# Organic Foods: Examining the Health Implications
# Case Study for AAC&U STIRS Project

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## Learning Objectives

**Part I**

1. Interpret and summarize research findings presented graphically.
2. Calculate a measure of association and explain what it means.
3. Explain the meaning of a confidence interval and a p-value.
4. Explain how sample size affects a confidence interval.

**Part II**

5. Describe possible health effects of pesticide exposures.
6. Use the Source-to-Effects model to characterize a variety of exposure pathways for pesticides.
7. Examine percentile distribution data from a table, and interpret whether population pesticide exposures vary across time and population subgroups.
8. Identify reasons why epidemiologic studies may be limited in their ability to causally link human health outcomes to pesticide exposures.
9. Assess factors relating to the carbon footprint of agriculture.
10. Research and summarize the evidence linking widespread animal antibiotic use to human health effects.
11. Identify ethical issues relating to meat consumption.

**Part III**

12. Discuss potential benefits and harms related to genetically modified (GM) foods.
13. Discuss how the precautionary principle may be applied to policy decision-making regarding GM foods.

**Part IV**

14. Consider a body of evidence to make a recommendation regarding a personal health behavior.

## Preparation

Before coming to class, please read carefully through this case study. Also please read the biomonitoring results and Biomonitoring Summary report described on pages 6-7.

Bring your laptop to class, as it will be helpful in researching some of the questions posed below.

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## A Grocery Aisle Conundrum

"Hmmm . . ." said your friend Jordan, standing in the produce aisle at the local supermarket, pondering a shopping list.

"I need strawberries and apples, bell peppers and lettuce, avocados, potatoes, and onions. I see organic produce over here. I've always kind of believed that organic is better for people and the environment ... maybe I should buy organic. But it's more expensive – a dollar here and two dollars there adds up really fast. And I heard a news report the other night saying that organic's really not much healthier anyway."

Indeed, in early September 2012, mainstream media sources and the blogosphere were buzzing over a just-released study by Stanford University researchers. (Smith-Spangler, et al., 2012) The paper, published in the *Annals of Internal Medicine*, a highly respected, peer-reviewed, biomedical journal, had reviewed 45 years of research, attempting to answer this question: "Are organic foods safer or healthier than conventional alternatives?"

Jordan had heard only short news sound bites – and it hadn't seemed that experts agreed about the answers. "I wish I knew more about these issues. Otherwise it's hard to justify the extra expense to buy organic. Hey – you're taking an environmental health [or insert relevant course topic here] course this semester! What do you know that might help me decide?"

## Part I. Background

**What is organic food production? How does it differ from conventional food production?**

Organic farming comprises a set of ecologically-oriented practices used to produce vegetables, fruits, meats, dairy products, grains, eggs, fibers, and flowers. Whereas conventional farmers typically utilize chemical fertilizers to promote plant growth, organic farmers use manure, compost, or other natural fertilizers. (Mayo Clinic, 2012) To minimize pests and plant diseases, conventional farmers spray synthetic pesticides. Their organic counterparts, on the other hand, utilize a variety of practices including naturally-derived pesticides, traps, strategies to disrupt pest mating, and beneficial insects and birds. (Mayo Clinic, 2012) To manage weeds, conventional farmers apply synthetic herbicides, while organic weed control practices may include crop rotation, cover crops, tilling, hand weeding, mulching, and application of natural herbicides (Mayo Clinic, 2012) such as corn gluten meal or essential oils. (Dayan, Cantrell, & Duke, 2009) The use of antibiotics, growth hormones and medications is common in conventional animal food production to prevent disease and promote growth. In contrast, organically-raised animals are given organic feed, and farmers utilize rotational grazing, balanced diets, clean housing and other preventive practices to help reduce disease. (Mayo Clinic, 2012) Finally, irradiation and genetic engineering may not be used in organic foods. (U.S. Department of Agriculture, 2012) According to the Organic Farming Research Foundation, "Organic farming management relies on developing biological diversity in the field to disrupt habitat for pest organisms, and the purposeful maintenance and replenishment of soil fertility," thus enhancing conditions for plant growth. (Organic Farming Research Foundation, 2012)

According to the Organic Trade Association, organic products are a worldwide growth industry. In the U.S. in 2010, organics comprised about 4% of all food and beverage sales. Organic fruits and vegetables showed the strongest U.S. market share, accounting for more than 11% of fruits and vegetables sold. **(Organic Trade Association, 2011)**

**USDA Organic Certification**

The United States Department of Agriculture (USDA) has developed regulations and guidelines pertaining to organic foods. Foods or other agricultural products that have "been produced through approved methods that integrate cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity" may carry the "USDA Organic" seal. (See Figure 1.) The label "100% organic" means that a product has been made only with certified organic ingredients and practices. The label "organic" applies to products made up with a minimum of 95% organic ingredients. Products that contain at least 70% organic ingredients can be labeled "made with organic ingredients." However, this latter category may not display the USDA Organic seal. (U. S. Department of Agriculture, 2012)

**Figure 1. USDA Organic Seal**

**What did the Stanford study show?**

The Stanford authors conducted a systematic review and meta-analysis. See Box 1 for explanations of these terms. Their purpose was to "comprehensively synthesize the published literature on the health, nutritional, and safety characteristics of organic and conventional foods." (p. 348) They used pre-defined criteria to identify all peer-reviewed studies published in English between 1966 and May 2011 comparing people consuming organic versus conventionally-produced foods, or comparing the foods themselves. The foods they focused on were fruits, vegetables, grains, meats, poultry, milk, and eggs – but not processed foods. Authors screened almost six thousand articles identified by their literature searches; from these, 237 studies were eligible for this systematic review. Smith-Spangler and her co-authors separated these 237 articles into studies in humans versus studies of foods. Then, they examined the findings for organic vs. conventional foods according to outcomes: nutrient levels, pathogen contamination, and pesticide residues – a challenging exercise given that the studies varied considerably by methods and quality. **(Smith-Spangler, et al., 2012)**

The main findings **(Smith-Spangler, et al., 2012)** were as follows:

- <u>Nutrients</u>: Organic and conventional foods were similar in their vitamin content and for most other nutrients. The most robust finding was significantly higher levels of phosphorus in organic produce. A few other differences – such as higher total phenols in organic produce, and higher levels of beneficial omega-3 fatty acids in organic milk and chicken – were difficult to interpret because of the variability in the studies.
- <u>Pathogens</u>: The overall presence of bacterial contamination did not differ substantially between organic and conventional produce or animal products. However, conventional chicken and pork were 33% more likely to be contaminated with bacteria resistant to three or more antibiotics.
- <u>Pesticide Residues</u>: Nine studies compared pesticide residues in organic fruits, vegetables, and grains. Seven percent of over 3,000 organic samples and 38% of over 106,000 conventional samples had detectable pesticide residues – a large and statistically significant difference. However, even when pesticide residues were detected, they rarely exceeded allowable limits, thus Smith-Spangler et al. noted that ". . . the clinical significance of this finding is unclear . . ." (p. 358) Figure 2 shows the meta-analysis results for pesticide residues.

