which are shown in .... They are all organic molecules of intermediate complexity, the synthesis of which presents no difficulty to the modern chemical industry." (Emphasis in the original.)

Is 2,4-D comparable to aspirin with regard toxicity? What definition of toxicity are you using and how do you measure it? The EPA re-registered, i.e., approved, of 2,4-D in 2005. The herbicide 2,4-D is one of the most widely used in the world. Is its use associated/correlated with any health problems? Is dioxin still present as an impurity in 2,4-D? Is there a negative synergistic reaction of 2,4-D with any other commonly found substance? Are there any unintended consequences to the use of 2,4-D? Are there methods of agricultural production that do not rely on synthetic herbicides? Is the manufacture of 2,4-D dependent on access to fossil fuels?

(ii) The U.S. Forest Service uses 2,4-D to kill "weeds" on public land. Do the people living near or in these forests have a right not to be sprayed? For a first hand account of one who was sprayed and felt she had a right not to be, see [672, 295].[16]

(iii) Steingraber in [666] briefly discusses health maladies associated with use of 2,4-D. She also recounts some peer reviewed literature. One of particular significance, [666, p. 145], was the occurrence of reproductive tumors in clams exposed to (2,4-D) herbicide runoff from blueberry bogs and herbicide drift from commercial forests in Cobscook Bay, Maine. This is a *control* experiment since otherwise this area is pristine. Note: A *control* experiment is one in which all the variables are under the control of, or at least known to, the investigator, and a particular variable of interest is varied. In this study, 2,4-D was the only synthetic toxin measured in that environment; 2,4-D was the variable being studied.

Is this "experiment" important for evaluating the effects of 2,4-D in the environment? Is such data taken into account in the EPA approval process of 2,4-D?

[16]The late Rachel Carson's answer to this question is: "If the Bill of Rights contains no guarantee that a citizen shall be secure against lethal poisons distributed whether by private individuals or by public officials, it is surely only because our forefathers, despite their considerable wisdom and foresight, could conceive of no such problem."

(iv) Do your own investigation of the toxicity of 2,4-D. In particular, find the *half-life* of 2,4-D.[17] Does the half-life depend on whether it is exposed to air or not? Whether it is in soil or water? Does the estimate of the half-life depend on the source of your information?

(v) Jessie De La Cruz, a farm worker all her life, first woman from the fields to become a United Farm Workers organizer, said (during an informal speech): *"What really got me going was the pesticides. I've seen those children born without limbs. I've seen them die of cancer, of leukemia, because of the pesticides. I've been there at the funerals. I've seen their parents cry. I've cried along with them, and it's something very sad to see."* (Here "pesticides" includes a wide range of chemicals.) Do you believe her? Explain your answer.

A Bad Review. Let's see how Steingraber's book, [666], was professionally greeted. A review of this book appeared in the *New England Journal of Medicine* (11/20/97) – a decidedly uncomplimentary review which the journal subsequently apologized for!

What readers of this review were not initially told is that the reviewer, Jerry Berke, was at the time he wrote the review (is he still?) the director of medicine and toxicology for W.R. Grace & Co., a major chemical company notorious for its release of carcinogenic substances into the environment, cf., the next exercise. *The New England Journal of Medicine* identified Berke as having an M.D. and a Master of Public Health degree, but not as an employee of a company whose interests are directly threatened by the thesis of Steingraber's book – namely, that industrial pollution is a major cause of an increase in cancer.

Exercise 4.6 W.R. Grace & Company and the Environment

(i) Read the non-fiction, suspense-filled story of the court case *Anne Anderson, et al., v. W.R. Grace & Co. et al.* as told in Jonathan Harr, *A Civil Action*, Vintage Books, New York, 1995. This book, which was made into a movie of the same name, tells the story of what it was like for citizens in Woburn, Massachusetts to do battle (for their health and/or lives) in court with a large corporation like W.R. Grace & Co, (and Beatrice Foods).

(ii) Go to www.jimhightower.com and search for May 2000, and find the one-page article: "Dying to Help W. R. Grace & Company." For book length accounts of what this company meant for the lives of many people in Libby, Montana see [607], [523].

Deceit and Denial: The WACU Pattern of Behavior. The general public is likely not aware of the extent to which some organizations will go to discredit or suppress the flow of even extremely well-documented information that said organizations determine is not in their economic interest.

Volumes could be devoted to this subject; however, here I bring up one example, viz., the book *Deceit and Denial: The Deadly Politics of Industrial Pollution*, by Gerald Markowitz and David Rosner, [443]. This book specifically deals with the "lead industry" and the "vinyl chloride industry"; both lead and vinyl chloride (VC) are certainly now known to have quite negative health effects on humans, cf., [284]. Why is the involvement of *historians* Markowitz and Rosner pivotal? Historians are uniquely suited to answer the

[17] The *half-life* of a substance is the length of time it takes for half of a given quantity to change into something else.

question: *Who* knew *What*, e.g., that "X" was toxic, and *When* did they know it?

