Social Acceptance of Technologies

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by

Andrey V. Sklyar

Jonathan W. Smith

Carlton C. Stedman II

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Dr. Nancy A. Burnham, Major Advisor

Dr. Jianyu Liang, Co-Advisor

Abstract

Nanotechnology is a rapidly growing field which brings benefits to all fields of technology. Social acceptance of technology is a very important part of the success of a technology. By studying patterns of acceptance in established technologies that range from unobtrusive to invasive technology, this report has shown ways that previous technologies have stumbled. By knowing the problems of the past we want nanotechnology to make as many efforts as it can to avoid them.

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1 Introduction

1.1 Scope of Report

As new technologies develop, a primary concern is how the public is going to respond to these novel applications of scientific research. Certainly, proponents of the technology, especially those with a financial motivation in the field, would like for all people, from industry and government down to consumers, to approve of their technology, accept it, and, most importantly, buy it. Unfortunately, this is not always the case. Typically, new technologies are met with some modicum of resistance; only through specific plans directed to proliferate the technology can widespread distribution of its applications take place. It is therefore incredibly important that stakeholders be made aware of specific means that can secure a high level of acceptance of their technology.

One of the most recent technologies that has begun to find real applications is nanotechnology. It is believed that nanotechnology has great potential, as "the panacea to all our woes", being able to bring about "a seismic shift in almost every aspect of science and engineering with implications for ethics, economics, international relations, day-to-day life, and even humanity's conception of its place in the universe" (Ratner and Ratner, 2003, p. 2). Many believe that within the next several decades, nanotechnology will grow up from the starting roots of today to revolutionize science and the world. Already there are various applications within the field, making use of components mere nanometers in size. These devices are currently trapped within niche markets, but the potential for such small, inexpensive, and efficient constructions seems unbounded. The nanotechnological field is growing without any end in sight.

While the nanotechnology revolution approaches, the question of social acceptance of certain applications is pertinent. A lack of social acceptance could greatly impede the development of applied nanoscience for particular uses. It is vital that the public finds nanotechnology to be agreeable for it to flourish. If nanoscience faces harsh criticism that turns the public against it, the field must find a way to save itself and ensure the growth of knowledge. Only by considering the issues society might raise and what could sway the opinion of the public can nanoscientists preserve the advancement of their field.

The likelihood of society condemning nanotechnology can be ascertained by inspecting historical evidence. By studying the social acceptance of other technologies, scenarios that determine the social response and the level of adoption throughout history can be considered. These historical models may draw parallels to nanotechnology such that potential issues and solutions can be hypothesized. The study of documented cases of public approval of different technologies can be used to find concerns that may stand in the way of nanotechnology becoming socially acceptable.

In this report, nanotechnology will be compared to three technologies, each with a different history of social acceptance, in order to extrapolate public responses to likely adverse situations. The technologies we chose include: nuclear energy, genetic modification of foods, and vaccines. Through looking at the issues encountered in these models we intend to draw parallels or show distinct differences to the growing field of nanotechnology. We intend to show why acceptance increases or decreases over time, in order to supply the scientific community with reasons for seemingly fickle public approval. Our goal as advocates of nanotechnology is to consider similarities and differences of the history of these technologies to purpose what can be done to secure the growth of nanotechnology and widespread public acceptance.

The rest of this section will provide the reader an entry into the research and findings of our report. First we shall provide some background information concerning nanotechnology, including a formal defintion, in section 1.2, and, in section 1.3, some potential benefits of the application of nanoscience. We shall then continue by discussing why we chose the three technologies to compare to nanotechnology in section 1.4 and then, in section 1.5, go into how we went about conducting the research for this report. This section will conclude with section 1.6, an outline for the rest of this report.

1.2 Definition of Nanotechnology

There is no doubt: nanoresearch is thriving. Simply claiming a link to nanotechnology is a tried and true method to receive copious research funds. With the advent of Clinton's National Nanotechnology Initiative, kept up under the Bush administration, a plethora of universities and corporations have received considerable funding to pursue advances in nanoresearch (Stix, 2001). It is a fact that if a company labels a proposal as nanotechnological in nature it has a much better chance of being funded. As Stix pointed out in 2001, “nanotechnology has become the most highly energized discipline in science and technology” (p. 6), noting that,

> “Probably not since Du Pont coined its corporate slogan 'better things for better living through chemistry' have scientists who engage in molecular manipulation so adeptly captured and held public attention – in this case, the votes of lawmakers in Washington who hold the research purse strings.” (p. 7)

This has lead to an inadequate definition of nanotechnology and has generated much hype, exclaiming it to be a “grand unifier of the applied sciences” (Stix, 2001, p. 16). At this time, merely saying something is “nano” is a sure fire way to garner acceptable capital.

And yet, most of the public does not even know what nanotechnology is, never mind the potential benefits. Business, industry and scientists build up much hype, but, at large, the average citizen is widely uneducated concerning nanotechnology. In fact, only thirty percent of the populace is familiar with the term “nanotechnology” (Penn, Schoen & Berland Associates, 2005). An unfortunate consequence of the freedom of writers' imaginations has associated nanotechnology with futuristic visions of Drexler's “gray goo” epidemic, where all living matter on Earth is devoured by rampant self-replicating nanobots, and technological utopias akin to Huxley's *Brave New World*. The sensationalism spread from such fiction leads many to see nanotechnology as a gateway towards providing “godlike control over matter” (Stix, 2001, p. 13), for better, as with Drexler's claims that nanotechnology could nullify pollution, provide for better space travel and even bring back the dead (2001), or for worse. Many nanotechnologists find these ideas laughable, mere brouhaha, but the public, misinformed from these sources, has connected these concepts with nanotechnology (Stix 2001), leading many of those that have heard of nanotechnology to follow these misconceptions.

It is important to understand the definition of nanotechnology in order for the public to accurately attribute benefits and risks. Without a proper definition, society may group the effects of many non-nanotechnological products with nanotech, including harmful and dangerous characteristics. The definition we have chosen to use was clarified by Mike Roco of the National Science Foundation in 2001, stating,

> “Nanoscale science and engineering here refer to the fundamental understanding and resulting technological advances arising from the exploitation of new physical, chemical and biological properties of systems that are intermediate in size, between isolated atoms and molecules and bulk materials, where the transitional properties between the two limits can be controlled” (as cited in

Ratner and Ratner, 2003, p. 7).

This definition sets a size requirement for nanotechnological devices and lays a further claim that this size must be what provides the product its special features. Therefore, simply miniaturizing current systems does not imply their nanotechnological nature, since the shrinking does not necessarily modify its characteristics or use. There are applications available right now that fit this definition. Unfortunately, many products that are currently being labeled as nanotechnology do not fit this definition, mainly because the size does not provide further functionality. As such, nanotechnology has become a buzz word within the business community, further confusing the public into misunderstanding nanotechnology. (Stix, 2001)

With a proper defintion of nanotechnology, the true potential and benefits can be made clear. Being able to distinguish that which is crafted on the foundational research of nanoscience versus products that are merely nanoscopic in size allows one to verify what the expected benefits of nanotechnology are. Now, the benefits of devices that are nanoscopic in size and functional due to their size can be discussed.

1.3 Potential Benefits of Nanotechnology

Nanoresearch has the potential to create an explosion of knowledge, driving towards a 21st-century revolution of technology, reaping bountiful gains in all matters of science, engineering, chemistry, biomedicine and more. As Stix summarized in 2001, "nanotechnology has become the most highly energized discipline It is impossible to truly predict the breadth or depth of innovation that could be made feasible with widespread nanoscientific methods. The industrial revolution and its effects could be daunted by the prospects of nanoscience applications.

The potential benefits from applying nanoscience are just beginning to catch the eye of industry and businesses. Striving to produce faster, more sensitive and less power consuming electronics, it is believed that the development of nanoelectronics could break the limits of the past (Lieber, 2001, p. 92). The properties of carbon nanotubes, "an entirely new form of matter" (Ratner and Ratner, 2003, p. 133) already developed through nanoscience applications, have people thinking about all of their possible applications, in various fields including nanoelectronics, nanocomputing and countless others. Materials can be engineered at the nanolevel to have certain properties, such as being hydrophilic or hydrophobic, granting them abilities beyond past possibilities of direct relevance to the biomedical and nanodrug fields. Using nanostructures, extremely thin and highly insulating materials have been made that can be used to make lighter and more effective fire protection suits and aid development of products in numerous fields of interest. The list of possibilities and potential applications goes on *ad infinitum,* virtually endless, with a myriad of applications that may seem like science fiction in the present day. The hopes for using nanoscience to make these materials and solve problems long considered impossible is that it will allow products to be smaller, faster, more efficient, more beneficial and less expensive than ever before. (Ratner and Ratner, 2003)

1.4 Purpose of Research

In order to evaluate the potential acceptance of and social reactions and possible counter-reactions to nanotechnology, it was necessary to consider the past. Only through looking at the history of acceptance of past technologies is it possible to hypothesize as to the route that nanotechnology may take in its quest to achieve social acceptance. Additionally, reviewing the problems and solutions to previous technologies affords the field the ability to learn from the past and find out what to do in order to provide maximum approval. To discern how society will react to nanotechnology and figure out what nanotechnology enthusiasts can do to keep acceptance high, we looked at three technologies with a history of differing levels of social acceptance that we found to be related to various applications of nanoscience.