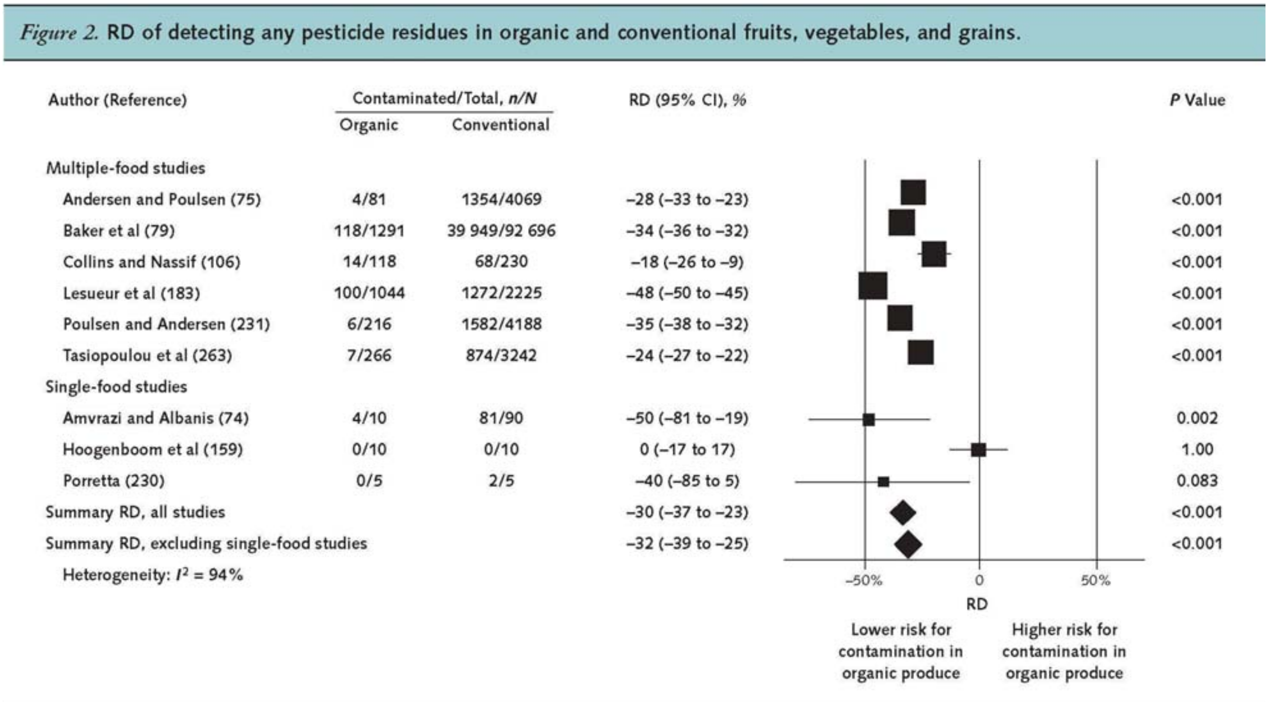


Figure 2. Risk Difference of Detecting any Pesticide Residues in Organic and Conventional Fruits, Vegetables, and Grains. Source: **(Smith-Spangler, et al., 2012)**, p. 354. Need permission from *Annals of Internal Medicine.*

Figure 2 is called a “forest plot.” A forest plot is a common tool used to display the results of meta-analyses. Here are the elements that can be seen in the figure:

- Each study is listed on the left. The numbers in parentheses are the citation numbers from the Smith-Spangler, et al. article.
- The next two columns present the pesticide residue data: the number of organic food samples with detectable residue over the number of samples, and the same for conventional foods.
- The RD, or risk difference, percent is calculated by subtracting the percent of conventional samples with detectable residues from the percent of organic samples with detectable residues. Each RD also has a 95% confidence interval (CI) and a *P* value, which reflect its statistical variability. See Box 2 for explanation of these terms used.
- The risk difference for each study is plotted graphically as a box. The RDs for studies analyzing more samples are shown as larger boxes, while studies analyzing fewer samples are represented as smaller boxes.
- Meta-analyses also calculate a summary measure of association, plotted as a diamond. Figure 2 shows two summary risk differences, the first for all nine studies, and the second for the multiple-food studies only. The width of the diamond reflects the confidence interval of the summary RD and allows us to draw a conclusion about statistical significance (see Box 2).

Let’s take a close look at some of the key findings displayed in Figure 2.

***Question 1***: *The risk difference (RD) shown for the first study listed (Anderson and Poulsen) is -28%. Use the data shown in the table to calculate this RD and, in your own words, explain what this RD means.*

***Question 2:*** *The 95% confidence interval of the RD for the Anderson and Poulsen study is -33% to -23%. Explain in your own words what this CI means.*

***Question 3:*** *The P value for the Poulsen RD is is <0.001. Explain in your own words what this P value means. Does it lead you to the same conclusion as the 95% CI about the statistical significance of the RD? Explain your answer.*

***Question 4:*** *The RD for the study by Amvrazi and Albanis is -50%, and the confidence is quite wide, -81% to -19%. Why is this confidence interval so much wider than the CI for the Anderson and Poulsen results?*

***Question 5:*** *Now look at Figure 2 for the results of this meta-analysis as a whole. In a paragraph, summarize what you think are the most important findings.*

## Part II. Environmental and Occupational Health Implications of Organic versus Conventional Food Production

**Pesticide Exposures and Health Effects**

What do we mean by the term "pesticide"? Synthetic pesticides comprise a very broad array of chemicals targeting weeds (herbicides), insects (insecticides), molds, mildew, and other microorganisms (fungicides, disinfectants), and rodents (rodenticides). Synthetic pesticides come from several chemical families, such as organophosphates, organochlorines, carbamates, pyrethoids, and others. Pesticides can also be made from natural materials.