Largely due to the determination of one woman, Elaine Ross, who filed a wrongful death suit against the vinyl chloride "industry" on behalf of her husband Dan, who worked in that industry, many tens of thousands of pages of industry documents[18] became available for inspection by attorneys for Ross (Billy Baggett, in particular) and historians. These documents established that the "industry" knew as early as 1959, for example, that 500 ppm of of VC in the workplace would cause "appreciable injury." Not to mention that VC was used in PVC plastic bottles (with the possibility of leaching) and as a propellant in many spray cans for drugs, pesticides, cosmetics (like hairspray), for example. Concentrations of 1000 ppm (VC) were documented in hair salons.[19] I cannot come close to effectively recounting this story. For that you can begin by reading [443] and see if you agree with the following review written by Keith Kloor of Audubon: "*Deceit and Denial* is so muscularly researched that it reads like a scholarly criminal indictment. The authors have marshaled an impressive body of evidence – from archival materials to legal documents – in depicting industry's disregard for worker safety and public health."

What is important for our look at the flow of information, however, is the fact that twenty of the biggest chemical companies in the United States: Dow, Monsanto, Goodrich, Goodyear, Union Carbide and others, hired lawyers who subpoenaed and deposed the five academics who reviewed and then recommended that the University of Calfornia Press publish [443]. Professor Philip Scranton of Rutgers University, enlisted by the chemical companies, wrote a 41 page critique of [443] and the ethics of its authors. (Professor Scranton also testified for the asbestos companies in their liability litigation.) Scranton charges that Markowitz violated "basic principles of academic integrity, historical accuracy, and professional responsibility" and engaged in "sustained and repeated violations" of the official "Standards" of the American Historical Association. Scranton doesn't claim to be an expert on the postwar chemical industry, but he does put himself forward as an expert on ethics, Markowitz's in particular. But Markowitz is an expert on what is most relevant here: what the chemical companies knew, and when they knew it.[20]

Such legal attacks on the people involved with [443] costs these individuals time (that could be otherwise used) and the effort of finding and hiring legal counsel to defend them from attorneys from fifteen different chemical companies. Reviewers were asked, for example, if they had checked all 1,200 footnotes, many referring to multiple sources, a task for which the authors alone are traditionally held responsible. In fact, attorneys for PBS (Public

[18] Some of which are posted at www.chemicalindustryarchives.org/dirtysecrets/vinyl/1.asp

[19] By the way, the current Occupational Safety and Health Administration (OSHA), created in 1971, has currently set a limit of 1 ppm (VC) in the air in the workplace.

[20] For a fuller account see "Cancer, Chemicals and History," by Jon Wiener for *the Nation*, posted at; http://www.thenation.com/doc.mhtml?i=20050207&s=wiener.

Broadcasting System) and HBO (Home Box Office) had already checked the entire manuscript, footnotes included. Why? Bill Moyers ran a PBS documentary, "Trade Secrets," on March 26, 2001 (available 1-800-336-1917) based on the research in [443]; and HBO ran a documentary, "Blue Vinyl," in 2002 based on the same research – both documentaries quite worth anyone's time.

One of the most potent observations of Markowitz and Rosner, however, is to be found on p. 300, [443]:

"The history of the lead and vinyl industries gives us a window into why the relationship between industry and the public is so strained today. These industries responded to potent evidence of the danger of their products by hiding information, controlling research, continuing to market their products as safe when they were known to be dangerous, enlisting industrywide groups to participate in denying that there was a problem, and attempting to influence the political process in order to avoid regulation. There are those who find the actions of the lead and vinyl industries so egregious as to constitute a subversion of democracy. They believe that by promoting secrecy, intefering with scientific research and thereby inhibiting the free exchange of ideas, by buying the loyalty of elected officials with donations to political action committees and with soft money contributions, by threatening economic abandonment and unemployment if communities insist upon safety and health regulations, these industries posed a serious threat to political democracy in the United States."

"The question is this: How representative are lead and vinyl of general corporate behavior?"

Later on:

"As with asbestos and tobacco, the lead and vinyl industries knew of dangers from their products but chose to ignore or conceal them. In fact, they actively deceived the public about the safety of their products."

I spent much of my life with advertisements extolling the virtues of smoking, e.g., "Now ... Scientific Evidence on Effects of Smoking! Much Milder Chesterfield is Best for You," (with a picture of Arthur Godfrey, a celebrity of the day, and his signature on a testimonial); "According to a recent Nationwide survey, More Doctors Smoke Camels Than Any Other Cigarette," (complete with a picture of man in a white coat and stethoscope who looks very much like a doctor); "Scientific tests prove Lucky Strike milder than any other principal brand!" (with a signed picture and testimonial of a celebrity of the day, Rex Harrison: "I smoke Luckies – they're mild and smooth." As the evidence of ill effects mounted over the years, so did the denials from the tobacco industry. Lucky for me, I did not believe the tobacco companies.