One of the least personal, yet highly controversial technologies is nuclear energy. People know that it produces electricity to power their home, but very few actually deal with a nuclear power plant directly. They accept the benefits while maintaining a distance from the actual source. This is an *apropos* technology to explore, since there will be applications in the nanotechnological field that do not affect people personally. Additionally, nuclear energy has certainly had its high and low points of social acceptance since the forties when it was first developed. Maintaining a personal distance, nuclear energy is technology similar to more removed nanoscience applications with a history of approval ups and downs.

A more personal technology is the genetic modification of foods. By engineering the food to have specific qualities, scientists can control what people consume. Although countless benefits of the modified food are possible, at the same time, there is always the question of whether or no the scientists did it right, or if they mistakenly increased the toxicity of the product. Since food is ingested and is such a large part of everyday life, it is more personal than nuclear energy is. People deal with food on an individual basis each day, and must willingly consume the food to be affected by it. Also, genetic modification of foods has come under fire from particular groups and has been subject to differing levels of social acceptance throughout its history. We decided that the pattern of social acceptance of genetically modified foods was worth investigating as well, since it operates in the middle ground of personal distance like many nanotechnologies will.

For the most personal level we chose to look at vaccines. There has to be complete trust in this technology, since after a person is vaccinated, they have no control over what the vaccine does. This is similar to the use of nanoscience in engineering nanodrugs and medical applications where nanoscopic devices will be able to go into one's body and repair or enhance it. Both these possible nanotechnological advances and vaccines are very intimate technologies, being literally injected into a person, yielding the closest personal distance of any of the technologies we looked at. Vaccines also have had trouble being accepted by society at times, while having staggeringly high levels of approval during other times. Looking into vaccines was considered appropriate due to its changing levels of acceptance over time and its incredibly personal level, paralleling maybe nanotechnological products in the nanomedicine fields.

With the three technologies of nuclear energy, genetic modification of foods and vaccines, we began a process to look into the social acceptance of technologies. In trying to understand why acceptance waxes and wanes over time, to find the causes of these changes, we underwent extensive research in our topics and discussed our findings. Our research provided us with the foundation to draw conclusions as to what the field of nanotechnology can do in order to guarantee high levels of public approval.

1.5 Methodology of Research

Each of the three students researched a separate model to draw correlations to the field of nanotechnology. We all researched the prospective development of the field of nanotechnology which nanoscientists and visionaries in the field claim for the present and near future. Additionally, one student each researched nuclear energy, genetically modified foods and vaccines, the background, benefits and risks, history and pattern of social acceptance. Through collecting information from related literature, published papers, journal and news articles, and the Internet, we looked into each technology. Consulting online searches, such as Google Scholar and PubMed, and Worcester Polytechnic Institute library databases, such as PsychINFO and MedLine, we found these sources of information.

1.6 Structure of Report

The rest of the paper will explore our research, findings and conclusions derived from studying the three topics of nuclear energy, genetic modification of foods and vaccines. First, we shall go into the three areas of research: chapter two will focus on nuclear energy; chapter three will discuss genetically modified foods; chapter four will explore vaccines. Our research sections will provide a background to the technology as well as a history of differing levels of acceptance and the causes for these changes in public approval. From the history, we shall present graphical models of the acceptance over time.

Next, we shall delve into comparing the technologies and their models to each other in chapter five. Finally, in chapter six, we will express the results of our findings. This will begin with a discussion on the psychology of acceptance and go into comparing our graphical models and technologies to present and future applications of nanoscience. The chapter will end with final conclusions explaining what we have found the field of nanotechnology can do to try to ensure high levels of acceptance of their technologies. Lastly, chapter seven will provide a bibliography, including all the works and references cited in this report.

2 Nuclear Energy

2.1 Background of Nuclear Energy Technology

Nuclear power generation is a process by which heavy elements are induced to decompose into lighter elements. This process is called nuclear fission and releases large amounts of heat along with varying amounts of radiation. To gain energy from this process the reaction takes place in a large containment building under a pool of water. The heat released from the reaction heats the water which can be used to spin generators. The average commercial size generator can produce around 200 Megawatts which is enough energy to power around 200,000 homes.

Although nuclear energy does not emit greenhouse gases it is not without its own environmental problems. Radioactive waste is the main output of a nuclear reactor. In some cases the byproducts can be recycled and re-enriched to be used in other types of reactors to generate even more power in other cases however the waste must be disposed of in sealed storage for thousands of years. Current solutions have most reactors keeping their waste on site in pools to keep the materials cooled and to contain any radiation while there are plans to create a long term and permanent storage facility. (World Nuclear Association)

As with anything created by man there is always the threat of failure in the components of a reactor. These failures could result in something as simple as shutting down the reactor to make a repair, or something as catastrophic as a meltdown. New reactor designs however reduce this chance by moving to a self regulating gas cooled system. The new design uses self contained balls of material encased in a ceramic which will heat up and once spent, contain the fuel and radioactivity within them. By gas cooling the reactor if the top were to be removed the reactor would be able to keep itself stable using only the atmosphere. These new designs give greater reliability and safety over the current water cooled designs. (Reiss, 2005)

2.2 Introduction of Nuclear Energy Use

Although research into nuclear technologies had been going on for many years, the first real point of public knowledge was born in war. The first major use and demonstration of nuclear technologies was shown during the atomic bombings on Hiroshima and Nagasaki. With World War II ending due to the use of nuclear weapons all nuclear technologies were given a sudden and immediate boost in acceptance with the general population.

This immediate acceptance of the technology allowed for much speculation about the future as well as rapid development and use of the technology. Speculation and science fiction brought forth ideas such as atomic powered cars and planes. Various polls showed that many people thought that nuclear energy would eventually power everything. (Bosconti, 1993)
Even with the connotations of war behind the technology and physical evidence of its destructive power people were able to keep peaceful uses of nuclear technology separate from the concepts of nuclear war.

2.3 General Use of Nuclear Energy

Throughout the fifties, sixties, and seventies public reactions to nuclear energy remained fairly consistent as most of the problems faced by nuclear technologies were a result of the cold war. Even with the cold war at its highest points acceptance of energy generation remained stable and surveys showed that people still believed that nuclear energy was a revolutionary technology and was of great benefit to society. In 1949, a gallop poll reported that sixty-three percent of those polled indicated they believed that within fifty years planes and trains would be nuclear powered (Bosconti, 1993). This sort of enthusiasm for nuclear energy was pervasive and lasted many years. Most of the issues that arose with nuclear technologies were not about its use for power generation or use in everyday good but the technology ending up in the wrong hands with problems such as proliferation of nuclear technology. (Bosconti, 1993)

2.4 Pivotal Events Affecting Nuclear Energy Acceptance

Two major events have shaped the American outlook on nuclear power in recent years. The first occurred in 1979 at the Three Mile Island nuclear facility in Pennsylvania. The second happened at the Chernobyl nuclear facility in the Ukraine in 1986. Both of these events had immediate impacts on public opinion however in both cases some of the impacts were short lived.

The Three Mile Island (TMI) accident happened on March 18, 1979, at the facilities number two reactor when an automated valve became stuck open after a pump failure. The valve was put in to control the pressure of the reactor and once it was stuck open the valve let coolant from the reactor escape. The operators of the plant did not have any instrumentation that would tell them they were losing coolant. This caused the reactor to overheat and generate large amounts of steam which filled a relief tank and then began to fill the reactor building with radioactive gas. The core began to melt as less and less coolant made it to the reactor. Eventually operators discovered the lack of coolant and were able to bring the temperature down but not without a portion of the reactor melting and contaminating the reactor building with radioactive gases and water.

