Gene drive for pests and disease control in plants and animals: Applications and Improvements

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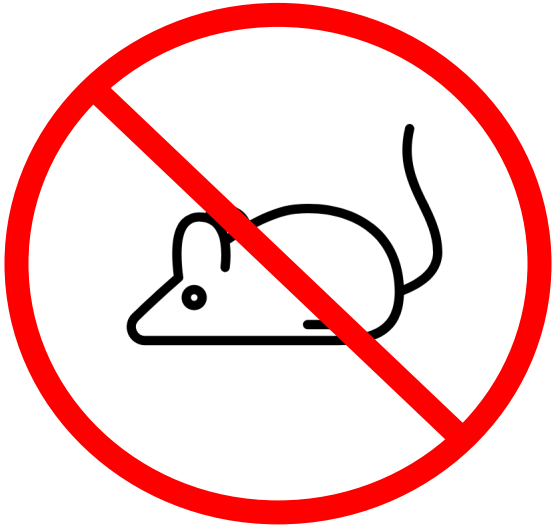
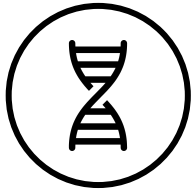
Gene drives can solve current world issues



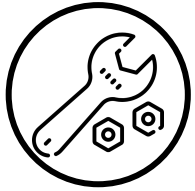
Solution?
Gene Drives!

Presentation Objectives and Outline



Introduction to Gene Drive

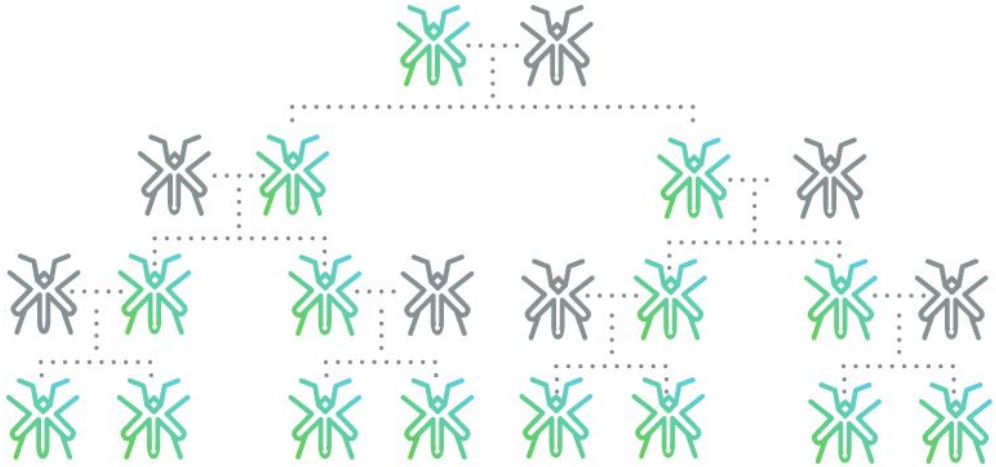
Potential Applications



Improving Potential Applications

Gene drives spread themselves in the wild

Gene drive systems passes on a gene through a population to at a higher rate than normal

