Short Term Gain...

Module 7 • i2P • Biodiversity

"Humans have long since possessed the tools for crafting a better world. Where love, compassion, altruism and justice have failed, genetic manipulation will not succeed."

--Gina Maranto, Quest for Perfection

Introduction

Dating back centuries there have been dire predictions that the worlds resources will not be able to meet the needs of a swelling human population. From Thomas Malthus in 1798, to Paul Erlich in 1968, many have predicted widespread famine when the number of people in the world surpasses the capacity of the planet to supply food. Yet, despite a dramatic increase in population in the 20th century from 1.6 billion to 6.1 billion, food production grew to meet the need. It is estimated that world wide agriculture produces 17% more calories per person today than it did 30 years ago, despite a 70% increase in population. Current world hunger is not believed to be a byproduct of food production, but rather food distribution, war and poverty (see: food).

Did you know?

There are more hungry people in the world than ever before. More than one billion people, almost a sixth of humanity, are now undernourished, according to the latest estimates from the UN's Food and Agriculture Organization.

see: UN food

Humans have met the food needs of the surging world population by expanding agriculture. Between 1700 and 1980 the total area of cultivated land worldwide has increased by 466% (see: agriculture). This process continues today with the deforestation of regions such as the Amazon rainforest to make way for crop and pastureland. However expansion alone would not have produced enough food for the human population. Improvements in agricultural yield were required, and have been achieved by:

Figure 1: A potato field (source: Christoph Neumüller)

- selective breeding - to create higher producing plants and animals
- irrigation - to convert dry regions into productive agricultural land
- use of fertilizers - to increase plant growth
- use of pesticides - to destroy competing insects and plants
- the mechanization of farming - to increase agricultural productivity
- genetic engineering - to create genetically superior plants and animals.

With the exception of selective breeding and irrigation, these methods have all been introduced in the past century, and have proven remarkably successful. However it has gradually become evident that these agricultural innovations may come at a long-term cost.

Figure 1: As a result of selective breeding, corn as we know it today bears only a small resemblance to it's ancient ancestor (source: John Doebley)

DISCOVERY

Humans have long bred plants and animals to produce superior agricultural yield. This process, known as selective breeding or artificial selection, is responsible for many of the agricultural plants and animals used today. A simple illustration of selective breeding is a farmer who mates his meatiest chickens together generation after generation to increase the average amount of meat his flock produces. Selective breeding is primitive genetic modification.

> Definition: Genes.
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> All living organisms have a unique code that determines the characteristics of that organism. This code is written on long molecules called Deoxyribonucleic Acid (DNA). Each section of DNA that gives instructions for a unique trait is known as a gene. In genetic engineering, DNA is cut up and specific genes are transferred from one organism to another.

A more potent type of genetic modification became possible after 1953, when James Watson, Francis Crick and Rosalind Franklin described the structure and function of Deoxyribonucleic Acid (DNA), the molecule that contains the genetic information of all living organisms. Knowledge of DNA allowed scientists to explore the genes responsible for the individual characteristics of a living organism. In other words the genes that make apple trees grow more fruit, wheat resist diseases or cows produce more milk. By 1973, Herbert Boyer and Stanley Cohen had discovered how to splice specific genes into the DNA of another organism. This ability allowed scientists to quickly change the characteristics of a plant or animal by introducing genes to make them bigger, or jucier, or allow them to fight off diseases or pests. Suddenly man had learned how to create ‘super species’ of domestic plants and animals that would produce more food. These plants and animals are called “genetically modified organisms” or “GMO’s” (see GMO).

List of Genetically Modified Plants
Rapeseed
Cotton
Rice
Soybean
Sugar cane
Tomatoes
Corn
Sweet corn
Canola
Potatoes
Flax
Papaya
Squash
Red-hearted chicory
Cotton seed oil
Tobacco
Peas
Sugar beets

Genetic Modification

Figure 3: Tomatoes (source: FoeNyx)

The first genetically modified food to end up on supermarket shelves was the Flavr Savr tomato produced by a company called Calgene. This tomato was genetically engineered to ripen slower and maintain its flavor and appearance longer. Based on its production the Food and Drug Administration of the US deemed genetically modified foods to be safe for consumption and ruled that genetic modification did not have to be acknowledged on labeling. Recently, this policy was updated to say there is no need to label meat from genetically modified animals (see: FDA Ruling). These events paved the way for an explosion of biotechnological experimentation in food and animal production. Today, a great deal of the food we consume on a daily basis is from a genetically modified plant or animal.