The TMI incident was well televised and was seen by many people. A few days before the incident a movie had been released called “The China Syndrome”. The movie depicted a fictionalized accident at a nuclear reactor which had very similar circumstances as those that were seen at the TMI event. This amplified the reactions to the reports that were being shown and caused an immediate negative reaction, even though the accident was eventually shown to be a design and procedural error and not a human error. (Three Mile Island)

From the accident an immediate reaction is shown in the public acceptance of nuclear energy. As can be seen in the graph below immediately after the accident there was a drop in acceptance. After about three months however the public confidence was restored to nuclear energy. Even with the recovery of acceptance a new problem began to arise which was “Not in my back yard”. The “Not in my back yard” idea was that the public would accept nuclear generation but would not let a new reactor be built anywhere near their homes. This problem of acceptance and concurrent rejection caused nearly all building of nuclear reactors to stop. Since the TMI accident only a handful of reactors have been constructed and no new licenses for nuclear reactors have been issued. Even though the public acceptance recovered almost immediately the impact on the nuclear power industry was still very great.

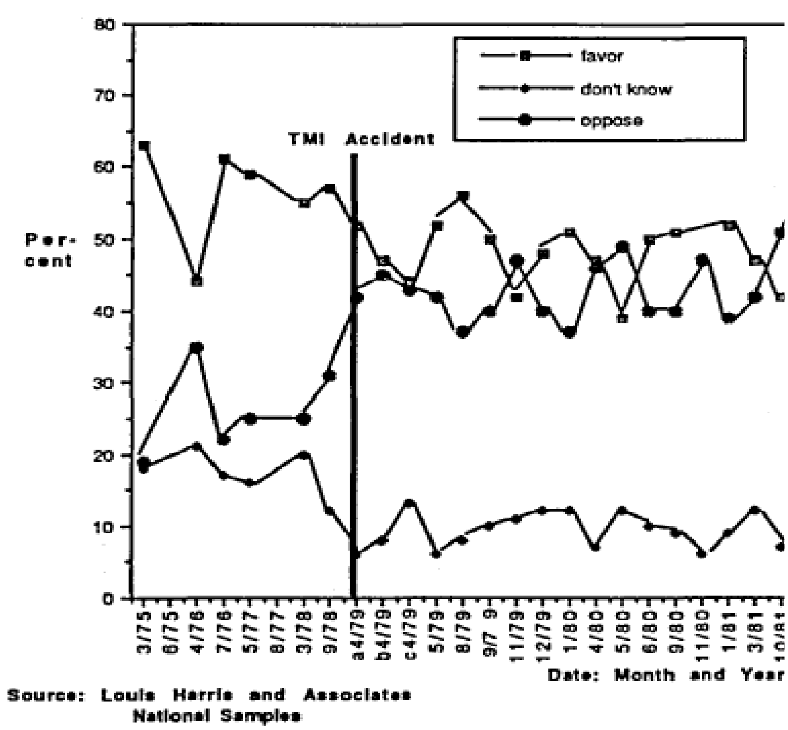

Figure 1: Public Attitudes Towards Building Nuclear Power Plants (Rosa, 1994)

The above graph shows a national study which shows the public attitude towards building nuclear facilities. As can be seen from the three samples taken in April of 1979 the relative acceptance dipped and then recovered by the next month. With the large amount of media coverage the accident received the impact on acceptance was very minimal. Although the attention it received made it seem like a very large accident no one was hurt during the incident. This fact may have contributed to the rapid recovery in U.S. acceptance.

The second major accident, by far the worst, was the explosion that occurred at the Chernobyl nuclear facility in the Ukraine. On April 26th 1986 the number 4 reactor exploded. This explosion released massive amounts of radioactive dust into the atmosphere which was carried as far as the eastern seaboard of the U.S. From the explosion and subsequent contamination fatalities were recorded from nuclear energy generation for the first time ever. (Chernobyl Accident)

The Chernobyl accident received large amounts of media attention and caused another dip in American confidence in nuclear energy. However due to the media informing the public that such an accident could not occur in America due to design differences the overall impact on public acceptance was minimal. With American and European media reporting that major differences in design such as the use of containment buildings over the reactor and stricter procedures caused the small dip in acceptance to quickly recover. In as little as a month from the accident acceptance had recovered. However the accident did become a divisive issue and has caused many groups to take sides in the arguments for and against nuclear power.

2.5 Public Reevaluation of Nuclear Energy

After Chernobyl and TMI the nuclear energy industry emerged on a relatively equal acceptance level as it had been before the accidents. The “Not in my back yard” phenomenon contributed heavily to a lack of new nuclear construction. A moderate level of acceptance remained steady through the nineties and into the first year of the new millennium, however with a renewed interest in moving away from fossil fuels acceptance of nuclear power has been ever increasing to an all time high this past year. Spurned on by a continuously safe record from the power industry and pushes from both the federal government and the media the acceptance level increased very dramatically over the past five years to end up at around seventy percent of people in favor of nuclear energy. (NEI - Perspective On Public Opinion)

With major governmental policy pushing for energy sources not derived from fossil fuels a large group of officials have been moving forward with initiatives to increase nuclear generating capacities. Both the push from the government and a rising confidence in the safety of nuclear plants has helped the current acceptance. Another recent change has affected the “not in my back yard” problem which has shown a rise in the percentages of those who would favor a new nuclear facility at current locations. (Industry Welcomes President's Call to Expand Supply of Reliable, Affordable Nuclear Energy)

As can be seen in the figure below the gap between those who favor and those who oppose nuclear energy has been steadily increasing over the past decade.

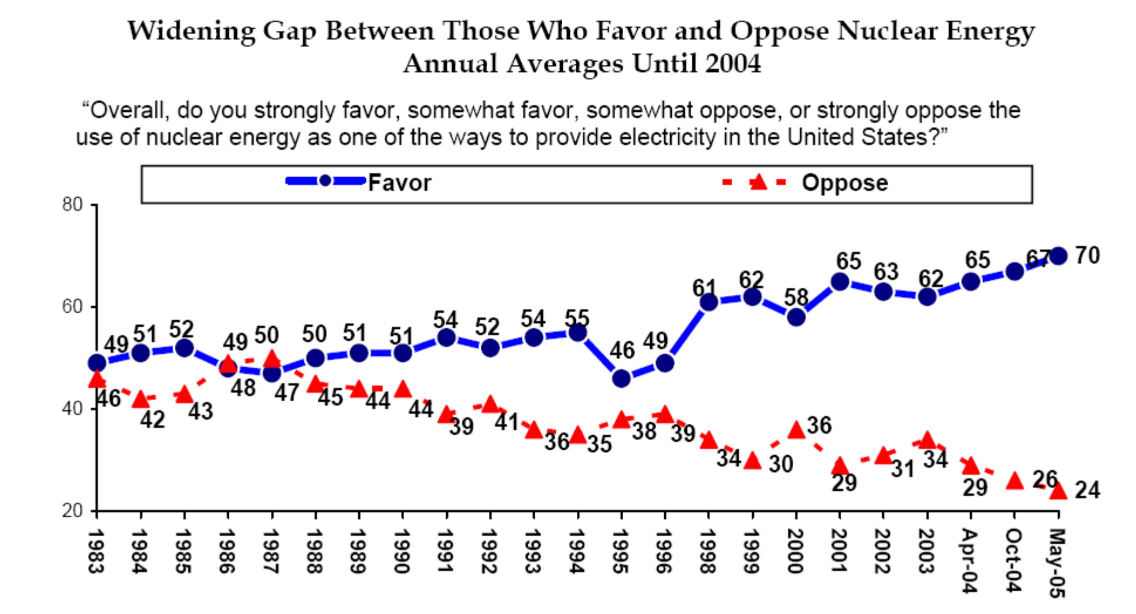

Figure 2: U.S. Acceptance from 1983 to 2005 (Bisconti, 2005)

2.6 The Pattern of Nuclear Energy

From all that has happened with nuclear technology and nuclear energy production specifically a pattern can be seen. The acceptance of nuclear energy was very dependent on the things that were happening to it and with it. With the introduction in the blaze of war an immediate acceptance was seen. This carried the acceptance for quite a while until the major events that shaped current acceptance occurred. With the events showing such sudden impacts on the acceptance while any campaigns by the industry itself had very little effect on the acceptance.

3 Genetically Modified Foods

3.1 Background on Genetically Modified Foods

Genetic modification is a process used to add desirable traits or remove unwanted genes from a substance. A careful design approach is taken to engineer a product to little to no harmful effects and an abundance of enhanced benefits. This methodology replaces the conventional experimental discovery approach, wherein new genes and benefits are added to a product through trial and error. This is a long, drawn out, costly technique that often ends up with a final product containing a myriad of unknown or unwanted and potentially dangerous excess genes. Unlike the experimental discovery method of the past, the systematic bottom-up technique of genetic modification can yield a much more fine-tuned product, with benefits dwarfing the conventional products and lacking the noxious side-effects, while taking less time and money to develop. The genetic modification process is an amazing scientific break-through, providing a consumer the possibility of products better than ever before.