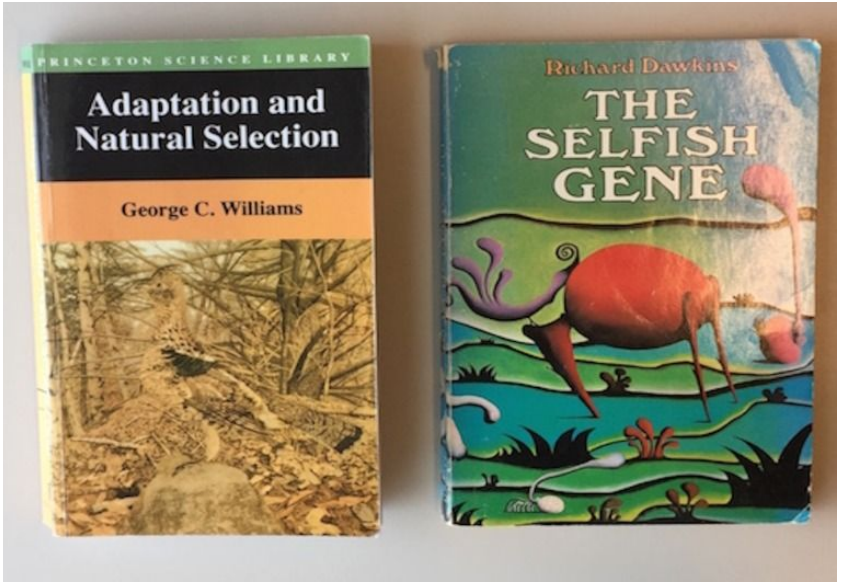


Enzmann, 2018

Gene drives are a natural phenomenon

Selfish genes

- promotes its own survival
- may not be useful to the organism

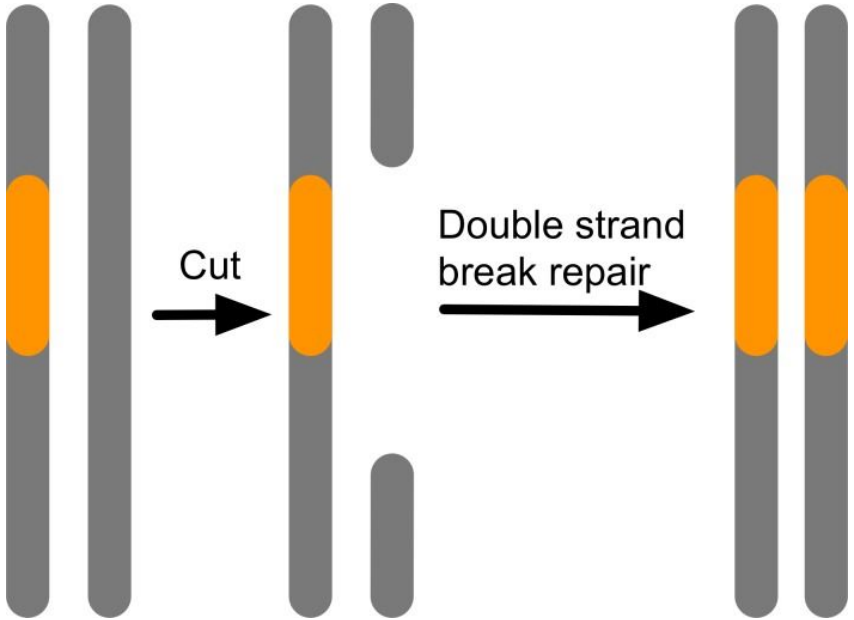


Arvid and Clark, 2018

Different kinds of gene drives present

Examples:

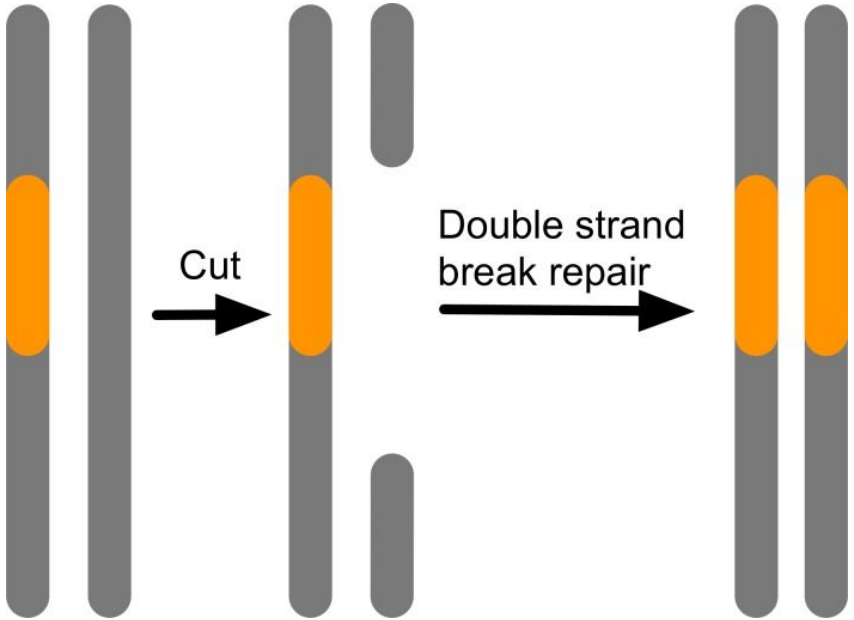
- Segregation distorters
- Transposable elements
- Greenbeard
- Homing endonuclease