Exercise 4.7 A Corporate Pattern of Behavior: WACU

(i) I refer to the *pattern of corporate behavior* associated with tobacco, lead, vinyl chloride and asbestos, outlined in the above quotes from Markowitz and Rosner as the **WACU** Pattern of Behavior, i.e., "We Are the Center of The Universe" Pattern of Behavior. The following question takes up the challenge of Markowitz and Rosner: Is the WACU Pattern of Behavior representative of corporate behavior for the majority of corporations? For the majority of large corporations? This question is difficult to answer in either the affirmative or negative, since most corporations are not transparent; do not allow inspection.

(ii) Although the financial industry (in the U.S. and elsewhere) does not produce a chemical product, has it exhibited the WACU Pattern of Behavior?

(iii) Does the health insurance industry exhibit the WACU Pattern of Behavior? Hint: See statements for the record of Wendel Potter. Did the energy company ENRON exhibit the WACU Pattern of Behavior? How about WorldCom?

(iv) Can you find any large corporation that you can convincingly demonstrate does not exhibit the WACU Pattern of Behavior? How many such can you find?

(v) Look up advertisements from the tobacco industry and statements regarding the safety of cigarettes from the last hundred years. Estimate a time when it is fairly certain that the industry started lying to the public. For how many decades have they lied to the public?

(vi) Are there any characteristics of a corporation that might naturally lead it to exhibit the WACU Pattern of Behavior? Size? Lack of regulation, effective feedback from society? What social institutions, processes, activities, or structures might minimize the WACU Pattern of Behavior on the part of corporations?

(vii) What is the relationship of the WACU Pattern of Behavior to the Bio-Copernican Axiom?

Think as Though Your Life Depended on it. The following exercise involves being critical of what you read in the papers, doing a little thinking; and it ends with a choice.

Exercise 4.8 Love Canal and Other Things: How Safe?

(i) From two articles by Jane E. Brody in *The New York Times*, Science Times, July 13, 2004 pages D5 and D7 we read the following quote from Dr. Robert L. Brent, a distinguished professor at Thomas Jefferson Medical College in Philadelphia who has been studying environmental toxicology for nearly 50 years, specializing in the effects of environmental factors like radiation, drugs and chemicals on the developing embryo and child: "Love Canal[21] was an example of a terrible environmental problem that should be cleaned up, but there was no evidence of risk to the people who lived there. Many fears are irrational."

Lois Marie Gibbs, a then resident of Love Canal, would give the part of the above quote following the comma a truth value of 0, [222, 223]. What truth value do you give Dr. Brent's statement? Investigate as thoroughly as you can.

(ii) Bjørn Lomberg would more likely agree with Dr. Brent, [408].[22] Does this change or confirm your answer to (i). You might peruse some comments of the many scientists who have criticized [408]. See, for example, [609, 538]. Lomborg defends himself and returns criticism at his Web site www.lomborg.com.

(iii) Jane E. Brody, in one of the two articles mentioned in (i), says: "Many parents worry that their children may be harmed by exposure to environmental factors they cannot avoid or control, including pesticide residues on fruits and vegetables, approved food additives, chlorinated drinking water and hormones in milk."

"They fear electromagnetic fields as a cause of childhood leukemia, a mercury preservative

[21] Love Canal, in New York state, was used as a toxic dumping ground in the 1940s and 1950s by Hooker Chemical Co. In 1978 the residents (then living on this dump site) became aware of the situation, and a long battle ensued. Lois Marie Gibbs, a then resident of Love Canal, led citizen protests and authored [222, 223].

[22] Lomberg's book has many, many references and footnotes. Do such guarantee the truth?

in vaccines as a cause of autism,[23] alar,[24] a growth stimulant on apples, as a cause of cancer."

"None of these are actual hazards. But even if they were, they are hardly the main threats to the health and lives of fetuses, infants, children and adolescents, says Dr. Robert L. Brent..."

J. Brody then goes on to discuss what she refers to as main threats: Sudden Infant Death Syndrome, falls, vehicular accidents, burns, poisoning, drowning, choking, guns, electrocution, secondhand smoke, sunburn, sports injuries, power tools, and obesity.

Discuss the extent to which Brody is comparing longer term, abstract-mathematical death to short-term, real-time death.

Pick at least one of the topics Brody mentions in her quote above and make your own assessment of risk, based on some study. If you pick pesticides, you might consider [481, 382, 701].

(iv) You can assess your level of belief in the present safety (or risk) of living at Love Canal. Houses are again being sold in the neighborhood. Would you buy?

Regulation and Enforcement Are Feedback. There are a number of agencies of the Federal Government that were created to *regulate* some aspects of society, such as the Securities and Exchange Commission (SEC), Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA). One important fact to remember is that any such government regulatory body was created, usually over stiff opposition, to address some compelling need of society. Thereafter, a "game" ensues (amenable in part to mathematical analysis) where those who are regulated do their best to "neutralize" or "capture" the agency in question, and various groups of citizens fight to prevent that from happening. Thus given any such agency, there is invariably a long and interesting story involving the history and contemporary politics of the struggle between these opposing forces. I can only hint at these struggles and suggest that the reader pursue their study as projects. I will, however, very briefly discuss the FDA, since it was the first citizen-protection agency of the