Seeing genetic modification as the panacea to fix all the problems of conventionally designed products, the crop and food industries naturally sought it out as a means to enhance the quality and safety of their products. The result, genetically modified foods (or GMFs), has been a topic of controversial debate over the past decade. GMFs bring the advantages of genetic modification directly to the consumers' hungry mouths. It seems as if GMFs and the incredibly advantageous benefits of genetic modification in general are here to stay.

There are various advantages of GMFs over experimentally discovered foods. As demonstrated by the biotechnology industry, genetically modifying foods allows an increase its nutritional value, adding higher quantities of the needed chemicals that power the human body and opening the possibility of healthier, more nutrient-rich foods. On the other side of modification, toxins can be removed or their quantity lessened in GMFs, removing allergens and other unwanted genes from the foods. Since the engineer knows each gene he adds or removes, GMFs can be thoroughly examined to ensure safety without the worry of having incidentally added dangerous other traits, a common concern of the traditional methods used for conventionally bred varieties of foods. In effect, GMFs are widely considered much safer than the old products. Considering the potential of significantly higher production rates and the possible aid to developing or agriculturally-lacking nations of GMFs is extreme. In 2000, Skerritt expressed that many saw "the use of crop genetic modification could have substantial benefits for developing countries" (p. 3). Countries stricken with famine and poverty will be able to be supplied with much more food, directly saving countless lives. Additionally, since the food they are being provided has a higher nutritional benefit, these countries will also be able to experience less illness and malnutrition, indirectly sparing innumerable other lives. Being a safer, more nutritious product, free of toxins and yielding a much higher rate of production, GMFs have a large number of significant benefits over conventionally bred foods.

Nonetheless, there are some whom would wish GMFs simply did not exist, demonizing the products as despicable plagues on society. There are worries over the long-term consequences of GMF consumption and the health affects that may show up after a life of eating GMFs. Additionally, some claim that negative effects on the environment are possible, through a reduction in biodiversity and beneficial insects, such as the Monarch butterfly, as well as the birth of new "super weeds" and the development of other possibly unforeseen environmental hazards. Also under question is the ethics of whether it is modify living organisms and the morality of tampering with the food supply. Some even claim that being created artificially implies that GMFs "are inherently hazardous, and despite safeguards built in, can genetic modification unwittingly make food unsafe" (Prakash, 2001). Concerns regarding consequences of genetic modification of foods on health and the environment, both physically and ethically, lay claim to the idea that GMFs are dangerous and should be banned.

The rest of this section will continue the discussion of genetically modified foods. First, in section 3.2, the history of the introduction of genetically modified foods to consumers will be explained, including global campaigns that quickly developed to ban GMF production. Next, in section 3.3, mobilization efforts in North America and Europe will be compared, followed by counter-mobilization events in each area, described in section 3.4. This chapter will conclude in section 3.5 by presenting and explaining the graphical model of genetically modified foods developed by the students.

3.2 Introduction of Genetically Modified Foods to Consumers

With the introduction of genetically modified foods to consumers in 1996, a Pandora's Box of controversy, disputes and social issues began. Immediately, many members of the scientific communities expounded on the myriad of advantages of GMFs already discussed, yet the public and certain groups were still very uncomfortable with the idea of genetic modification of foods. The reasons for their concerns were varied, instantiating a number of claims on the dangers of GMFs as mentioned previously. Although these claims were countered in the scientific community, trying to educate the public to make them understand why their fears were unsubstantiated, the damage done by the initial fears and was certainly felt. Even from the moment they were known to the public, GMFs stirred up negative reactions, leading to global mobilization against the technology early on. As genetically modified foods were being introduced, a global backlash grounded in uneducated fears of the technology drove the acceptance low from the start.

In under a year after the arrival of GMFs, there was global outcry calling for an end to genetic modification of foods. Starting with the “Pure Food Campaign”, a collaboration between Greenpeace, Friends of the Earth, RAFI and more groups, including grassroots organizations such as women's networks, environmental groups, consumer associations, farmers and youth, global mobilization efforts echo the worldwide distaste for GMFs early on. In April of 1997 the “Global Days of Action Against Gene-Foods” took place with groups from Africa, Australasia, Europe, Latin America and North America participating, showing the universally low acceptance levels. This was quickly repeated in October of that year, and in February of 1998 “Physicians & Scientists Against Genetically Engineered Food” issued “a moratorium on the release of Genetically [Modified] organisms and the use of [GM]-food”, calling for an end to GMFs. Clearly, acceptance was very low. From the start, global organizations tried to shut down the production of GMFs, echoing and feeding into the low level of acceptance of the technology seen in the public sector. (Directorate-General for Agriculture, 2001)

These movements against the technology globally culminated in 1999 with large companies bowing down to anti-GM groups. In September of 1999, activists from thirty countries launched a lawsuit against major biotechnology companies, claiming multi-billion dollar compensation for monopolistic practices, calling on the use and proliferation of GMFs. Finally, in October of 1999, the anti-GM groups exclaimed success when Monsanto CEO Robert Shapiro announced the decision of his company “not to pursue technologies that render seed sterile”, saying his decision was “based on input from [anti-GM groups] and a wide range of other experts and stakeholders, including our very important grower constituency”. At this time, first-generation GMFs were in use that caused sterility in the seeds as a safety precaution. The anti-GM groups claimed a victory and the acceptance of the technology could not have been lower. (Directorate-General for Agriculture, 2001)

Overall, the global mobilization led to creating very low levels of social acceptance of genetically modified foods throughout the world. Following this global mobilization which drove acceptance so low, the situations in Europe and North America became drastically different. Both areas had differing levels of mobilization and counter-mobilization, leading to significantly different outcomes. The next sections will consider Europe and North America individually, in order to show the importance of how the situations were handled in each area. The acts of mobilization and counter-mobilization which took place in Europe and North America afterwards had to combat the dwindling acceptance level set by the universal collaboration against GMFs during its introduction.

3.3 Mobilization Efforts Against Genetically Modified Foods

Mobilization efforts were made to get rid of genetically modified foods. These mobilization efforts were backed by the fears of GMFs previously discussed. Initially, acceptance can be low from the fear of the technology. Mobilization spreads this fear, as a result of the low acceptance levels. But then, the fears and mobilization create a cycle where mobilization comes from the fears and circularly, empowers them, extending there reach, causing more perceived risk in the technology. This inevitably results in lower acceptance levels. Mobilization efforts both show and feed into the low acceptance levels of a technology, since they only exist when acceptance is already low in certain groups and their existence heightens fears, lowering acceptance.

There were different levels of mobilization in Europe and North America. The differing intensity of these efforts cause GMFs to be viewed in a different light in each area and set the acceptance of the technology low. Due to the ferocity of mobilization in Europe, much more counter-mobilization would be required than in North America which had a less aggressive stance against GMFs. The variance in the magnitude of the anti-GM sentiments in Europe and North America produced two distinct levels of public acceptance.

In Europe, the mobilization efforts were strong, many and very aggressive, causing a dramatically low level of acceptance that was difficult to raise. As early as 1997, law suits were being put through in Europe dealing with GMFs in stores. This was coupled with campaigns by supermarket owners versus genetic modification in general. Austria and the UK both petitioned against genetic modification of foods just a year after they were introduced. By 1999, UK doctors were demanding a ban on all GM products. Some countries in Europe have actually banned GM products, not just GMFs. These acts were just some of the multitude of anti-GM movements made throughout Europe. Europe was inundated with anti-GM groups and efforts to quell the production and distribution of GMFs, if not GM products in general. Additionally, the allegations and demands made were very powerful, suing companies and calling for complete bans on genetic modification. These hard claims and strict demands in such a large number exhibit and resulted in the very low acceptance level of GMFs in Europe. (Directorate-General for Agriculture, 2001)

This is in great comparison to the mobilization found in North America, which was weak and less numerable as in Europe. Unlike Europe trying to ban all GM products, the mobilization efforts in North America largely considered GMFs separately and industry spear-headed movements to control their production and distribution. North American industry and the public was more interested in the regulation of GMFs and ensuring they were safe, than completely banning it. In 1998, a lawsuit was pushed against the FDA in response to the fact that no regulation was in place for GMFs. This was coupled with a petition in 1999 for labeling of GM foods. Seeing just how passive the anti-GMF groups in North America were, the Corn Growers

Association merely "recommended" using non-GM seed in 1999. Although the Canadian Wheat Board in 1999 did decide to not use GM wheat in their products, the president of the board claimed it was on the grounds that "the consumer is always right, even when they might be scientifically wrong", showing that industry in North America realized GMFs where safe and beneficial, accepting the technology and waiting for consumers to catch up. (Directorate-General for Agriculture, 2001)

The intensity of mobilization efforts in Europe and North America were significantly different. In Europe, the anti-GM groups, which include industry, were far more aggressive. Their efforts were a lot more negative, going so far in some places as to ban GM production. For a long period of time, even the government was outright anti-GM, pushing for more regulation and labeling of GM products. In North America, however, the mobilization efforts were few and weak, and industry and government where pro-GM.