> Did you know?
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> About 22% of cows in the U.S. are injected with genetically modified bovine growth hormone.
>
> see: cows

Short Term Gain

Since the creation of the first genetically modified tomato, the list of genetically modified foods has grown very long. Genetic modification has enabled the creation of ‘super’ organisms with increased agricultural yield (see: GMO foods). Examples are:

- Soybeans are genetically modified to be resistant to herbicides. This allows farmers to apply herbicides to an entire field to selectively kill weeds that stunt soybean growth.

- Foods such as oranges and rice have been genetically engineered to be more nutritious. Oranges now contain more Vitamin C, and species of rice have been developed that are higher in Vitamin A (see: Golden Rice). This enables humans to get more nutrition from a single serving of these foods.

Did you know?

About 22% of cows in the U.S. are injected with genetically modified bovine growth hormone.

see: cows

- Peas have been inserted with a gene from kidney beans, which creates a protein that acts as a pesticide. This allows the peas to withstand disease.

Genetically modified organisms are being used for industrial and medicinal purposes as well. Genetic engineering techniques have been applied in the production of insulin (see Humulin) for the treatment of diabetes. Genetic engineering is also used to create commonly used vaccines and medications (see: vaccine). There is even new rice being developed in the United States which contains human genes. The modifications make the rice a healthier option for those suffering from diarrhea. The rice is to be used in the developing world (see: rice)

In the industrial sector, genetically modified oil eating bacteria was used to help clean the recent oil spill in the Gulf of Mexico. Developed 30 years ago, many experts believe that these bacteria are the answer to the enormous task of cleaning up the oil. While the effectiveness of these bacteria is still debated, many hope they will become the reliable, efficient and "natural" spill clean-up methods of the future (see: oil-eating).

Figure 4:
Top: Lesser cornstalk borer larvae extensively damaged the leaves of this unprotected peanut plant.
Bottom: After only a few bites of peanut leaves of this genetically engineered plant (containing the genes of the Bacillus thuringiensis (Bt) bacteria), this lesser cornstalk borer larva crawled off the leaf and died.
(source: Herb Pilcher).

Student exercise

Please consider what characteristics of a plant or animal make it more profitable to grow/raise for widespread food distribution and consumption? Do these characteristics always align with what is best for humans to eat?

Genetic Erosion

The success of agriculture seen in the past century has been the byproduct, in part, of the creation of superior species of plants and animals that grow rapidly, are easy to manage, and are pest resistant. The creation of these 'super' species means that they are preferentially chosen and grown around the world. A perfect example is the chicken. One would not imagine that the chicken is an endangered animal, yet today there are 20 breeds of chicken on the critically endangered species list (see: chicken). This is because farmers have been replacing many breeds with the 'super' species that grows rapidly, has more flavor, plumper meat, and produces eggs quicker. Followed to its logical conclusion this could ultimately result in there being just 1 breed of 'super' chicken that is mass-produced around the globe.

Figure 5: Baby domestic chickens (source: Herbert T)

The preferred use of a 'super' species, such as the chicken, results in a rapid artificial selection that decreases the genetic diversity of a species. The process whereby an organism has fewer and fewer different genes in the genetic pool of its species is called genetic erosion.

> **Did you know?**
>
> 77% of soybeans, 49% of cotton, and 26% of corn (maize) grown globally are genetically modified.

Worldwide the selection of 'super' species of genetically modified plants and animals is propelling genetic erosion and driving less desirable breeds into extinction. This is rapidly decreasing the genetic biodiversity of the world.

