CRISPR-Edited Crops

Florida's Citrus Economy

The Florida orange is a staple of an American breakfast. Whether in a fruit salad or poured into a cup, Florida oranges are iconic and delicious. The Sunshine State produces 70% of the annual U.S. production of citrus (oranges, grapefruits, etc.) and 95% of commericial orange production in the state is mostly used for producing 40% of the world's orange juice supply.[1]

The citrus industry, directly and indirectly, generates approximately 45,000 full time and part time jobs. The total impact of citrus in Florida's economy is roughly $8.6 billion a year.[2]

Oranges Under Attack

The **Asian citrus psyllid** is not native to Florida, but this small insect has slowly spread across the US in recent years, infecting citrus trees with a bacteria that causes a serious plant disease called **Huanglongbing (HLB)**, also known as **citrus greening disease**. Trees with HLB decline over a few years, displaying yellow leaves and misshapen fruits, falling production, and finally succumbing to the disease.

In the past decade in the US, HLB has led to a 72% decline in the production of oranges used for juice and other products. More than $4.6 billion and over 30,000 jobs have been lost in the Florida because of HLB, and the statistics keep rising.[3]

A Genetic Remedy

In addition to other countermeasures, scientists hope to use **CRISPR genome editing** as a way to halt the spread of HBL. Researchers are fervently working to understand the genetics of HLB infection and identify genes that make the citrus plants vulnerable or resistant. Using CRISPR genome editing, scientists plan to engineer orange trees that are resistant to HBL, thus preserving the iconic fruit and local economy.

Assignment

A new proposal has reached the Governor's desk. This latest piece of legislation would prohibit the growth of **genome-edited** crops in Florida, which would include the use of CRISPR genome editing. The Governor must hear from a range of different voices and take into account all relevant concerns before coming to a final decision. If the Governor does not feel that complete approval or ban of edited-crops is justified then the Governor may alter the bill accordingly.

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1. Florida's Economy: The 6 Industries Driving GDP Growth, https://www.investopedia.com
2. Citrus Statistics, Florida Citrus Mutual, http://flcitrusmutual.com/citrus-101/citrusstatistics.aspx
3. Citrus greening is killing the world's orange trees. Scientists are racing to help, C&EN, https://cen.acs.org/biological-chemistry/biochemistry/Citrus-greening-killing-worlds-orange/97/i23

Roles

Florida Governor

The Florida governor is set to vote on an upcoming bill that would ban the farming of CRISPR-edited crops, including oranges. This bill has garnered support from those who are hesistant about the environmental impact and health safety of edited-crops. Alternatively, farmers and business owners are worried that this bill will halt necessary innovation that could save the state's rapidly declining orange production.

Florida Farmer

The local farmer is open to any effective means of defending orange trees against HLB, including the use of tree removal, antibiotics, or gene editing. The 1,000 acre farm relies on orange orchards and will need to close the business if the spread of HLB infection persists. The farm employs 80 full time residents and 20 seasonal employees, and sells oranges to large companies like Topicana and at local farmer's markets.

Farmer's Market Shopper

The local Farmer's market is a place where shoppers are able to find "farm-to-table" fresh and natural foods. The farmer's market shopper values supporting the local economy while buying **organic** fruits and vegetables that have not been sprayed with pesticides or other chemicals. Unsure about how CRISPR-edited crops are similar or different to GMOs, the shopper is hesitant to the idea of CRISPR editing oranges, which may pose an unpredictable health risk for the shopper's family.

Supermarket CEO

The price of orange juice has slowly climbed over the past five years and profits are falling, causing some stores to pull orange juice from their shelves. The CEO of a national supermarket chain values transparency and customer satisfaction, thus any products containing **genome-edited** material must display a clear label. If the supermarket sells juice made from CRISPR-edited oranges, will customers buy it? Is engineered orange juice better than no orange juice?