3.4 Counter-Mobilization Efforts Supporting Genetically Modified Foods

With the low acceptance levels brought about my mobilization, counter-mobilization efforts were necessary to raise acceptance of GMFs. Like the efforts of anti-GMF groups, counter-mobilization also was handled very differently and to a much different degree in Europe and North America. Through powerful counter-mobilization campaigning in North America, benefits of the technology were perceived as greater than the risks and GMF acceptance rose tremendously. Europe, on the other hand, was much more passive in their counter-mobilization, and only in recent years have they made any headway in some countries towards the acceptance of GMFs. The different methods of counter-mobilization found in North America and Europe show that raising acceptance is not a trivial task but that it can be done when it has faltered due to previous mobilization efforts.

The counter-mobilization efforts in Europe has been overwhelmed by the mobilization efforts. There has not been nearly as many counter movements in Europe as there has been campaigns and petitions by anti-GM groups. As a result, combined with the intense mobilization in Europe, a study in 2001 showed that sixty percent of Europeans perceived genetically modified foods had the possibility to hurt the environment (Frewer, 2003), dismissing the technology as something damaging, showing there disapproval. Some progress, however, has been made. Late in 1999 farmers in the UK did decided on a code of practice for introducing and producing GMFs. Yet, simply having some farmers introduce a *modus operandi* is not nearly enough to fight back against the many groups pushing for the ban of GM products throughout Europe, and, in fact, seems rather weak compared to the aggressive push by mobilization efforts. More recently, in the pass few years, the Commission of the European Communities has tried to follow suit after the North Americans and introduce a promotional campaign. So far they have seen public approval of GMFs rise in some sections, but this is a very gradual process, beset on all sides by very strong anti-GM sentiments enlarged by the various mobilization efforts Europe has been subject to. (Directorate-General for Agriculture, 2001)

North America handled counter-mobilization swiftly and ferociously, annihilating most of the anti-GM feelings and procuring a very high acceptance level of GMFs. There were strong promotional campaigns introduce as early as 1999, at the height of global mobilization and as industry was pushing for regulation. The “Better Foods” campaign, which promoted the benefits of GMFs, greatly eased anti-GM notions throughout the United States and into Canada. In fact, as this campaign was underway, that same year, scientists demanded more money and research for biotechnology including genetic modification of foods. As such, now, GMFs are widely accepted in North America. And genetic modification has been applied to many crops. In example, before the campaigning, in 1999, only seven percent of soy beans in the United States were genetically modified, but as of 2002 this ratio has jumped to over seventy-five percent (Chern, Rickertsen, Tsuboi & Fu, 2002). Throughout North America, due to a quick and strong response to mobilization efforts, counter-mobilization has caused acceptance to rise to incredible heights. (Directorate-General for Agriculture, 2001)

Counter-mobilization efforts differed greatly between Europe and North America. Europe had few reactions and the small number of pro-GM groups were overly passive and slow to act. Recently, the Directorate-General for Agriculture, 2001 has flipped sides and has begun to promote GMFs. This has lead to a rise in public acceptance, but the waves of mobilization efforts inundating Europe have made this process very gradual. North America, on the other hand, was aggressive and quick to respond to anti-GM sentiment. In the United States, for example, a government-sponsored "Better Foods" Campaign, promoting GMFs as beneficial and safe, had a profound impact on acceptance.

3.5 The Model for the Acceptance of Genetically Modified Foods

Below is a physical depiction of the two models of acceptance in North America and Europe. We derived this graphical model from the historical research mentioned earlier, charting out the acceptance levels seen at different times. Particular events are indicated along the horizontal axis with dotted vertical lines corresponding to their location. The metric being evaluated versus time is the relative acceptance level, with lower values indicating lower acceptance. The graphical model intends to show the general features of the changing acceptance level over time. This is all depicted in the following figure.

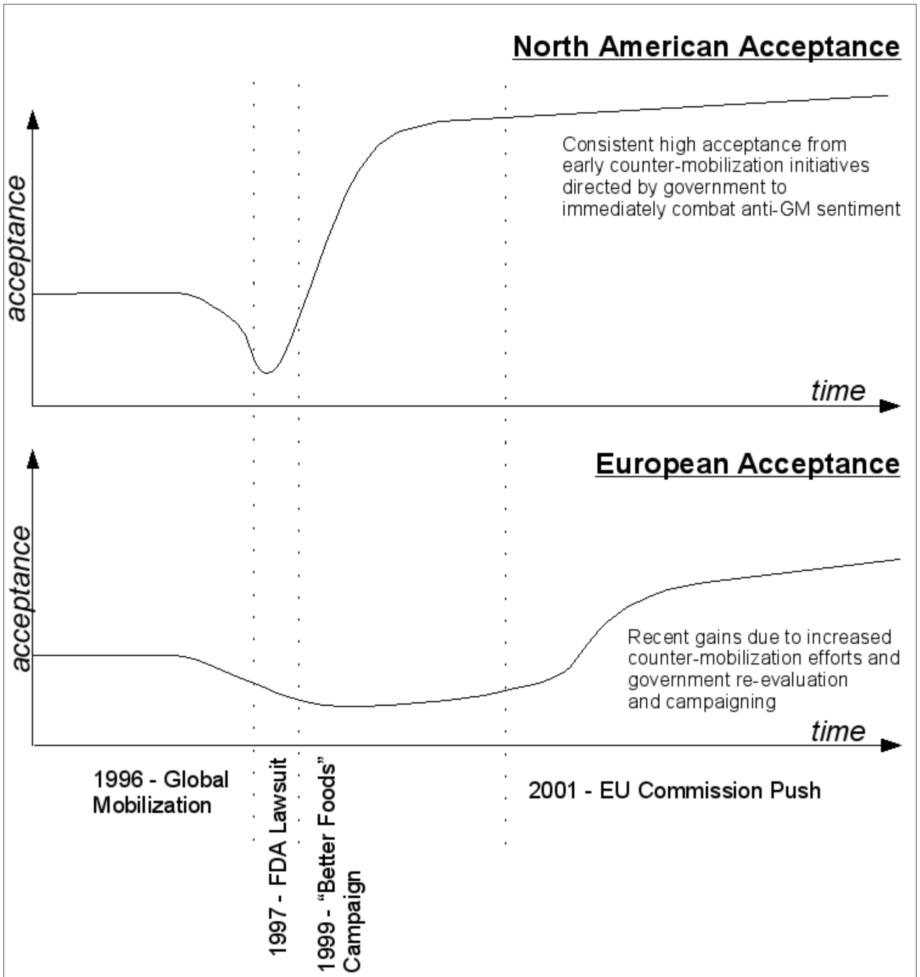

Figure 3: Graphical Models for Genetically Modified Foods

A dip in acceptance is seen in both graphs from global mobilization efforts, but North America quickly initiated counter-mobilization promotional campaigns and the social acceptance rose dramatically. In Europe, a longer time was dominated by mobilization efforts and only recently has a government push for GM products lead to gains in social acceptance. These models show that a quick response to mobilization efforts through a powerful promotion of the technology can easily drive public acceptance high.

4 Vaccines

4.1 Introduction to Vaccines

Vaccines are currently one of the only preventative measure against getting sick from a virus. Though proper hygiene can help prevent some forms of disease transmission, contact with a sick person or an infected doorknob will still spread the disease unless one is vaccinated. The reward from this technology is thus great. It is so great that even though it is the most personal of the three technologies discussed in this report, since the injection goes directly into the body, it is the most readily accepted. The benefit of not having to worry about getting sick is infinitely greater than the risk involved in receiving the shot.

In the case that a vaccine is challenged, scientific study may be used to either to dismiss the opposition or, if there truly is a valid flaw, to develop a new and safe alternative to the current vaccine. None the less, a vaccine for the given virus will exist and will be administered when the benefit from it outweighs the risk, such as when lack of vaccination causes an epidemic.

Most vaccines are either a dead or weakened form of a virus. The body combats the virus and builds up immunity to the disease without the person ever having to experience the general feelings associated with getting sick.

This section discusses the social acceptance of vaccines for measles and the Avian Flu. For the measles vaccine, there was a drop in social acceptance that quickly rebounded due to scientific backing of the technology. With Avian Flu, fears of a pandemic and the devastation of the Spanish Flu of 1918 have caused a high demand for a vaccine with an associated social acceptance spike.