Student Exercise

The following website contains a list of genetically modified foods. How much of what you are eating has likely come from a genetically modified source?

see: GMO

Genetic Pollution

Another concern with genetic modification is the possibility of spreading genes from the modified organism to other species. This process is called genetic pollution (see: genetic pollution), and is defined by the United Nations as the:

"Uncontrolled spread of genetic information into the genomes of organisms in which such genes are not present in nature."

Imagine if a canola plant is genetically modified to produce a particular herbicide that will kill typical pests that feed on it. If this herbicide gene spreads into the DNA of a common weed, then this weed will also be resistant to the pests. The weed will have a genetic advantage and could spread rapidly, destroying ecosystems and crops. While lab tests suggest that the likelihood of a genetic transfer between genetically engineered crops and other organisms appears to be low, there is some evidence that it can occur (see: Horizontal Gene Transfer).

Figure 6: A genetically modified canola plant (source: Canada Hky)

Long Term Pain

Recall that genetic diversity, and by extension biodiversity, ensures the survival of a species when faced with major threats, such as disease, climate change and habitat destruction. The greater the genetic diversity, the more likely members of a species are to survive when met with sudden environmental change (see: genetic erosion).

Did you know?

Of the 7,000 plant species that people consume, 103 species account for 90% of the world's crops.

see: monoculture

Throughout history, many organisms have gone through *population bottlenecks*, a time where environment conditions or disease threatens the survival of a species. Historians believe that humans experienced a population bottleneck after a mammoth volcanic eruption changed

Did You Know?

Annually, population growth adds 78,000,000 more people to the planet while 27,000,000 tons of topsoil is lost.

see: topsoil

earth's climate. Due to the environmental changes and strains on food resources, the theory argues that the human population dropped as low as 10,000 (see: bottleneck). One can't help but wonder whether any members of our species would have survived if we all had the same genetic make-up?

Today we need to ask these sorts of questions regarding the use of genetic modification for the 'short-term' gain of increased production for human use. As we use genetic modification to promote traits needed for our immediate demand for food, medicine and comfort we also limit the biodiversity within a given species or ecosystem. In doing so are we eliminating natural safeguard's against extinction? Will the lack of biodiversity propel many species to extinction if there is a major environmental challenge?

We may know the answer to these questions sooner rather than later. Human activity is is also generating a significant environmental challenge in the form of climate change. Together global warming and decreased genetic diversity may provide the perfect storm that will test the survival of many species, including our own.

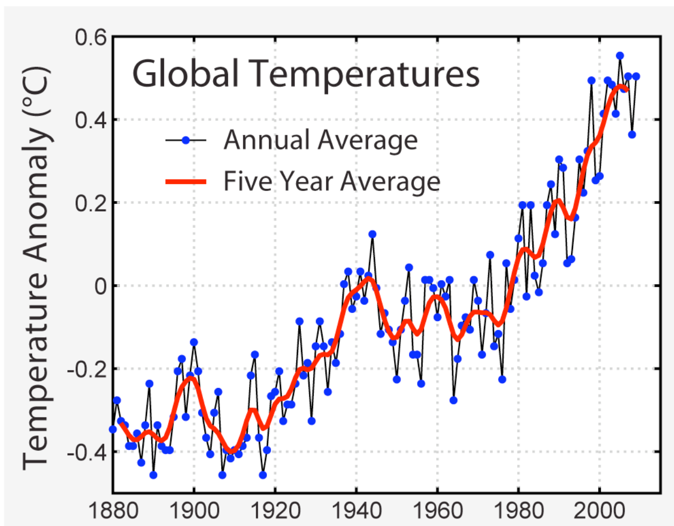

Figure 7 : A graph of the average world temperature between 1880 and today (source: NASA)

Student Exercise

Genetically Modified Organisms in Developing Countries

There is much debate about the benefits and harm of developing countries importing living modified organisms or growing genetically modified crops locally. Proponents argue that when used correctly, genetically modified foods can significantly increase a country's crop yield, thereby enabling an impoverished country to feed more people. Opponents point to the fact that eliminating diverse local crops in favor of only a few major genetically modified crops would threaten the stability of the local ecosystem.

Please review the following discussion paper on the current debate surrounding this issue:

GMO in Developing Countries