[23] Eli Lilly, inventor of thimerosal (a mercury preservative in vaccines), was granted protection from lawsuits by parents of autistic children under a short-lived provision slipped into the Homeland Security Act in November 2002, [207]. Relevant to this discussion, an article by Robert R. Kennedy, Jr., details how the American government rushed to conceal data and prevent parents from suing drug companies, cf., "Deadly Immunity," *The Progressive Populist*, July 15, 2005, and Salon.com. Also relevant, the British Journal *The Lancet* recently retracted the controversial 1998 study that first set off widespread fears about a vaccine autism link because the editors found serious flaws and false claims. It was also discovered that the lead author had been paid by a lawyer suing the vaccine makers, see *U.C. Berkeley Wellness Letter*, June 2010. As was pointed out in a letter to the editor, *In These Times*, August 9, 2004, as thimerosal is phased out of vaccines it may become evident whether or not the autism-thimerosal correlation is with or without a cause. Of course, even if mercury is a cause of autism, there are other sources of mercury pollution, e.g., burning coal. And there are likely multiple causes of autism, cf., page 79.

[24] From www.nrdc.org, the Web site of the Natural Resources Defense Council, which led a campaign against alar: "Alar was a pesticide used on apples. Uniroyal withdrew it from the market following a *60 Minutes* story viewed by 40 million people on the health dangers it posed. The story was based on an NRDC study called *Intolerable Risk: Pesticides in Our Children's Food*. Alar was later banned by the EPA."

federal government. The FDA's modern regulatory functions began with the passage of the 1906 Pure Food and Drug Act.

The FDA is relatively small for the tasks it faces, and it does not carry out tests of its own, relying primarily on studies carried out by the industries it regulates. One success story is its regulation of thalidomide, the dangers of which were missed by many other countries. For this story and general history of the FDA see [309].

On the other hand, the FDA has its critics. See www.citizen.org/hrg, for example, an organization inspired by Ralph Nader, which is one of the players stuggling against the aforementioned "neutralization." A famous critique of the FDA is the 1970 book, *The Chemical Feast: The Ralph Nader Study Group Report on Food Protection and the Food and Drug Administration* by James S. Turner.

The following exercise is one among many possible exercises dealing with controversial decisions of the FDA. The FDA "changed its mind" about the artifical sweetner *aspartame* and in 1983 approved it for use in liquids, e.g., diet sodas. We cannot herein devote the space necessary to evaluate this decision; however, we can raise some issues the reader may or may not be aware of.

Exercise 4.9 Aspartame: Pro or Con

(i) An advertisement from Tufts University's Friedman School of Nutrition Science for its health and nutrition publication, the Tufts Letter, begins with "If you've been told ..." It then gives a list of 10 statements one of which is "aspartame sweetner is dangerous." The advertisement then asserts that "you might be interested to learn that ALL are FALSE" (referring to the 10 statements). Thus the advertisement asserts that aspartame is not dangerous. Nowhere in the ad does it discuss PKU, i.e., phenylketonuria. Of course, if you have this disease, you no doubt have read the following warning on any can of soda sold in the U.S. that contains aspartame: "Phenylketonurics: Contains Phenylalanine." Why the warning?

(ii) We learn interesting aspects of the history of the FDA approval of aspartame from Chapter 4 of [95], a book about Donald Rumsfeld, at one time the Secretary of Defense. Rumsfeld was the CEO of G.D. Searle & Company (owner of aspartame) from 1977 to 1985. It was during this period that Rumsfeld guided aspartame through the FDA approval process. What qualifications did Rumsfeld have for this task? In April 1981 Arthur Hull Hayes was selected to be FDA commissioner, replacing previous commissioner Jere Goyan, who had just been fired by an administration transition team (a rare occurence). On July 18, 1981, Hayes approved aspartame for use as a sweetner in solid foods. Aspartame was cleared for use in liquids, e.g., diet sodas, in July 1983. Soon thereafter, Hayes resigned from the FDA and accepted a consultancy contract from Searle's PR firm, Burson-Marsteller. Searle was then sold to Monsanto for $2.7 billion. What would have been the value of Searle if aspartame had not been approved? Is there a "revolving door" involved here between industry and government? Note: Revolving door refers to the situation where persons from the industry being regulated by an agency later take positions in that agency and/or persons in a regulatory agency later take positions in an industry being regulated by said agency.

(iii) Some of the history in part (ii) is recounted as well in [235, p. 175]. Chapter 10 of this book discusses Miraculin, an extract of the naturally occuring "Miracle Fruit,"i.e., *Synseplaum dulcificum*. Though petitioned, the FDA would not approve the sweetner Miraculin. Why do you think this is the case? Miracle fruit, native to Africa, is grown

in Florida, cf., www.miraclefruitman.com. What very unusual property does the Miracle Fruit have?

(iv) Research the pros and cons of aspartame as deeply as you have time for. Do you eat aspartame?