4.2 Measles: History, Vaccines and Acceptance

One of the diseases and vaccines considered in our research was measles. Measles is an easily noticeable virus, transmitted with ease, allowing for rapid infection. The symptoms of measles begin to show up during the incubation period of the disease, typically ten days after the initial infection. At that time, the infected person may have a fever, a cough, red eyes and a runny nose. Three or four days later, a red rash develops, starting as small red bumps on the forehead and spreading to cover the whole body within three or four days. Grey spots, called Koplik Spots, may develop on the inside of the mouth before the rash begins to spread. Measles is spread by contact with nasal or oral secretions, usually by sneezing and coughing, which allows it to spread very rapidly. Due to its communicable nature, measles is promptly dispersed among a close knit populace, which soon exhibit the telltale signs of the virus.

As one would expect, since measles is transmitted so facilely, it has been fairly widespread, leading to an epidemic at times. Before the introduction of the measles vaccine there was an average of 297,216 reported cases resulting in an average 5,948 reported deaths annually. Clearly, the threat was significant and the infection substantial. In 1963, when the measles vaccine was introduced, the number of cases per year dropped very quickly. This success lead to several national initiatives to rid the country of measles and reduce people's vulnerability to it through vaccination in 1966-70, 1971-78, and 1978-88 (Hinman, Walter & Papania, 2004). Developed vaccines were able to protect many from the hazards of contracting the easily spread virus, proposing a solution to the Measle epidemics plaguing countries.

With the goal in mind to rid the country of measles entirely, a specific program was designed. The first measles eradication program had four parts: routine immunization of infants, immunization of school children, surveillance and epidemic control (Hinman, *et al.*, 2004). For the first part, the vaccine is usually administered between twelve and twenty-four months, when the infant begins to rely on his immune system to make antibodies, rather than the maternal antibodies present at birth. Next, the immunization of school children was meant to prevent the disease from spreading in areas of close personal contact. Since most children go to school, this would be a highly effective measure at protecting children, and people in general, from the virus. Acquiring accurate statistics on the disease would prove to be quite useful in the evaluation of the eradication programs. This first program designed to rid the country of measles was met with mixed success.

This program did managed to reduce the number of cases by ninety percent from 1966 to 1968, and by over ninety-five percent relative to the pre-vaccination era. Unfortunately, no more than sixty-three percent of one to four year old children were vaccinated in any of the years of this program, due to a lack of a routine infant immunization plan (Hinman, *et al.*, 2004). This vaccination percentage did not increase much during the 1971 eradication goal either, but the number of cases kept dropping until the outbreak of 1977. While measles usually occurs in young children under the age of five (Meissner, Strebel & Orenstein, 2004), this outbreak was very peculiar in that eighty-nine percent of the affected people were ages five to nineteen (Hinman, *et al.*, 2004). Upon analysis of the situation, this outbreak was linked to the high percentage of children susceptible to measles entering schools.

In general, the unvaccinated children were protected as long as their peers remained well. Since the disease could not spread through the vaccinated children, those who did not have immunity to the disease were protected by their mere presence, since it required the unvaccinated children to come in contact with the infected individual directly. Unfortunately, the high percentage of unvaccinated school children reduced the effectiveness of this indirect protection provided by the immune individuals. This led to unforeseen outbreaks among school aged children.

Learning from this incident, all fifty states required children entering school to have either had a dose of the vaccine or have been infected with the disease and built up immunity to it by 1981 (Hinman, *et al.*, 2004). Nonetheless, there were still incidents of measles in young children and vaccinated adolescents. An individual whom received the vaccine might not build up an immunity if the vaccine happens to be impotent, therefore failing to trigger the body's natural immune responses. Other factors may also affect the effectiveness of a vaccine. As a result, in 1989, the American Academy of Pediatrics and the Advisory Committee on Immunization Practices recommended that two doses of the vaccine be administered after the age of twelve months. A resurgence of the disease between 1989 and 1991, due to low child immunization rates, put a strengthened emphasis on getting this program instated. Consequently, the number of cases dropped to about one hundred per year and has remained in that vicinity ever since. (Meissner, *et al.*, 2004).

In the early 1990's, public opinion of the vaccine dropped, due to a claim that linked the measles vaccine to gastrointestinal abnormalities and autism spectrum diseases (Meissner, *et al.*, 2004). This claim was based on the fact that more cases of both diseases were reported at the same time that the measles vaccine began to be more readily administered. As a result, immunization rates in some countries dropped to below eighty percent. The number of measles cases and hospitalizations spiked, causing scientists to investigate the validity of these physicians' findings. None of the conducted studies showed any statistical evidence to support it, with the evidence suggesting a rejection of the statement. As a result, public acceptance rose back up and vaccination continued as before.

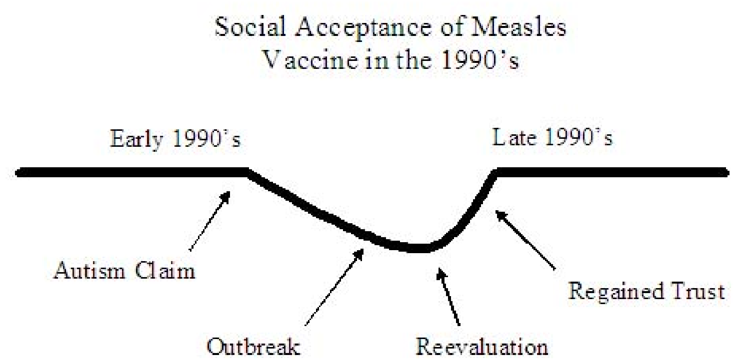

Figure 4: Social Acceptance of Measles Vaccine in the 1990's

Presently, measles is all but gone in America, with virtually all cases being of foreign origin, through immigrants or people traveling abroad in countries without strong vaccination programs. Yet, until other countries are rid of measles, high immunization rates will be required to keep it from becoming endemic again. It is possible to rid the world of measles, since it does not have a reservoir outside of humans, it cannot hibernate and there is an effective immunization routine already set up for combating it (Meissner, *et al.*, 2004). However, in order for this to happen, the program will have to have strong financial and social backing, which could prove to be a very difficult process.

4.3 Avian Flu: History, Vaccines and Acceptance

Bird flu is scaring the nation into frenzy. The perceived threat from the disease is so great that the benefit of having a vaccine's protection completely outweighs any perceived risks associated with taking the vaccine. This is easily seen by the immense demand for the vaccine. When Tamiflu came out, people hoarded it zealously. Currently, the government has ordered twenty million doses of an experimental bird flu vaccine (NPR Report). Again, the perceived threat of the virus causes people to consider the benefits over the risks and accept the vaccine. It is plain to see why people are so scared of Bird Flu and so accepting of the vaccine, considering the Spanish Flu of 1918 was also of avian origin.

The Spanish Flu of 1918 infected twenty million Americans in forty-six states and killed over 500,000 people. At the time, there was no flu vaccine and people had to suffer through the disease in order to overcome it. Since there was no cure, the government tried to control the spread of the disease by banning public meetings and fining people for spitting. As one can imagine, this had a very negative effect on the economy and society of that time.

In general, influenza causes fever, body aches, runny or stuffy nose, and extreme fatigue. Without a cure, many different types of homemade remedies were tested, including inhaling smoke and cooking spicy peppers. More scientifically sound suggestions were to eat well, stay warm, and keep strong so that the body may fight the disease. The largest problem from the flu was that it weakened the body and made it easy for pneumonia to set in, which was the primary cause of death from the bird flu (Illinois and the 1918 Spanish Flu Epidemic Trail).

After some time, a serum was developed that helped the sick build up immunity and overcome the disease. It was administered as soon as possible, with large headlines proclaiming its effectiveness. With the disease gone, workers could come back to work. This inspired employers to vaccinate their employees. Within a couple weeks, the disease was under control and life went back to normal.

The Spanish Flu was of avian origin and much more virulent than regular seasonal influenza. It infected healthy adults in their twenties to middle age, rather than children and old people as most diseases do. Just like all viruses, the flu undergoes slight changes in its genetic constitution due to chance. Almost every time that the disease changes, it infects people. Every several decades a very virulent strain evolves, in the past, resulting in epidemics (Bird Flu Special). It is speculated that flu has probably coexisted with humans for more than 400 years (Bird Flu Special), the Spanish Flu being the worst case in terms of deaths of the past century. Each time the Flu virus evolves, it branches off into several strains. At every branching, though, one of the strains eventually becomes extinct while the other survives to infect people and mutate again, to create newer strains that people do not have immunity against.