Foods differ widely in their potential for pesticide contamination. One helpful resource is published by the Environmental Working Group (EWG) and catalogs the fruits and vegetables most likely to carry pesticide residues. EWG's 2013 Shopper's Guide to Pesticides in Produce (Environmental Working Group, 2013) describes the Dirty Dozen Plus™ along with the Clean 15™ – those produce items that are, respectively, most likely and least likely to carry pesticide residues.

The Smith-Spangler meta-analysis found that organic produce and grains were 30% less likely than conventionally-grown foods to carry detectable synthetic pesticide residues. However, it was also encouraging to see (in the small number of studies that examined this) that it was rare for pesticide residues to exceed government safety thresholds. (Smith-Spangler, et al., 2012) So, if we are exposed at very low levels to pesticides from our foods and from pesticide contamination of our air or drinking water, does this pose a health risk? Are government safety thresholds protective enough?

In a *New York Times* article published on the same day as the Smith-Spangler meta-analysis paper, reporter Kenneth Chang commented, "The scientists sidestepped the debate over whether the current limits are too high." He elicited the following comment from Dr. Dena Bravata, the senior author of the meta-analysis paper: "Some of my patients take solace in knowing that the pesticide levels are below safety thresholds . . . Others have questioned whether these standards are sufficiently rigorous." (Chang, 2012)

A very limited body of research has demonstrated that what we eat can affect pesticide body burden. For example, Lu and co-authors (Lu, et al., 2006) conducted a 15-day dietary intervention study with 23 children aged 3 to 11 years. On days 1-3 and 9-15, children consumed their typical diets. However, for days 4-8, children ate a mostly-organic diet substituted by the researchers. Results showed a clear decrease during the organic diet phase in the metabolites (breakdown products) of organophosphate pesticides commonly used on produce and grains.

And what about pesticide exposures related to agricultural use, but not coming through the food chain? It is essential to identify other routes by which humans may be exposed to agricultural pesticides. One helpful framework used by environmental health practitioners could help us organize our thoughts about this question. This framework is the Source-to-Effects Model. See Box 3 for a description of the Source-to-Effects Model.

***Question 6**: In addition to ingesting pesticides in our foods, what are other routes and pathways of pesticide exposure that could result from the use of pesticides in agriculture? For each pathway you think of, please use the framework shown in Box 3 to sketch out a Source-to-Effects Model.*

Collectively, all of these exposure pathways (and others[1]) have resulted in widespread exposure to pesticides, as indicated by results from a national biomonitoring program which measures levels of pesticide metabolites in the urine or blood of a representative sample of the U.S. population. Smith-Spangler et al. summarized the results as follows: "Testing of 44 pesticide metabolites revealed that 29 were detectable in most people from whom samples were analyzed (ages 6-59 years) . . ." (Centers for Disease Control and Prevention, National Center for Laboratory Health Division of Laboratory Sciences, 2005) as cited by (Smith-Spangler, et al., 2012, p. e1766) [2]

Take a look at the most recent U.S. biomonitoring results for organophosphate pesticides, taken from the nationally representative National Health and Nutrition Examination Survey. (Centers for Disease Control and Prevention, 2013)

- Go to http://www.cdc.gov/exposurereport/
- Click on Updated Tables, September 2013
- Go to pages 120-121 of the document (labeled pages 112-113 within the report). These are the biomonitoring results for dimethylthiophosphate (DMTP), which is a metabolite of several organophosphorus pesticides. (These results are creatinine corrected, which means they are adjusted for how dilute a person's urine was when he or she gave the sample.)

***Question 7**: Examine the table of biomonitoring results for DMTP (creatinine corrected), focusing first on the total population results for the survey years 2007-08.*

a) *Think about what the percentile distribution means, and describe in words one of the percentile results shown for 2007-08.*
b) *Now look down the total population columns at the percentile distribution for the five survey periods. Do you see any notable time trends across the five survey periods for the total population? (It may help to sketch a graph of the data.)*

[1] For example, insecticides are used in the home or in non-agricultural work settings, or in public spaces.
[2] These results are based on samples collected from 1999 to 2004. More recent nationally representative biomonitoring sample results are available (Centers for Disease Control and Prevention, 2013) for some, but not all, of the pesticides included in the report evaluated by Smith-Spangler, et al.

c) *Now compare the 2007-08 results only by age, gender, and race/ethnicity subgroups. Do you see any notable differences between demographic groups?*

To learn more about what these DMTP results mean, next click on the Biomonitoring Summary link[3] at the bottom of the page. (Centers for Disease Control and Prevention, National Biomonitoring Program, 2013) Read this report.

***Question 8**: From information presented in the Biomonitoring Summary, revisit your answer to Question 6. Does the Biomonitoring Summary mention any possible routes of exposure and/or receptors (exposed populations) that you missed? Did you think of any not mentioned by the Biomonitoring Summary?*

***Question 9**: The health effects of organophosphate pesticides are well documented in workers, whose potential exposures can be much higher than for the general public. From the Biomonitoring Summary, what do we know about pesticide health impacts among workers or other highly exposed populations?*

***Question 10**: From the Biomonitoring Summary, also identify and describe two <u>other</u> issues you believe are relevant in the context of this case study – that is, issues relevant to the environmental health implications of purchasing organic foods.*

So, what is known about the health effects of low dose pesticide exposures – not just for organophosphates, but for pesticides in general? Epidemiologic studies have investigated the relationship of chronic pesticide exposures with a wide variety of possible health outcomes. A recent review of research on children and pesticides (Roberts, J. R.; Karr, C. J.; Council on Environmental Health, 2012) identified the most consistent associations for acute lymphocytic leukemia, brain tumors, and neurodevelopment and behavior. Other child health outcomes for which the evidence base is not as robust include birth defects, low birth weight, and fetal death. Some pesticides are endocrine disruptors, synthetic chemicals that mimic or block hormones such as estrogen. The research base is not yet adequate to draw conclusions about the effects of exposure to endocrine disrupting chemicals in either children or adults.