Environmental Activist

The rise of offshore drilling, deforestation, and temperatures are growing concerns for Florida residents. Now, many environmental activists are adding CRISPR to this long list. In addition to potential heath concerns, altering the DNA of produce could pose unpredictable risks to balanced ecosystems. CRISPR-edited orange trees could make their way outside of farms and into the wild. Activists are also skepetical of the state and federal government's ability to adequately regulate and test this edited produce.

CRISPR Embryo Editing

From One Comes Many

The human body can be divided into two types of cells: **somatic cells** and **germ cells**. Somatic cells make up the majority of our body including eyes, lungs, skin and more. Germ cells are unique in that they pass on genetic information to future generations and include eggs, sperm, and **embryos**. A single-celled embryo begins to divide and become different types of cells, eventually developing into organs and tissues. The genomic sequence a human embryo holds the blueprint for development and the same DNA will be present in every nucleus across the rest of the body.

Treatment and Enhancement

While most nucleotide changes across the human genome do not lead to a noticeable change, mutations in specific genes may have a significant impact to one's health. For example, one letter change (**mutation**) amongst the 3 billion base pairs of the human **genome** leads to **sickle cell disease**. Swapping out this single letter would cure sickle cell disease, an approach that scientists are taking using **CRISPR** technology. In addition to causing a range of **genetic disease**, tiny changes in human DNA can also lead to new traits that might be considered "**enhancements**." For example, altering the **myostatin gene** can lead to muscle growth.

Altering the Human Germline

The rise of CRISPR gene editing holds promise for treating a range of previsouly incurable genetic diseases, but also presents new ethical questions. As the technology becomes more afforable, precise, and easy to use, more people will be able to engineering human embryos. Although techniques like **preimplantation genetic diagosis** already exist to screen embryos for genetic diseases, some view embryo editing as a new tool on the horizon. Many questions still surround the basic biology of embryo genomics and development, but once these questions are answered the groundwork will be laid for human germline editing.

Assignment

A US Congress committee is preparing to vote on a new measure that would significantly impact the future of medicine in America. To date, the **FDA** is not allowed to consider any research proposals that involve genetically modifying an embryo. This committee is deciding whether to overturn this rule, opening the possibility for scientists to test new therapies and potentially cure genetic diseases at the embryo stage.

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Congress Person

Until recently, the ability to precisely change the genomes of human embryos was extremeley difficult or impossible. This implossibility made it easy for policymakers to ban proposed projects aiming to engineer the human germline. Now with CRISPR, the ability to treat genetic diseases at the embryonic stage is forcing Congress to reconsider previous bans. The Congress person must listen to all relevant opinions in order to determine whether to allow genetic research on embryos and the eventual **implantation** of edited-embryos.

Fertility Doctor

Every year, couples across the country enter **fertility clinics** and leave learning that they carry potentially deadly genetic mutations within their DNA. Preventing the passage of these mutated genes on to the next generation is an option that many couples wish they had. The fertility doctor wants to offer aspiring parents all potential options for having a happy and healthy child, even if that may require correcting genetic mutations using CRISPR gene editing.

Disability Advocate

Diversity is what helps makes society vibrant and inclusive. A key part of societal diversity comes from everyone's unique genomes, leading to a range in appearances, interests, and abilities. Removing people with genetic disabilites from society would decrease beneficial diversity and stigmatize those living with "undesirable" genetic mutations. The disability advocate views genome editing as a way to create a society of idealic babies, leading to a new age of **eugenics**.

UN Health Official

The US is not the only country quickly working to establish modern policy that is keeping pace with advanced biotechnologies. If the US creates policy that is too strict and conversative then many parents may go overseas to countries with more lenient laws. The **United Nations (UN)** health official believes that communication between countries is imperative. What may be a treatment in one country may be an enhancement in another, exemplifying the nuance of international dialogue.

Parent of Child with Genetic Disease

Any parents who have raised a child with a debilitating genetic disease, are well aware of the associated mental, physical, financial, and emotional burdens. Based on the severity of the disease, some parents would chose to correct mutations at the embryonic stage if given a second chance, while other parents would choose not to. This parent of a child with a genetic disease wants to ensure that parents are given the option of correcting mutations, but that such an option would not only be available to wealthy couples.