Birds are the reservoirs of all subtypes of influenza viruses. There is a hypothesis that all influenza subtypes come from birds. The virus is spread among birds through fecal matter, which can be very potent. It spreads very quickly among water fowl, who can introduce the virus into water supplies. In order to infect humans, the disease has to mutate. Once it does it is usually very potent. As stated in a research paper on the evolution of influenza,

> "In 1997, 18 people (six of whom died) were infected with [avian flu], and in 1999 two more people were infected [with another strain]. Neither of these avian viruses turned out to be directly transmissible among humans, but these events heighten anticipation of future shifts in human flu viruses." (Earn, Dushoff & Levin, 2002)

Because of the devastation of the Spanish Flu, people are really worried about bird flu today. Demand for the vaccine has spiked very drastically, with the government ordering a small stockpile of experimental vaccine. There is but a slim chance that the disease will mutate to infect humans any time soon, and the shelf life of the vaccines is only twelve to eighteen months. It is most likely that the ten million dollars of vaccine will expire before any sort of epidemic.

With the amount of hype the media is giving on bird flu, many people are now scared of being infected and dying. One person was quoted as saying that if there was an outbreak of bird flu that it could, “in the worst case, kill as many people in a few months as AIDS has done in two decades.” The disease’s virulence is no less stressed, being lethal in ten out of ten embryos. These types of reports raise people’s fears of the disease, making any sort of solutions highly accepted. Tamiflu and experimental vaccines are some examples. Unfortunately, these vaccines have relatively short shelf lives: three years for Tamiflu, which inhibits the disease from spreading, and less than eighteen months for the vaccine, which actually causes the body to build up immunity. Also, it takes a lot of the vaccine to stimulate an immune response, which gives immunity. The government has spent ten million dollars in order to stockpile vaccines for four million people, less than two percent of the American population.

Below is a graphical model representing the flu vaccine. It depicts that as the fear of the pandemic increases, the demand for the vaccine increases. This demand is a better measure of how well a vaccine is indoctrinated into society than the actual acceptance, which is typically constant over time, with fluctuation due to unusual and typically unsubstantiated claims against the vaccine.

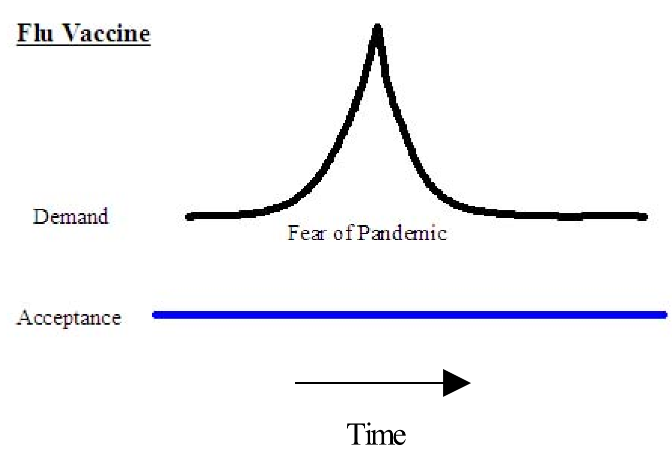

Figure 5: Acceptance of Flu Vaccine

Though scare tactics are effective in raising acceptance of a vaccine, educated actions are better. Less hype and more facts about the bird flu could help calm the populous. Working on a better hospital infrastructure and making sure people are informed would be better than binge stockpiling of experimental vaccine.

5 Comparisons of Researched Technologies

5.1 Report Recap

So far we have introduced our three technologies and gone through the research conducted. The history of nuclear energy, genetically modified foods and vaccines has been covered, as well as detail explaining the rise and fall of acceptance levels over time.

This chapter and the rest of the report will continue discussing our technologies and then go into implications for nanotechnology. This chapter will focus on comparing our technologies to each other. First, in section 5.2, we shall compare genetically modified foods and vaccines. Section 5.3 goes into nuclear energy and vaccines. Finally, this chapter will finish up with section 5.4, discussing similarities and differences of nuclear energy and genetically modified foods. Chapter 6, which follows, will purpose implications for the field of applied nanoscience and draw our final conclusions.

5.2 Genetically Modified Foods vs. Vaccines

The situations regarding the rise and fall of social acceptance of genetically modified foods and vaccines share a number of characteristics. Acting on a very personal level, each technology has been subjugated to concerns involving long-term health effects. Although differences exist, both genetically modified foods and vaccines are judged in terms of perceived risk to benefit, driving the public approval of these technologies.

Genetically modified foods and vaccines affect people on a very personal level. When a person eats GM food, he is willingly introducing it into his body. This is akin to vaccination, where antigens are injected directly into a person's blood stream. In both cases, a decision on a private, personal level is made as to whether or not to expose oneself to the effects and hazards of the food or drug. Nuclear energy, on the other hand, produces electricity, which allows one to power their home, appliances and all the devices necessary for comfortable living. In this case, a person's decision is detached: he is not drinking from the power outlet or plugging the electricity into his veins. The situation is not private like with GM food and vaccines. The repercussions of nuclear energy are not perceived as so personal. He is merely lighting up his home. If the food was bad or the vaccine toxic, the repercussions would be immediate, direct and severe to the person, compared to an energy issue in which the only worry is what to do when the power goes out. Both GM foods and vaccines have had their social acceptance subject to the fact that they are technologies which carry personal repercussions.

One of the personal repercussions shared by both technologies is the fear of long-term health effects. Anti-GM groups claim that GM foods are very dangerous to a person's health, inciting fear regardless of heavy testing of GM food in recent years, replacing the widely untested “natural” foods resulting from nearly unregulated mutation breeding schemes (Prakash, 2001). Nonetheless, these fears, as unwarranted as they are, can greatly outweigh the perceived benefits of cheaper, healthier foods, at least in first-world countries. The situation is greatly different in developing nations where any food is a luxury and the benefits of cheaper, better GM food is clearly much more important than any perceived risks of long-term health effects. After all, if you are going to die of starvation, who cares about long-term effects? Typically, in such a situation, the acceptance rises substantially. As far as vaccines, in the case of measles, the risk of autism was presented, making some choose to go without vaccination. However, largely, the perceived benefit of not dying from the disease without being properly administered the vaccine overshadowed the risk of potentially contracting autism. When people got sick, the vaccine was widely used, showing that as the risk of sickness rises and the benefit of taking the vaccine becomes clear, use and acceptance rise as well. As in both cases, the fear of long-term health benefits can be overcome when the perceived benefits of the technology are apparent and seem to surpass the risks.

An important difference between GM foods and vaccines is present above, concerning the possible alternatives. There are alternatives to GM food, namely, non-GM food. As mentioned above, in many places, saving a couple bucks on GM food is not enough of an incentive to buy, especially in countries like the United Kingdom where the risks were greatly exaggerated and the benefits played down. In agriculturally-lacking countries, on the other hand, this risk to benefit ratio will swing greatly towards acceptance, as any perceived risks associated with GM food would be outweighed by hunger. In countries without such a bounty of natural resources, the benefits of GM being able to provide mass amounts of food much cheaper than the cost of importing from other countries has lead to wide use, such as China. Even the United States has over 75 percent of its soybeans genetically modified (Chern, *et al.*, 2002). It is probable that in the future, when there is a greater need for food in order to support an ever-increasing world population, the benefit of GM foods will greatly outweigh any perceived risks associated with it. Vaccines, however, have little alternatives, except potentially contracting the disease. Naturally, their acceptance is exceedingly high as the believed risk of infection arises and the benefits become visible. As the perceived benefit of using the technology rises due to other options falling out and the risk of not using the technology goes up, the acceptance of GM foods and vaccines is affected, showing that the number of feasibility of alternatives affects their acceptance.

Another important comparison of the public perception of vaccines and GM foods is that people seem to judge vaccines on an individual basis, while all genetically modified foods are blanketed under GM. Just like there are different vaccines for measles, flu and small pox, there are also different genetically modified foods, including rice, soy, corn and wheat. The autism claim for measles did not affect people's perception of the polio vaccine. Persons were able to distinguish between the two and realize that the problems associated with one has no bearing on the other. Such is not the case with GM foods. For example, the fear of GM corn decreasing the diversity of corn has been used to make all GM foods seem dangerous (Prakash, 2001). This blanket effect is most clearly seen in how countries that ban GM consumption or production ban all GM foods, not select varieties. GM food is not considered on an individual basis. A possible explanation for why different vaccines are treated distinctly but GM food is all grouped together is that different diseases have different symptoms that the individual vaccines combat. The symptoms of hunger are the same regardless of which food a person has not eaten. For vaccines the perceived risks and benefits are separate, but for GM food the perceived benefit is the same, even if the actual risks may differ. Persons may clearly segregate the vaccines and consider each one separately and yet integrate all GM foods together for this reason. [more research next year on this?] This all-encompassing distaste of GM foods is very different from the case-by-case analysis of vaccines, affecting how the two technologies are accepted due to the types of perceived risks and benefits.