As with all epidemiologic studies of environmental exposures, a number of issues limit our ability to causally link health outcomes to pesticide exposures. Health problems may develop many years after exposure starts – a concept called "latency." Consequently, researchers must try to estimate exposures going back years or decades. This is especially challenging for dietary exposures, since it's challenging to recall past diet, and also because consumers of conventionally-produced foods have no way to tell whether or not the foods they ate were contaminated with low-level pesticide residues. The research base is inadequate in other aspects as well. Regulatory risk assessment considers safety limits for one chemical at a time, when in fact, we are exposed to multiple pesticides and other chemicals whose effects may be cumulative.

In the face of uncertainty about the health risks from low-dose exposures to wide variety of pesticides, many environmental health experts hold up the "precautionary principle" as a lens through which public policy decisions should be made. The precautionary principle has been described in many different ways, including: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." (Wingspread, 1998) This formulation, called the "Wingspread Statement," is

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[3] If the hyperlink does not work, access the Biomonitoring Summary at http://www.cdc.gov/biomonitoring/OP-DPM_BiomonitoringSummary.html

just one way of describing the precautionary principle. However, they all boil down to one simple idea: that we should err on the side of prevention in environmental decision-making.
U.S. pesticide regulation and chemical regulatory reform are beyond the scope of this case study. It is worth noting, however, that individual decisions whether to purchase organic or conventionally-grown foods are made in a wider context – that of whether pesticide exposures from conventional agriculture pose a risk to our health.

**Meat Animal Production Practices**

In the U.S., most of the meat, eggs, and dairy products we consume come from animals produced in large-scale industrial operations. (Hribar, 2010) According to the U.S. Environmental Protection Agency's, concentrated animal feeding operations, or CAFOs, are specific types of animal feeding operations that house large numbers of animals in confined conditions and that have the potential to discharge waste into surface water. For example, a "large CAFO" might have at least 55,000 turkeys, 10,000 swine weighing less than 55 pounds, or 700 mature dairy cows. (U.S. Environmental Protection Agency, 2012) What are the environmental health implications of industrial meat production practices, in contrast with organic animal production practices?

The waste generated by all those animals is a major environmental challenge posed by CAFOs. Feedlots typically store manure in lagoons or pits to be anaerobically digested while awaiting application to nearby fields. These lagoons may leak or may overflow during heavy rains, or waste applied to fields may run off the land or leach into groundwater. Livestock waste contains the nutrients nitrogen and phosphorus, as well as heavy metals such as zinc and copper. It may also be contaminated with pathogens, antibiotics, and naturally excreted hormones. (Burkholder, et al., 2007)

Because the high density of animals in CAFOs can enhance the spread of pathogens, producers commonly administer antibiotics to prevent microbial infection. Furthermore, antibiotics are used as growth promoters.

***Question 11****: Briefly characterize as many environmental and occupational health impacts as you can that are likely to differ between conventional and organic production of animals for food.*

***Question 12:*** *Can you find any evidence from credible online sources to suggest that the widespread use of animal antibiotics is harming humans? In a couple of paragraphs, summarize this evidence.*

***Question 13:*** *Some people make decisions about whether to eat meat, or what types of meat to eat, based on ethical considerations rather than health considerations. Describe one ethical issue that resonates with you or with someone you know.*

**Carbon Footprint of Organic vs. Conventional Farming Practices**

Speaking about the U.S., author and food policy expert Michael Pollan wrote: "After cars, the food system uses more fossil fuel than any other sector of the economy – 19%." (Pollan, 2008) Some of these types of energy demands are common to both organic and conventional agriculture, while others are more specific to conventional agriculture.

***Question 14****: Describe the primary mechanisms by which our food system contributes to the USA's carbon footprint. Select <u>one</u> of these mechanisms for which you believe that conventional and organic* *farming practices might differ substantially in their carbon footprint. See what you can find online to support your assumptions. Summarize the evidence you find.*

**Nutrient Pollution**

In addition to reducing pesticide exposures, organic farmers adhere to soil conservation practices, reducing soil erosion and retaining nutrients on the land. This reduces runoff of fertilizers and manure, which are rich in nitrogen and phosphorus and contribute to nutrient pollution. According to the U.S. Environmental Protection Agency, nutrient pollution ". . . is one of America's most widespread, costly and challenging environmental problems . . ." (U.S. Environmental Protection Agency, 2013) Overloads of nitrogen and phosphorus promote growth of too much algae in our rivers, lakes, estuaries, bays, and oceans. This, in turn, decreases oxygen levels necessary for the health and survival of fish and other aquatic species. Nutrient pollution is so severe in some parts of the world that massive low-oxygen areas, or "dead zones," have been created. (U.S. Environmental Protection Agency, 2013)The northern Gulf of Mexico, adjacent to the mouth of the Mississippi River, comprises the largest dead zone in the U.S. and the second largest dead zone in the world. (Louisiana Universities Marine Consortium, 2013)

In addition to its impacts on surface waters, the U.S. EPA notes: "Nutrient pollution in – which millions of people in the United States use as their drinking water source – can be harmful, even at low levels." (U.S. Environmental Protection Agency, 2013) Nitrates in drinking water are particularly hazardous for young infants. (U.S. Environmental Protection Agency, 2013)

## Part III. Other Health & Economic Issues

In considering whether to consume food produced organically vs. conventionally, a few other health and economic issues might be taken into account. First, U.S. food products must meet the same quality and safety standards whether they are conventional or organic. (Mayo Clinic, 2012) Secondly, as discussed in the Stanford meta-analysis, research indicates organically & conventionally produced foods have comparable nutrient content. (Smith-Spangler, et al., 2012)

Food additives are yet another distinction between organic and conventional foods. Chemical additives are commonly used in nonorganic foods as preservatives, artificial sweeteners, coloring agents, and flavoring agents. Although food additives are regulated in the U.S., it is, according to the popular Discovery Communications website howstuffworks.com, ". . . not uncommon for a food additive that was originally believed to be safe for consumers to later be found toxic." (Discovery Communications, LLC, 2013) The limited research on the long-term health risks of food additives is one reason that some people opt for organic foods, which severely limit food additives, processing aids, and fortifying agents. (Mayo Clinic, 2012)

As mentioned previously, use of genetic engineering (also known as genetic modification or GM) is prohibited in U.S. organic food production. (U.S. Department of Agriculture, 2012) Genetic engineering modifies the genetic material (DNA) of organisms in ways that do not occur naturally, by transferring individual genes between organisms, including between non-related species. Genetic engineering has a number of potential benefits. It can protect crops and animals by increasing their resistance to pests or diseases (thus decreasing needs for pesticides). It can create herbicide-tolerant crops, so that weeds can be removed with a single, quick application of broad-spectrum weed-killer. It can create plants to grow in poor soil or drought conditions and can create faster-growing plants and animals. (World Health Organization, 2013) Finally, it can improve nutritional value of foods; the most commonly cited example is "golden rice" fortified with Vitamin A. (Golden Rice Humanitarian Board, 2013)

However, there are also a number of potential health and environmental concerns relating to the production of GM foods, and research is not keeping pace with rapid developments and market expansion of GM food products.