A Note on Biomonitoring: Some Signs of Hope. Biomonitoring consists of using living organisms to measure various aspects of the environment, such as the presence and quantitative level of toxins. In one such biomonitoring study called "Mussel Watch,"[25] begun in 1986 and ongoing, NOAA[26] has found that restrictions on some toxins have helped reduce their levels in the environment. Mussels and oysters are filter feeders and concentrate assorted toxins which are present in their aquatic environment. Among the banned or restricted toxins monitored are PCBs (Polychlorinated Biphenyls), chlorinated hydrocarbons and cadmium. A recent review of 17 chemicals at 246 different sites showed 108 increased concentrations, 830 decreased concentrations. Thus, regulations have had a measurable and positive effect.

4.5 You Cannot Do Just One Thing: Two Examples

Fluorine: Atomic Bombs and Teeth. There is a fuzzy boundary between "natural" chemicals and those new, human-made, i.e., synthetic ones not previously found in Nature. For example, fluorine, F, is one of the elements. See F on page 253 in the periodic table: one of Nature's basic building blocks. But fluorine reacts immediately and strongly with almost everything, and hence is not normally found on Earth as a pure element. During World War II, however, large quantities of pure fluorine were produced as one step in the production of atomic weapons. Some chemicals, called fluorides, are added to toothpaste and some municipal drinking water, but not without controversy, however, see [62]. I will soon have more to say about F.

Putting the Lead in, then Taking It Out: The Story of Leaded Gasoline. Lead, Pb, is another element in the periodic table. For eons lead was largely held separate from most living things by rock formations in the Earth's crust. Humans have brought Pb in contact with living beings for thousands of years by mining. Lead is or has been used in pipes, radiation shielding, bullets, paint, and many other things including ethyl gasoline. We have also known lead is a poison for hundreds of, if not a couple thousand, years of human history.

[25] This is the longest continuous contaminant monitoring program in United States coastal waters. Over 250 sites are monitored including Atlantic, Pacific and Gulf coasts, the Great Lakes, Alaska, Hawaii and Puerto Rico. Recent results have been published in the journal *Marine Environmental Research*.

[26] The National Oceanic and Atmospheric Administration

On December 9, 1921 the brilliant inventor, Thomas Midgley, Jr., found what he had been seeking for a decade. At a ratio of 1:1,300 mixture of lead to gasoline, car engines showed increased compression, greater fuel economy, 25% increase in horsepower, and most of all the annoying "knock" was eliminated. In addition, lower grades of oil could be used for gasoline, since performance was enhanced by the almost magical gasoline additive known (to be precise) as tetraethyl lead, [702, page 119][27]

Charles Kettering,[28] Midgley's boss, went to his boss, Pierre Du Pont, the president and chairman of the board of General Motors, with the good news. Presumably since lead was (is) a known poison, the new additive was named "ethyl." General Motors and the Standard Oil Company of New Jersey formed the Ethyl Corporation with Kettering as president and Midgley as vice president and general manager. Du Pont, the chemical corporation, got the contract to provide the tetraethyl lead. The deaths of workers in the tetraethyl plant momentarily set back the public relations for ethyl; however, using their power with politicians, government, communications, and universities[29] ethyl gas was sold in the United States until a brief surge of politically effective environmental concern swept the United States in the 1960s and 1970s. At that time a number of environmental laws were passed, including the regulation of lead in gasoline.

The fascinating history of how lead got in gasoline is found in [66, 702, 443]. For some details of the science and politics that got the lead out of gas, see [562, 702, 443]. Pay particular attention to the role of citizen activists and scientist Herbert Needleman who risked his career when he published his research on the observed effects of lead pollution on children.[30] Science and citizen action were pivotal in getting the lead out of gas.

Exercise 4.10 The Lead Now in Your Body and the Environment. From [562, page 98] we read:

"Even today, however, the average North American carries between 100 and 500 times as much lead in his or her blood as our preindustrial ancestors. In cities where there has been a high density of automobile traffic, adults have blood levels of about 20 to 25 [micro]grams per deciliter – roughly half the level at which lead exposure leads to impairment of peripheral

[27] The book [702] gives an in-depth discussion of occupational, pediatric, and environmental lead exposure/poisoning.

[28] The man after whom the Sloan-Kettering Research Institute is named.

[29] Notably Robert A. Kehoe, Director of the Kettering Laboratory of Applied Physiology at the University of Cincinnati, defended the safety of lead in gasoline for decades. Kehoe similarly defended fluoride on behalf of a group of corporations that included Du Pont, Alcoa, and U.S. Steel, all of which faced lawsuits for industrial fluoride pollution. Professor Yandell Henderson of Yale led academic opposition to lead in gasoline, but lost the battle.

[30] Needleman found a correlation: for every 10 parts per million increase of lead in a child's (baby) tooth there was a two-point drop in IQ. With the help of others, including some honest scientists and professors, Needleman survived and eventually "won" a battle with other professors and scientists (supported by industry money) and with the public relations firm of Hill & Knowlton.

nerves. No other toxic chemical has accumulated in humans to average levels that are this close to the threshold for overt chemical poisoning.. . .

What we do know is that the lead industry continues to lobby, even today, against measures such as an excise tax on lead that would discourage its use and generate funds to help clean up its toxic legacy. Cleanup is needed because some three million tons of lead remain on the walls of homes that were built and painted prior to 1970. Another five million tons is found in the soil near busy roadways."