Both technologies, genetically modified foods and vaccines, share a number of traits and differ in important ways. Each acts on a personal level, affecting the person himself, making clear the benefits and risks to him directly. Additionally, each raises concerns over long-term health effects. However, vaccines has maintained a high perceived benefit to risk ratio since alternatives do not truly exist and each vaccine is concerned disparately. This contrasts to GM food, which has many alternatives in many countries and is affected by a blanket effect, causing it to seek other means to increase acceptance. For both technologies, the perceived benefits fall as the risks rise dramatically, due to their personal nature, until there are few other options and the benefits greatly outweigh the risks, pushing public approval high.

5.3 Nuclear Energy vs. Vaccines

Nuclear energy's driving force is the world's need for power. For vaccines, it is the need to not be sick. The only way to not get sick is to be vaccinated, while one can burn wood or coal instead of nuclear energy. Not having an alternative helps the acceptance of vaccines. Possibly in the future, when fossil fuels will become depleted and expensive, nuclear energy would be one of the few viable alternatives. None the less it would still have to compete with solar and wind power.

One may draw parallels in the way that the measles vaccine autism claim and the Three Mile Island incident were handled. In both cases, the acceptance of the technology dropped due to a drop in public opinion. Investigations into the details of the incidents lead to results that calmed the public, rejecting the autism claim with the measles vaccine and pointing out the insignificance of the escaped radiation in Three Mile Island.

Except for that, the ways that public acceptance is kept up for nuclear energy and vaccines are quite different. Just the mere existence of diseases advocates the acceptance of vaccines. In order for nuclear energy to be accepted, there has to be a lot of media and industry support. Everybody knows that nuclear radiation can make you grow an extra arm, or at the very least instigate cancer. Industries that rely on nuclear energy have to counter these fears by promoting the safety of current nuclear power plants. These promotions were key in the quick rebound in public opinion after Three Mile Island and Chernobyl incidents. Once public opinion is brought up, proponents of nuclear energy don't say anything else about it. There haven't been any big pushes for Nuclear Energy use in the past several decades, until recently.

5.4 Genetically Modified Food vs. Nuclear Energy

Nuclear energy and genetically modified foods are technologies that, although widely considered safe in scientific communities, have had to struggle for public approval. Their paths towards disapproval, reevaluation and eventual acceptance share a common thread centered in the perceived risk to benefit.

The public has presented similar arguments against the distribution and use of nuclear energy and genetically modified foods. Both technologies have caused questions to be raised concerning the environmental impact and long-term health effects, typically pushed by environmentalists groups and market competitors. The nuclear waste byproduct of nuclear energy as well as the possibility that GM food production could lead to a great decrease in crop diversity has caused serious concern in the public. Since nuclear energy has been around much longer than GM technology, it has been well tested and there are many widely published scientific examples touting its safety and benefits. Even with the few accidents that have occurred and have had sudden impacts on nuclear acceptance they have been balanced by the continued safety of the industry. GM foods, however, are a relatively new technology and only now are studies underway to discuss these implications. However, due to the nature of GM production, that they are developed to specifically isolate beneficial genes and remove toxins, it is inherently difficult to check the toxicity or side effects of some GM foods. Such concerns have stymied the acceptance of GM foods in Europe. These worries about environmental and long-term health implications have affected the level of acceptance of both nuclear energy and GM foods.

Not only nuclear waste but the use of radioactive materials for power generation in a variety of applications has been held as a major point against the technology. The current debates over the use of nuclear fuels and the disposal or reuse of the byproducts of the reaction have become a major issue in recent times. This concern over nuclear wastes and its protection has been a problem for many decades however is just now getting attention as the need to non-fossil fuels has increased. GM Foods however will cause a reverse effect as crops become more resistant to disease and pests with engineering environmental contamination can become smaller with a reduced use of pesticides and fertilizers.

Both technologies have undergone a critical period of acceptance and bounded back. The global mobilization and environmental groups pushing for the criminalization of GM technology during the late 1990's were met with quick counter-mobilization in North America. This directly lead to a high level of acceptance of GM foods throughout North America. Nuclear energy, after TMI and Chernobyl, returned to its previous acceptance levels quickly with media reports showing the overall safety of the industry and in the TMI case the very negligible impact it had on the area. In each case, this counter-mobilization has come about from government and industry backing of the technologies through promotional campaigns directed to increase social acceptance. The counter-example concerns GM acceptance in Europe, where counter-mobilization came late, was less aggressive and less effective lowering acceptance greatly. In each case of nuclear energy and GM foods where there has been an event to lower public approval, a decisive promotional effort to combat anti-technology sentiment has lead to a great outpouring of acceptance.

A main issue affecting acceptance and use of both nuclear energy is the social drive for resources. Right now both technologies face many alternatives. In countries which are not so lucky, such as agriculturally-lacking communities or large populations, however, these new technologies are much more accepted and put into greater use. For example, due to the incredibly large number of people in China, GM rice and soy is greatly used, and the people have no qualms about it. This issue really comes down to the perceived risks and benefits. With many alternatives, the perceived benefits of nuclear energy or GM foods is very low – people could easily deal with the alternatives, even if they are a little more expensive or less effective. However, as the alternatives drop out, the risk of not using such technologies grows very high, leading to a much more widespread acceptance and drive to use these technologies.

Likewise for nuclear energy more developing and other industrial countries are embracing it as a major portion of their energy generation. In China as GM is being embraced so is nuclear energy with China planning on building forty third-generation pebble bed reactors. This embrace of nuclear energy shows that it is one of the best ways for countries undergoing rapid industrialization to keep up with its growing energy demands. In other established industrialized countries in Europe total energy generation by nuclear power can exceed seventy-five percent. Even as debates go on in countries such as the UK as to whether or not to continue to use nuclear energy or to look towards other fuel sources.

Nuclear energy and genetically modified foods share a specific pattern. Both technologies are considered safe in the academic and scientific communities, and yet face criticism on grounds of environmental and long-term health impacts. To dispel these notions, promotional campaigns initiated by government and industry have lead to homogeneous acceptance. Eventually, as alternatives become less and less feasible, technologies like these are apt to be accepted greatly, as the perceived risk of missing out on the benefits they provide is daunting.

6 Conclusions

6.1 Implications for Nanotechnology

From what we have learned from our investigations of the individual technologies, the perceived risk vs. benefit ratio will be most important part in acceptance of nanotechnology. Risk perception correlates directly with how close the technology is to the user. Benefit perception is usually dictated by need. Since there have not yet been any major applications of nanotechnology, most of these comparisons are extrapolations based on the correlations made in the study of the social acceptance models of the three technologies.

The least controversial applications of nanotechnology will be in materials and computer processors. The fact that the transistors on a chip will depend on quantum properties of nano sized particles does not change the fact that a computer will do calculations. The benefit in this case would be smaller size and or faster computational speed. The personal risk would be nothing. As for the nanoengineered materials application, that too has very low personal risk. An example would be hydrophobic material that does not get wet. There are currently water resistant materials and people are not afraid of them, so one can assume that whether it uses components on the level of several nanometers or not, risk perception would be low. The benefit of not getting wet would outweigh the non-existent perceived risk.

Just like with GMFs, though, the fact that there is a macro version of the technology available as an alternative might hinder the public's conversion to the nano version. This would be most greatly felt if somehow nanotechnology as a whole had a negative connotation associated with it. As we saw with GMFs, though, the fact that the technology is safe and is better than its original counterpart, society, or at least industry, will eventually switch over, changing the norm to accepting nanotechnology applications.

More personal applications of nanotechnology would be in nanoengineered drugs and other technologies that would directly interact with the human body. As long as it is portrayed to be safe, the benefits of having precise delivery of chemicals to specific receptor sites in the body will make nanodrugs the future standard in medicine. Unfortunately, the misuse of this technology would raise fears of nanobioterrorism with the same precision. With such great potential for destruction, should nanodrugs be allowed to be pursued and produced? Proponents of nanotechnology and drug researches would say yes, and so do we. In order to ensure public acceptance nanodrugs will need both government and industrial backing from the start, with media publicizing their safety. This was effective for making people feel safe with nuclear energy and in the counter mobilization efforts with GMF. With more research into these methods, an effective promotion campaign may be developed.

6.2 Recommendations for Future Research

We would strongly recommend further research into the risk vs. benefit ratio and its correlation to public acceptance of technologies. The three technologies studied in this report show a strong correlation to this model and it is reasonable to hypothesize that all technologies can be evaluated using it as well. There is surely more information available on this approach in social psychology and other fields that future IQP teams could look into to development of a more specific description of the model.

With more applications, it would also be of interest to our successors to look at the current stage of nanotechnology development. How many valid applications are there, that truly rely on the small size of its components for function? Are there any controversial projects underway? What initiatives are the government taking to promote nanotechnology? All of these topics would make for interesting research that would help evaluate the state of nanotechnology with respect to public, government, and industrial perceptions.

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