***Question 14***: *The World Health Organization has a good FAQ discussion of current GM issues that consumers and health and regulatory authorities have been concerned about. Read this information, at http://www.who.int/foodsafety/publications/biotech/20questions/en/. Describe two concerns that you think deserve the most attention. What types of research would help to resolve these concerns? How has examining this brief evidence about potential harms and benefits of GM foods changed any of your own prior conceptions?*

***Question 15:*** *How might the precautionary principle be applied in governmental decision-making regarding genetically modified foods?*

Finally, organic foods are more expensive to buy, compared to conventional foods. First, demand for organic foods is outpacing supply, keeping prices up. But there are many real cost factors as well that explain this price premium; here are just three examples. For one thing, organic practices are more labor-intensive. Secondly, economies of scale during growing, post-harvest handling, and marketing and distribution are not as prevalent for organic foods. (Food and Agriculture Organization of the United Nations, 2013) (Fox News, 2012) Government subsidies for foods such as corn and soybeans also drive down prices of commodity crops, meat, and dairy. Agricultural subsidies thus influence the price gap between organic and conventionally grown foods, but also fail to support "healthy" conventional foods such as fruits and vegetables. (Fox News, 2012) During the fall 2007 Congressional debates over the Farm Bill, the Physician's Committee for Responsible Medicine published a now-popular graphic (see Figure 3) that helps to illustrate the impact of agricultural subsidies.

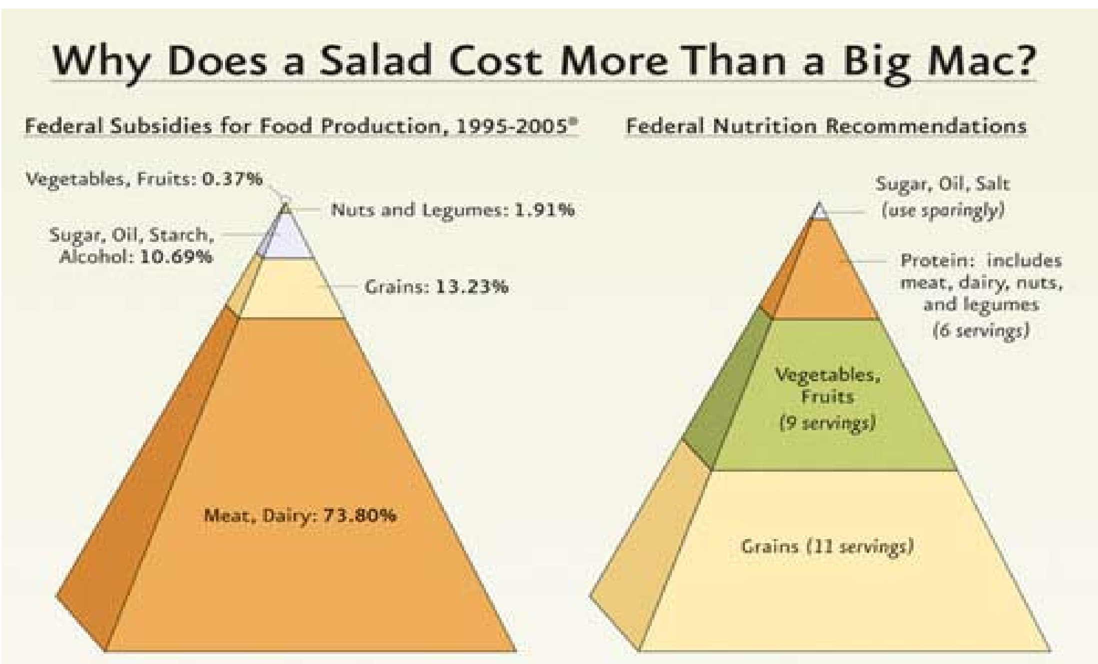


Figure 3. Why Does a Salad Cost More than a Big Mac?
Source: (Physicians Committee for Responsible Medicine, 2007) Additional discussion at: http://www.pcrm.org/good-medicine/2007/autumn/health-vs-pork-congress-debates-the-farm-bill

## Part IV. Jordan's Shopping Basket

Conventional and organic agricultural practices impact environmental quality, health, and sustainability in other ways as well, but the issues summarized above are some of the most important considerations.

***Question 16**: What else is important to know about Jordan, to inform your advice? Are there any other factors that might influence this decision?*

***Question 17:** Of all the issues raised in this case, which do you think are most important for consumers like Jordan to consider? Why?*

***Question 18**: What will you suggest to Jordan? What would you put in <u>your own</u> shopping basket?*

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## About the Author

Katherine Hunting is Professor of Environmental and Occupational Health (EOH) and of Epidemiology and Biostatistics at the George Washington University (GW) School of Public Health and Health Services. Dr. Hunting earned her B.S. in Environmental Science from the University of California at Riverside and an M.P.H. and a Ph.D. in Epidemiology from Johns Hopkins University. She joined GW in 1988 as a research scientist, and was appointed to the faculty the following year. Professor Hunting is an expert in epidemiologic study design and injury epidemiology, particularly as they pertain to studies of workers. She co-edited *Essential Case Studies in Public Health: Putting Public Health into Practice*. This text, published in 2012, consists of 21 teaching cases illustrating a wide variety of public health issues.

An experienced academic administrator, Professor Hunting directed the MPH program in Environmental Health Science and Policy for 18 years. She also served for six and a half years in the dean's office, first as Associate Dean for Student and Faculty Development, and then as Associate Dean for Academic Affairs. In Fall 2010 she returned full time to the EOH department, where as Vice Chair for Educational Activities, she focused on educational program development, operations, and evaluation. During the 2013-14 academic year, she is enjoying a sabbatical leave.