CRISPR Gene Drives

Malaria'a Global Impact

In 2017 alone, there were an estimated 219 million cases of **malaria** and approximately 435,000 deaths. 93% of these deaths were in Africa, a majority of which are chidlren under the age of 5. Malaria is caused by ***Plasmodium*** parasites, which are carried and delivered into humans by the ***Anopheles*** mosquito species. The majority of malaria cases arise in Africa due to *Anopheles's* ability to thrive in tropical and warm regional climates.

Stopping the Spread

Despite malaria's wide spread, the disease is both preventable and treatable. Common methods of prevention include **insecticide**-treated mosquito nets and indoor insecticide spray. These tools have helped protect roughly half of all at-risk people in Africa. Antimalarial medications are effective, preventative treatments, especially for travelers, preganent mothers, and young children. Beyond prevention, multiple drugs are available to treat mild and severe cases of malaria. More recently, a **vaccine** has entered early piloting in select African countries, focusing on young children.

Genetically-Modified Mosquitoes

The advancement of **CRISPR** technology has allowed researchers to more precisely engineer the DNA of multiple mosquito species, leading to the development of **gene drives**. A gene drive is an organism that is engineered with a specific trait, which rapidly spreads through a population. There are two main gene drive strategies: "**population replacement**" and "**population suppression**" (see Glossary for details). Only a few, out of all 3,000 mosquito species, transmit malaria, so the removal of one species does not mean all mosquitoes will be removed from an area.

Assignment

The **United Nations (UN)** have turned attention to the rise of African economies and efforts to support sustainable growth of emerging markets. Part of these efforts include addressing the spread of malaria, a major factor in health, education, and economies. Scientists have made progress on the development of gene drives to address the spread of malaria, but many groups are cautious of this technology's use. The UN policy director must determine how, or even if, to incorporate gene drive technology into UN policy. Things to consider include: funding, testing, release, regultation, and accountability.

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[1] World Health Organization, https://www.who.int/news-room/fact-sheets/detail/malaria

Roles

United Nations Policy Director

There is no single way to fix complex global issues, but instead all potential tactics and measures must be considered in order to establish effective policy. Although gene drives have only recently been proven as a proof-of-concept for preventing the spread of disease, it has the potential of saving thousands of lives. The policy director values hearing all pertinent voices and performing **risk/benefit analyses** when making rational decisions.

President of Benin

Although Benin shares a border with Burkina Faso, the country experiences a significantly lower infection rate than its neighbor. The president of Benin desires safety and stability for Burkina Faso, yet release of genetically-modified mosquitoes in Burkina Faso will surely make their way over the border. The president is tasked with protecting the people of Benin, thus any potential environmental or health risks imposed by gene drives may outweigh the benefits.

Burkina Faso Doctor

Burkina Faso is one of the most heavily impacted country in the world when it comes to Malaria mortality. Many young lives have been cut short, and those who survive malaria see negative long-term health effects. The doctor supports aggressive but safe measures that can help his local community fight malaria. If gene drives are appropriately tested and proven effective, then the doctor advocates for timely release to save thousands of lives.

Conservation Activist

Releasing **genome-edited** mosquitoes into the wild introduces unpredicatable risks and may lead to irreversible environmental consequences. Some gene drive designs aim to eradicate entire mosquito species, thus removing potentially vital links in complex food chains. The conservation activist opposes outside human influence on delicate ecosystems. The activist requires that a released gene drive must be reversible and well-controlled.

Aid Worker

There are multiple effective ways of reducing malaria infection without the use of genome editing or species removal. For instance insecticide-treated mosquito nets have protected approximately half of all people at risk in Africa. This number has recently plateauted, indicating that more work can be done to hand out nets and other resources. The aid worker advocates for these proven methods before taking more extreme paths, such as mosquito eradication using gene drives.