From [562, page 93] we read:

"In fact, even Henderson's warning turns out to be a gross underestimate. By the mid-1970s, 90 percent of the gasoline used for automobiles in the United States was formulated with ethyl. During the 60 years that leaded gasoline was used in the United States, some 30 million *tons* of lead was released from automobile exhausts. 'When many cars were getting just ten miles to a gallon in stop-and-go traffic, a busy intersection might have gotten as much as four or five tons of lead dumped on it in a year,' notes Howard Mielke, an environmental toxicologist and lead expert at the College of Pharmacy at Xavier University of Louisiana, in New Orleans. 'That's roughly equal to having a lead smelter at every major intersection in the United States. As a result, there is a very, very large reservoir of lead in soil.' "

(i) By doing your own estimates verify or debunk the statement that four or five tons of lead could be (have been) dumped at a busy intersection in a year.[31]

(ii) By doing your own estimates verify or debunk the statement that another five million tons (of lead) is found in the soil near busy roadways.[32]

(iii) What form does lead take when it comes out of the exhaust pipe of a car? How biologically active is it in this form? How would it enter a mammal's body?

(iv) Where is all that lead now?[33]

(v) Are there any commercially edible plants that take up lead? For example, see [727] and [730].

(vi) If you know what a deciliter is (see Table Greek Prefixes, page 60), estimate the how much lead is in the blood of Americans. An adult male of "average" weight has about 5 liters of blood.

CFCs: The Story of Refrigeration, Spray Deodorant, and Bug Bombs. In June of 1918, General Motors entered the refrigeration business. They bought the Guardian Frigerator Company and renamed it Frigidaire. In those days the concept of pumping heat from inside an airtight enclosure via a compression and expansion cycle of a "suitable" gas was a novel idea, an alternative to the ice box.[34] Problems arose, however, with the "suitable" gas. Ammonia gas, though efficient and nonflammable, was toxic if breathed in large quantities. Its stinging odor caused consumer complaint whenever even a small leak occurred – fouling the air and spoiling the refrigerator's contents. This

[31] The ratio 1:1,300 of lead to gas should be helpful. You now need to estimate the amount of gas.

[32] You will need to estimate how much gas is involved. You may have to look up some relevant data.

[33] For example, if there has been 30 million tons of lead released from auto exhaust and there are 5 million tons along the busy roadways and five tons per year at busy intersections, does that mean that *all* the lead is piled up along roads and at "several" busy intersections.? Has lead been found in the Arctic that came from auto exhaust? Is there lead in the bodies of animals (including humans)? See also [493].

[34] Literally an ice box was a box wherein a block of ice was periodically placed to keep the interior of the box cold.

is, of course, an improvement over a toxic refrigerant gas that smelled bad and might explode. In the 1920s General Motors switched to methyl chloride, which was efficient and odorless. The main problem was its extreme toxicity. For example, on May 15, 1929, 125 patients and employees at a Cleveland hospital died in an accidental release of methyl chloride fumes.

General Motors' Kettering again called on their inventor, Midgley; and with a stroke of genius he invented a fluorine based compound, dichlorodifluoromethane, or CFC-12, which was ideal for refrigerators. This chlorofluorocarbon was christened Freon, and by 1935 it was the standard refrigerant gas in America's household refrigerators.

Freon was extensively tested and found to be inert. It does not burn or smell; it is nontoxic. It was a brilliant solution to an important problem, and it found applications beyond refrigerators. It was discovered that Freon was an ideal propellant and aerosolizer for insecticides like DDT.[35] Spray cans containing compressed Freon and insecticide, i.e., Bug Bombs, were quite popular and were used extensively by U.S. troops in the Pacific during World War II. Also, spray cans dispensing Freon-propelled deodorant eventually became nearly universal.

The Ozone Layer: Who Needs It? In 1970 I was finishing up my studies at the then new campus of the University of California, Irvine. UCI was small and beautiful with the math department sharing a building with the chemistry department. If you had mentioned the ozone layer to me at the first Earth Day, April 22, 1970, I could have easily recited the problems with the SSTs (SuperSonicTransport) – airplanes traveling faster than the speed of sound through the stratosphere, impacting negatively on on the Earth's protective ozone shield. It was a hotly debated topic.

However, I was completely unaware that the amiable F. Sherwood Rowland, i.e., "Sherry," the director of chemistry at UCI, together with his postdoctoral assistant, Mario Molina, would in June of 1974 publish a theoretical atmospheric chemistry paper of unparalleled importance. Their paper predicted that CFCs, though inert in the lower atmosphere, broke apart when exposed to ultraviolet light in the upper atmosphere – liberating chlorine atoms that efficiently[36] destroyed O_3, ozone. This ozone shield protects life on Earth from excessive ultraviolet radiation and its associated deleterious effects.[37]

[35] DDT is short for dichlorodiphenyltrichloroethane.

[36] By efficiently I mean that via a "chemical recycling process" just one chlorine atom, Cl, liberated from a CFC molecule by ultraviolet light, can destroy a multitude of ozone molecules; before other processes render that chlorine atom less harmful.