Professor Hunting finds it vastly gratifying to help students understand and appreciate research methods. Over her 25 years at GW, she taught hundreds of graduate students in courses including principles of epidemiology, environmental and occupational epidemiology, injury epidemiology. Furthermore, Professor Hunting was also privileged to teach environmental health to undergraduates for six semesters. This case study was born from her interest in organic gardening and her observation that young adults are intensely interested in issues connecting food, health, environment, and sustainability.

**Box 1 – What is a systematic review? What is a meta-analysis?**

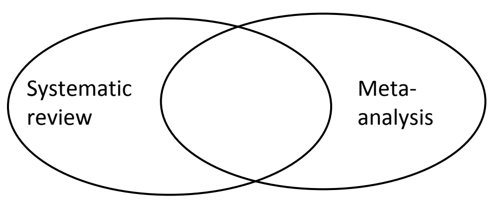
Systematic review and meta-analysis are related types of research synthesis activities.

A *systematic review* uses an "explicit and systematic approach" (Khan, Kunz, Kleijnen, & Antes, 2003) to identify, evaluate, and summarize the evidence on a given research question. Systematic reviews typically follow these steps:

1) Clearly define the question to be addressed.
2) Use a systematic and thorough approach to identify relevant studies. The study selection criteria – including sources that will be searched and minimum quality criteria for inclusion – should be specified in advance (*a priori*).
3) Assess the quality of selected studies.
4) Summarize the evidence. This is the data synthesis step, where study characteristics and specific results are tabulated.
5) Interpret the findings. Consider whether findings are consistent (homogeneous) or variable (heterogeneous). If results are heterogeneous, consider whether study quality or other study characteristics explains the variation in findings.

*Meta-analysis* is a method for systematically extracting data from individual studies, and then calculating a quantitative summary result across all studies. The summary result might also be labeled a summary measure of association, and is calculated as a weighted average of the individual studies. Sample size of individual studies is always used as a weighting factor. Sometimes the quality of individual studies is also used to weight the summary measure. In addition to estimating a specific summary measure of association, a meta-analysis also calculates the confidence interval (see Box 2) of the summary measure to take into account the possibility of chance variation.

Though they are related, they are not the same. Every systematic review does not include a meta-analysis. And every meta-analysis is not based upon a systematic review, though it should be! The Cochrane Collaboration illustrates this with a Venn diagram:




The Smith-Spangler article presents a systematic review, as well as a meta-analysis for the research questions where enough evidence was available to calculate quantitative summary measures.

Sources: (Khan, Kunz, Kleijnen, & Antes, 2003); (The Cochrane Collaboration, 2002)

**Box 2 – What is a p-value? What is a 95% confidence interval? What is statistical significance?**

When evaluating a particular result from a research study, we must consider three general explanations:

- the finding is real;
- the finding can be explained by bias – that is, systematic flaws in the way a study population was selected or variables were measured, or errors from being unable to account for all relevant factors;
- the finding occurred by chance.

Researchers use statistical testing to evaluate the role of chance, that is, to figure out how likely it is that chance might be accounting for the observed result. We call this "testing for statistical significance." *Statistical significance* can be evaluated from *p (probability) values* and *confidence intervals*.

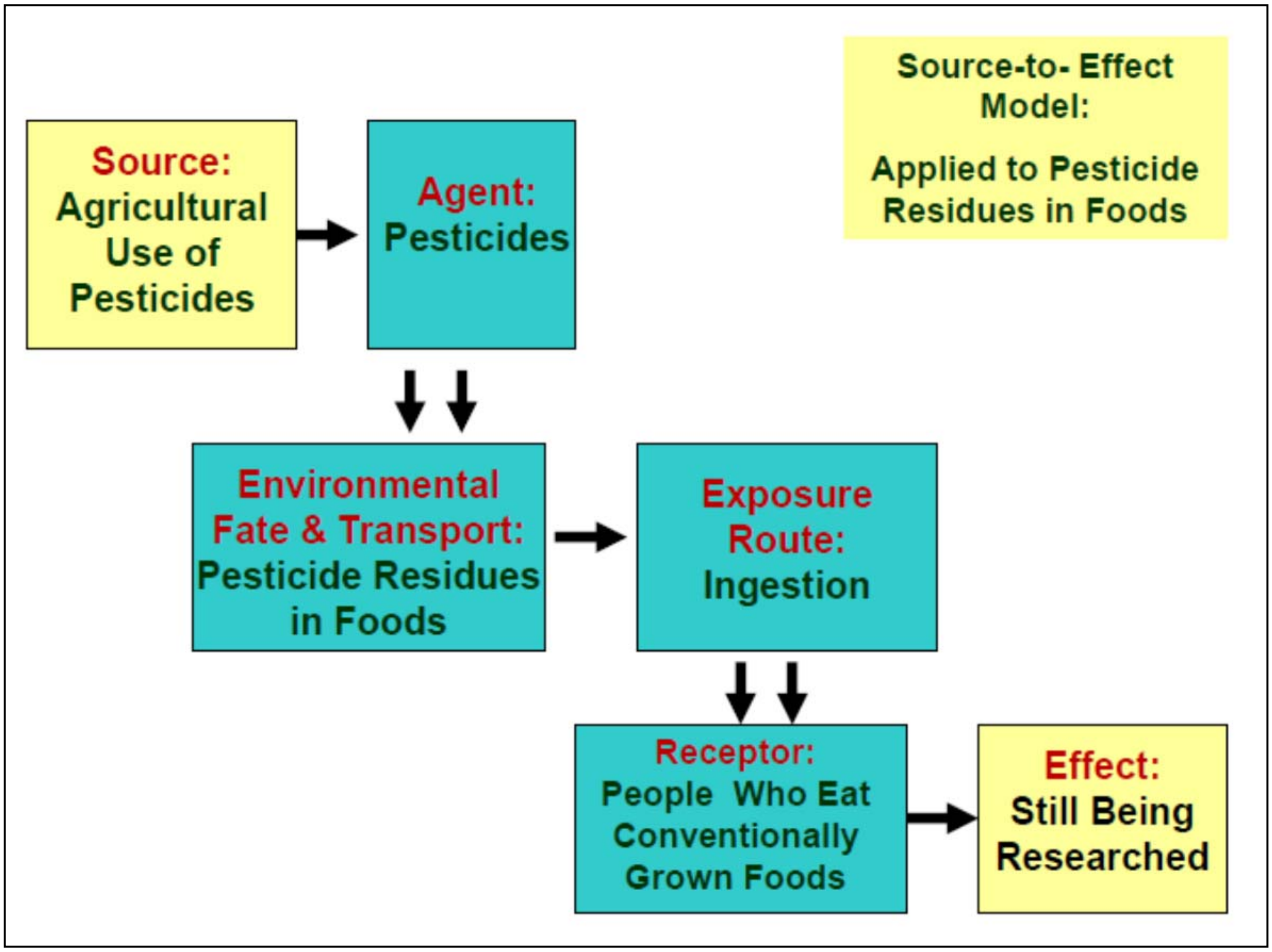
According to Last's Dictionary of Epidemiology (International Epidemiologic Association, 1995):
*P (probability) value* is "the probability that a test statistic would be as extreme as or more extreme than observed if the null hypothesis were true."