[37] In the July 13, 2004 issue of *The New York Times – Science Times* it is stated that we are in the midst of a reversal of the Earth's magnetic field, i.e, this magnetic field is in the process of collapsing and reappearing with north and south magnetic poles reversed. This could cause further damage to the ozone layer. Additionally, there are other chemicals (synthetic and not) I have not discussed that destroy ozone. You might want to look up what ultraviolet solar radiation at various levels does to living things.

This theory had its critics in industry for obvious financial reasons as well as among scientists. Most notable was critic James Lovelock, of Gaia hypothesis fame, who had published a paper in *Nature* in 1973 reporting that he had measured CFCs virtually everywhere in the atmosphere with an instrument that he had invented. Lovelock denounced Rowland and Molina's theory, and he also happened to have received research funding from the Manufacturing Chemists Association, cf., [66, p. 201].

Nevertheless, the U.S. banned CFCs in spray cans in 1978 over protests that it would put lots of people out of work. (It did not.) The production of CFCs was far from being banned, however. For example, U.S. Interior Secretary, Donald Hodel, was famously quoted as saying that damage to the ozone layer would be no problem if people would just wear broad-brimmed hats and sunglasses when they went outside.

Experimental evidence of CFC destruction of the ozone layer started pouring in, such as the discovery of the "ozone hole" over Antarctica; but politicians did not act. Susan Solomon, a NOAA[38] scientist in Boulder, Colorado, headed up the National Ozone Expedition to Antarctica in August 1986. Combining her knowledge of atmospheric physics and chemistry, she proposed a theory which explained the precise mechanism by which CFCs could lead to the dramatic thinning of Antarctic ozone. Still no CFC ban was forthcoming.

The United Nations Environment Program (UNEP), directed by Mustafa Tolba, hosted and prodded the international political process, and in October 1987 in Montreal, Canada, politicians from around the world were shown the "smoking gun graph," see Figure 4.1, of data collected September 16, 1987, on a NASA[39] plane which flew from Punta Arenas, Chile directly toward the South Pole and into the ozone hole. In this graph rises and drops in ozone are almost exactly mirrored by drops and rises in chlorine monoxide, ClO. Other measurements showed that about two thirds of the chlorine in the stratosphere was coming from human-made chemicals.

Although Du Pont had put on hold its search for CFC substitutes when Ronald Reagan was elected in 1980, in 1989 it pledged to phase out CFC production completely.[40] Nations around the world signed the famous Montreal Protocol regulating CFCs. Led by UNEP, representatives from 92 countries met in London in 1990 and agreed to phase out all CFC production by 2000. The ozone layer continues to thin and the effects of CFCs will continue for a long, long[41] time; but it could have been much worse. For a great many more details see [66, 450, 578].

An Argument that Might Sound Good but Is Not Sound. I invite you to test your ability to analyze an argument critically in the following exercise

[38] National Oceanic and Atmospheric Administration.

[39] National Aeronautics and Space Administration.

[40] Apparently relevant patents were running out as well.

[41] If the atmosphere is a box and CFCs are the stock with flows, what is the residence time of CFCs in the atmosphere?

based on [404] which indirectly says that most of the science, data and theory I have discussed above about CFCs and ozone (and much else) is rubbish. At the time I write this, Rush Limbaugh is a popular radio commentator with an apparently large following that believes much of what he says and votes accordingly.[42]

Exercise 4.11 Rush H. Limbaugh, III Says There is Nothing to Worry About. From [404] we read:

"...ozone is *created* by the sun, particularly ultraviolet sunlight. And yet these dunderhead alarmists and prophets of doom want us to believe that because there are occasional reduced levels of ozone over Antarctica (which, incidentally, always rebound to normal levels), our own activity, based purely on our natural behavior and technological advancement, is responsible for what they predict will be the destruction of the ozone layer. Poppycock. Balderdash.

Mount Pinatubo in the Philippines spewed forth more than a thousand times the amount of ozone-depleting chemicals in *one* eruption than all of the fluorocarbons manufactured by wicked, diabolical, and insensitive corporations in history. So much so that respected scientists now say that a 4 percent to 6 percent ozone loss–*could*, but may not–occur over the Northern Hemisphere in the next two or three years. Now, wait–before you think I have just destroyed my own argument, remember this: volcanoes have been doing this for 4 billion years. And guess what? We still have a healthy ozone layer! Isn't it wonderful? Aren't you thrilled? Hmmm. You still don't get it? Read it again, folks. One eruption in 4 bilion years of eruptions–a thousand times as destructive as all man-made CFCs–and a temporary maximum loss of 6 percent of the ozone. Conclusion: mankind can't possibly equal the output of even one eruption from Pinatubo, much less 4 billion years' worth of them, so how can we destroy ozone? In other words, Mother Nature has been attacking her own stratospheric ozone for millions of years and yet the ozone is still there, and in sufficient quantities to protect Democrats and environmentalist wackos alike from skin cancer."

(i) There is enough information on the preceding pages to offer a tentative rebuttal to Limbaugh's argument above. Can you create such a rebuttal?[43]

(ii) If you are at all familiar with the pronouncements of Rush Limbaugh, written or verbal, can you find any substantive differences between the arguments/discussions in this (my) book and those of Limbaugh?