For example, one outcome examined by the organic foods meta-analysis (Smith-Spangler, et al., 2012) was the proportion of chicken and pork samples found to carry bacteria resistant to three or more antibiotics. The null hypothesis was that there is no difference in the proportion of conventional and organic meat samples showing this level of antibiotic resistance. In fact, when relevant results from five studies were compiled, conventional chicken and pork samples were 33% more likely than organic samples to find bacteria resistant to three or more antibiotics. The *P value* was less than 0.001. This means that a difference of 33% (or more) would likely occur by chance alone less than 1 in 1,000 times, if the null hypothesis were true (that is, if there was really no difference in the occurrence of antibiotic resistance). Because 1 in 1,000 is very unlikely, we *reject the null hypothesis* and we say that the 33% observed difference is *statistically significant.* That is, it was unlikely to be explained by chance. Researchers often use a 5% cutoff to evaluate statistical significance; that is, if $P < 0.05$, then they will reject the null hypothesis and declare that an observed difference is *statistically significant*.

The same Smith-Spangler analysis of antibiotic resistance in chicken and pork also found that the *95% confidence interval* around the 33% difference was 21% to 45%. Here is one definition of the confidence interval: "The confidence interval describes the uncertainty inherent in [an] estimate, and describes a range of values within which we can be reasonably sure that the true effect actually lies. . . [This] is based on the hypothetical notion of considering the results that would be obtained if the study were repeated many times." (The Cochrane Collaboration, 2011) A 95% confidence interval of 21% to 45% means, if the research was repeated, that 95% of the time the observed difference would lie between 21% and 45%.

"There is logical correspondence between the confidence interval and the P value . . . The 95% confidence interval for an effect will exclude the null value (such as an odds ratio of 1.0 or a risk difference of 0) if and only if the test of significance yields a P value of less than 0.05." (The Cochrane Collaboration, 2011) Thus, in the Smith-Spangler example, the 95% confidence interval of 21% to 45% definitely excludes the null difference of 0%. This supports the conclusion already made above from the *P* value, that we can reject the null hypothesis and declare there is a statistically significant difference in the likelihood that the bacteria found in conventional and organic chicken and pork samples demonstrate resistance to three of more antibiotics.

**Box 3 – The Source to Effects Model, Applied to Pesticide Residues in Foods**



**Organic Foods: Examining the Health Implications**
**Case Study for AAC&U STIRS Project**

**©Katherine Hunting, PhD, MPH**
**The George Washington University School of Public Health & Health Services**

**Draft Facilitator Materials for Part I Only** (10/20/2013)

*Note to prospective facilitators about my first experience teaching this case:* Part I of this case study focuses strongly on statistical concepts, and only introduces issues relevant to the health implications of organic vs. conventional foods. Parts II and III focus most strongly on the environmental and occupational health implications of organic vs. conventional food production. I have taught Parts I and II with my undergraduate environmental health class of 30 students. I gave them a version of the case study omitting questions 2, 3, and 4 because I didn't want to emphasize the statistics so much, and omitting questions 12 and 13 because I had not written them yet.

Their assignment ahead of time was to read the case study (with questions included), the DMTP biomonitoring table referenced on page 6, and the Biomonitoring Summary referenced on page 7. I asked them to come to class prepared to work on the case study in small groups. We started class with a brief group discussion of the key findings of the Smith-Spangler systematic review and meta-analysis. Then I set them to work in groups of three on discussing the questions. I rotated between groups to answer questions and to check in on how they were doing. They found it challenging to interpret the results from the DMTP biomonitoring table. At the end, we had another brief all-class discussion focusing on the last two questions (Jordan's decision). Many but not all of the small groups were able to get through all the questions in our 75 minute class session. We could have used a bit more time for all-class discussion of some of the key issues. I did not have my students do a written assignment when I piloted the case.

The following facilitator materials pertain ONLY to Part I of the case. Additional facilitator materials are currently under development.

**Part I Learning Objectives**

1. Interpret and summarize research findings presented graphically.
2. Calculate a measure of association and explain what it means.
3. Explain the meaning of a confidence interval and a p-value.
4. Explain how sample size affects a confidence interval.

**Teaching Suggestions**

Following is a suggested outline for using Part I of the case study as an in-class activity. These activities should take approximately 60-75 minutes.

1. Have the students read the Part I of the case study before coming to class. (Do not include Questions 1-5 in the student reading assignment.)
2. Open the class with the following brainstorming exercise: "Let's do a quick brainstorming session and try to identify as many of the possible health implications as we can for choosing organic vs. conventional foods. Consider what you've learned so far from reading this case. Take 3 minutes

and write down two health issues you'd like to know more about. For each health issue you identify, write down an example of a scientific question you would like to have answered about that issue." Depending on the size of your class, you can ask the students to brainstorm singly, in pairs, or in groups of three.

3. Elicit student ideas and write issues on the board, along with the research question or type of evidence that the students suggest. This is a partial list which just happens to outline the other parts of this case study! It will be helpful to organize these suggestions roughly as follows:
   - Health effects from exposures to pesticide residues in foods
     - What types of health effects? How high is the risk? Are there particularly susceptible populations? How much exposure does one need to experience health risk? Are government standards protective enough?
   - Health effects from exposure to pesticides through environmental contamination (drinking water, air exposures to spraying, etc)
     - Same questions as above. Both of these questions have to do with relatively low level exposures.
   - Health effects to workers from pesticide exposures.
     - Same questions as above. Here we are concerned about acute poisonings from higher exposures as well as health effects of chronic low level exposures.
   - What are the human health implications of industrial animal production practices, in contrast with organic animal production practices?
     - What are health impacts from nontherapeutic use of antibiotics (to promote growth or prevent disease) and related development antibiotic resistant bacteria? (on workers, on population at large)
     - What are the environmental health impacts of animal waste from concentrated animal feeding operations (CAFOs)? (odors, air emissions, water quality)
     - Is meat from organically raised animals more nutritious?
   - What are the animal health implications of organically vs. conventionally raised meat? (this is more an ethical question than an environmental health question)
   - What is the carbon footprint of organic vs. conventional foods?
   - Do organic production practices have other sustainability advantages that impact human health?
   - Do food additives used in conventional foods have adverse human health effects?
   - What about the risks and benefits of genetically modified foods?
   - Organic foods cost more. Is the cost worth the benefit?
4. Hand out questions 1-5. Ask students to work in pairs or groups of 3 for about 20-25 minutes to answer the questions.
5. Discuss answers to questions 1-5 with entire class.

**Answers to Part I Case Study Questions**

***Question 1***: *The risk difference (RD) shown for the first study listed (Anderson and Poulsen) is -28%. Use the data shown in the table to calculate this RD and, in your own words, explain what this RD means.*

- For the Anderson and Poulsen study, 4/81 of organic samples had detectable residues (4.9%), compared to 1354/4069 conventional samples (33.3%). The RD = 4.9% - 33.3% = -28.4%, which rounds to -28%. This means that the organic foods sampled by Anderson and Poulsen were 28% less likely than the conventional foods sampled to have detectable pesticide residues.

***Question 2:*** *The 95% confidence interval of the RD for the Anderson and Poulsen study is -33% to -23%. Explain in your own words what this CI means.*

- The 95% CI of -33% to -23% means that, if this study was repeated many times, the observed risk difference would be between -33% and -23% ninety-five percent of the time. Thus, the true RD is highly likely to be in the range of -33% to -23%.
- The other conclusion we can draw from this CI is that the risk difference of -28% is statistically significant – you can tell this because the 95% CI does not include the null risk difference of zero. Thus, we can reject the null hypothesis that there is no difference in the prevalence of pesticide residues between the conventional and organic foods sampled by Anderson and Poulsen.

***Question 3:*** *The P value for the Poulsen RD is is <0.001. Explain in your own words what this P value means. Does it lead you to the same conclusion as the 95% CI about the statistical significance of the RD? Explain your answer.*

- The null hypothesis would be that there was truly no difference in the prevalence of pesticide residues between conventional and organic foods.
- The P value of <0.001 means that, if this study was repeated numerous times, and the null hypothesis was true, the probability of observing a risk difference this strong or stronger (that is, -28% or stronger) by chance alone would be less than one in 1,000. Thus, we would be highly unlikely to observe an RD this strong by chance if the null hypothesis were really true. Because this P value (probability value) is less than the conventional cutoff of 0.05, we declare the risk difference to be statistically significant and we reject the null hypothesis.
- Here, the 95% confidence interval and the P value lead to the same conclusion about statistical significance. This should always be the case. If the CI and P value lead to different conclusions, then check for calculation errors!

***Question 4:*** *The RD for the study by Amvrazi and Albanis is -50%, and the confidence is quite wide, -81% to -19%. Why is this confidence interval so much wider than the CI for the Anderson and Poulsen results?*

- Sample size is the primary determinant of the width of the confidence interval – the bigger the sample size, the narrower the confidence interval. The Amvrazi and Albanis results are based on a very small number of samples, so the confidence interval is much wider.
- Note that this is true despite the very strong RD, -50%. The RD (a measure of the strength of the association) and the confidence interval (a measure of statistical precision) describe two different aspects of the data.

***Question 5:*** *Now look at Figure 2 for the results of this meta-analysis as a whole. In a paragraph, summarize what you think are the most important findings.*

- Key Results: The summary RD is -30%, with a 95% confidence interval of -37% to -23%. Thus, taking results from all nine of the reviewed studies into consideration, the samples from organic foods were 30% less likely than the samples from conventional foods to be contaminated with pesticide residues. The P value of <0.001 indicates the risk difference is highly statistically significant.
- The results appeared quite consistent across studies; eight of the nine studies yielded statistically significant negative risk differences ranging from -18% to -50%, while one study showed no difference in the prevalence of pesticide residues.
- Six of the studies sampled multiple types of foods, while three focused on single foods. When only the multiple food studies were considered, the summary RD was slightly stronger, -32% (95% CI -39% to -25%).

- Three aspects of these Figure 2 results support the assertion that this association is causal or true – that organic foods are truly less likely than conventional foods to be contaminated with pesticide residues.
    - First, that the strength of association is substantial; a difference of 30% is observed.
    - Second, that the CI is highly statistically significant (P value <0.001), thus we can rule out the role of chance as an explanation for the difference seen.
    - Third, that the results were quite consistent across the studies reviewed.

*These five questions from Part I all revolve around statistical concepts. Here are the most applicable key words: Reductionist science; Validity; Accuracy; Precision; Strength of Association; Risk Difference; Null Hypothesis; Statistical Significance; Random or Chance Error; Interpretation of Causality; Visual Display of Data; Graphical Methods.*

**Other Instructional Resources**

Audio interview with authors (4 minutes) at http://annals.org/article.aspx?articleid=1355685&atab=4

The key article upon which this case study is based:
Smith-Spangler C, Brandeau ML, Hunter GE, Bavinger JC, Pearson M, Eschbach PJ, Sundaram V, Liu H, Schirmer P, Stave C, Olkin I, Bravata DM . Are Organic Foods Safer or Healthier Than Conventional Alternatives? A Systematic Review. *Ann Intern Med*. 4 September 2012;157(5):348-366.

Summary news articles and lots of reaction on web:
- http://med.stanford.edu/ism/2012/september/organic.html
- http://www.nytimes.com/2012/09/04/science/earth/study-questions-advantages-of-organic-meat-and-produce.html?_r=0
- http://scopeblog.stanford.edu/2012/09/04/stanford-study-on-the-health-benefits-of-organic-food-what-people-are-saying/ (among others)

PowerPoint slide set (to be developed)