(iii) An environmentally concerned acquaintance of mine was concerned about chlorination of our municipal water. He thought that chlorine was not good for citizen health and that using chlorine in the water supply was helping deplete the ozone layer. There might be some positive and negative health effects of water chlorination that one can ponder. However, does chlorination of city water supplies measurably impact the ozone layer? Explain.

(iv) On October 3, 2006, Alex Morales reported the following for *Bloomberg News*. The European Space Agency, ESA, announced that 2006, in terms of the mass of ozone lost, 40 million metric tonnes, set a record for ozone loss over the South Pole. The previous record was 39 million metric tonnes ozone loss in the year 2000, cf., the Web site of the ESA, (data was collected from Envisat, the largest earth observation spacecraft built so far). The loss was in part a result of the lowest Antarctic temperatures recorded since 1979. Would you say humans have solved the ozone thinning problem?[44]

[42] For two references critical of Mr. Limbaugh see [343, 571].

[43] Just to complicate things I mention that organisms in the world's oceans create enormous quantities of chemicals that can also destroy ozone! Much of what Mr. Limbaugh says is true, so why worry about CFCs? Why then were (legal) CFCs then phased out?

[44] On November 4, 2006 an Associated Press article by Rita Beamish announced that the United States lobbied successfully against objections from European nations and the Montreal Protocol treaty's own technical committee to continue the use of methyl bromide, a

(v) In December 2009 Rush Limbaugh said: "Climate change is a lie and a hoax." Discuss.

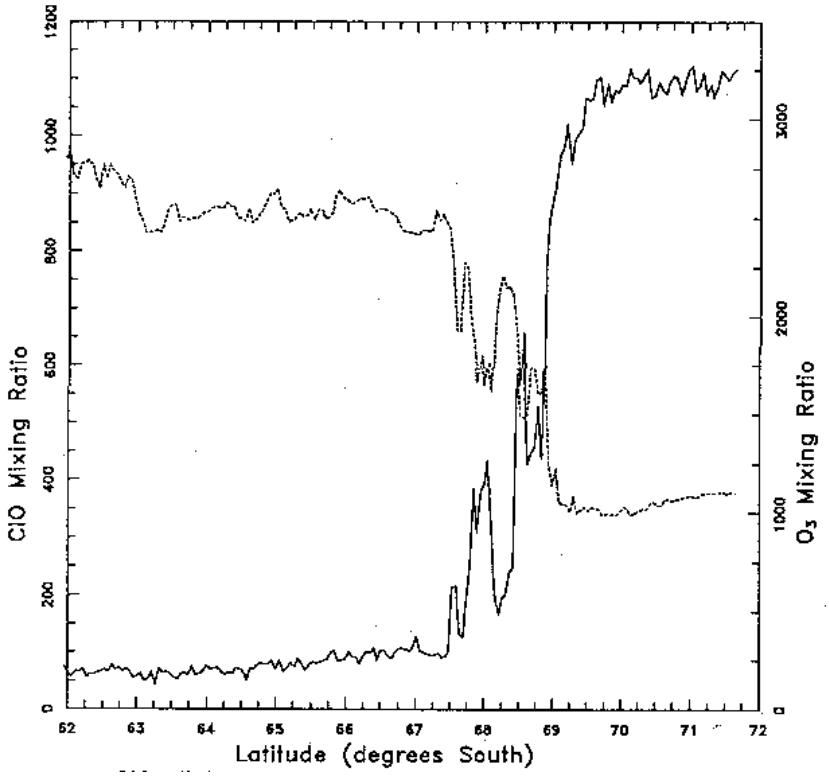

FIGURE 4.1: CFC-Ozone Smoking Gun Graph

Figure 4.1 is from J. G. Anderson, W. H. Brune, and M. J. Proffitt, "Ozone Destruction by Chlorine Radicals within the Antarctic Vortex: The Spatial and Temporal Evolution of ClO-O_3 Anticorrelation Based on in Situ ER-2 Data," *Journal of Geophysical Research* 94 (30 August 1989) 11,475. Copyright 1989 American Geophysical Union; Reproduced by permission of American Geophysical Union.

potent destroyer of the ozone layer. The U.S. not only is continuing to use U.S. stockpiles of 11,000 tons of methyl bromide, it is manufacturing more that 5,000 new tons of the pesticide – despite proof that alternative methods and chemicals can replace methyl bromide.

This graph is often referred to as the "smoking gun graph," since the graph of ozone, which is falling, is nearly the mirror image of the chlorine monoxide graph, which is rising. Thus it was strongly implied that chlorine byproducts resulting from the breakdown of CFCs were responsible for the thining of the ozone layer over the Antarctic. The data shown above were collected on September 16, 1987 by instruments on NASA's ER-2 research airplane as it flew from Punta Arenas, Chile (53 deg S) to 72 deg S. As the plane flew into the ozone hole over the Antarctic the concentration of chlorine monoxide increased to about 500 times normal levels while ozone levels declined drastically.