Arvid and Clark, 2018

Problems with homing endonucleases

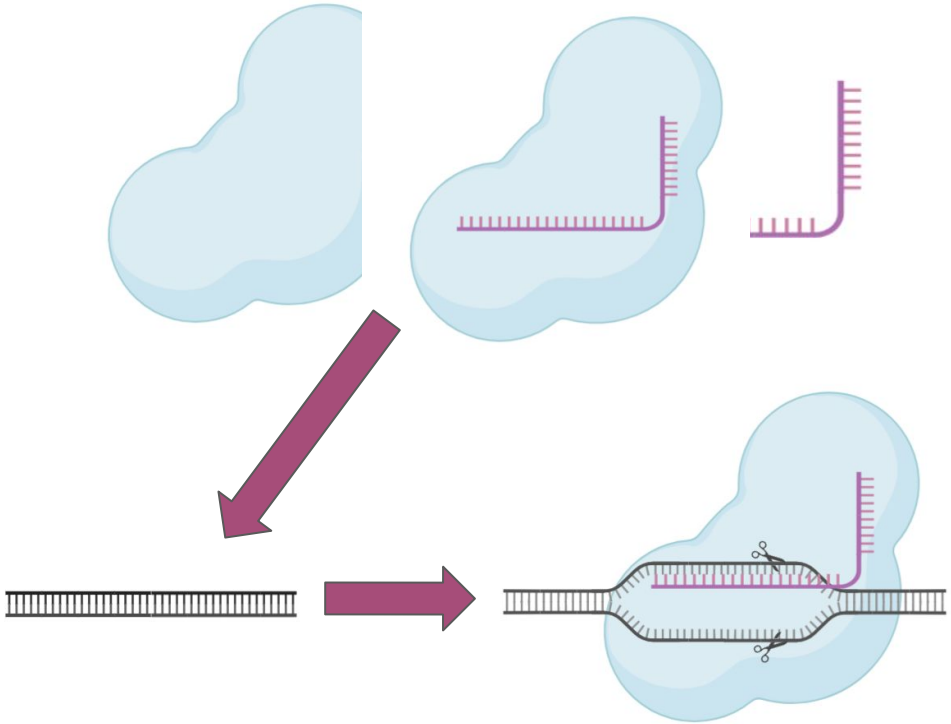
- Construct design is difficult
- Hard to change target site
- Target is too specific for broad purpose



Arvid and Clark, 2018

CRISPR/Cas9 revolutionized gene drives

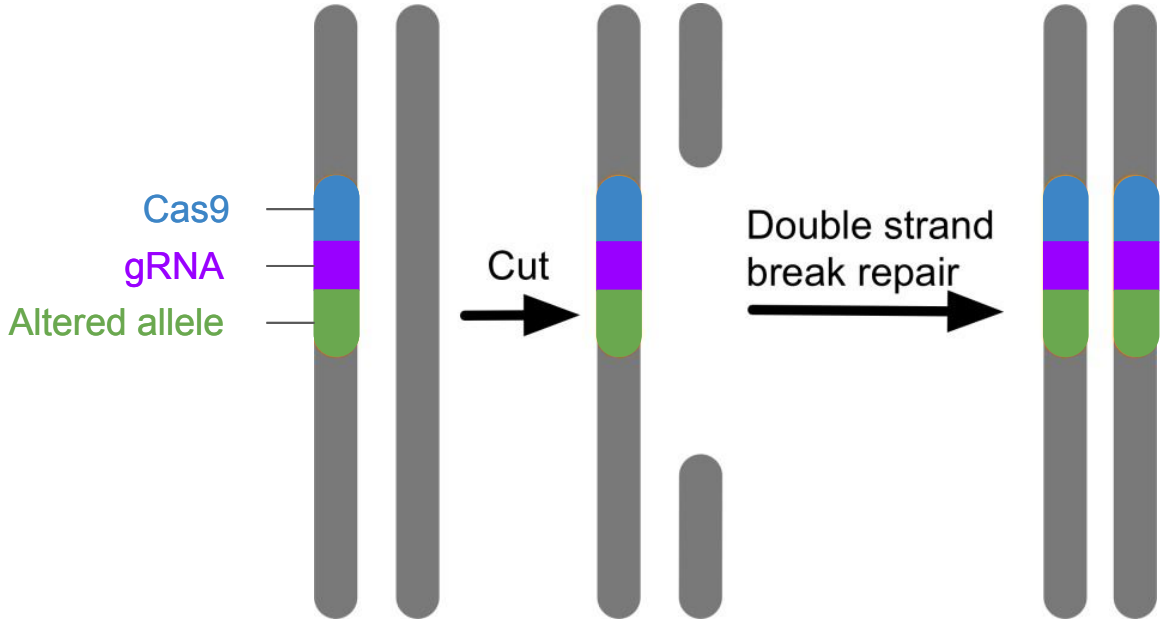
- CRISPR/Cas9 and gRNA work together to specifically cut where targeted
- Can design gRNA to target different genes and organisms



Synthetic gene drives use CRISPR/Cas9

Synthetic gene drive

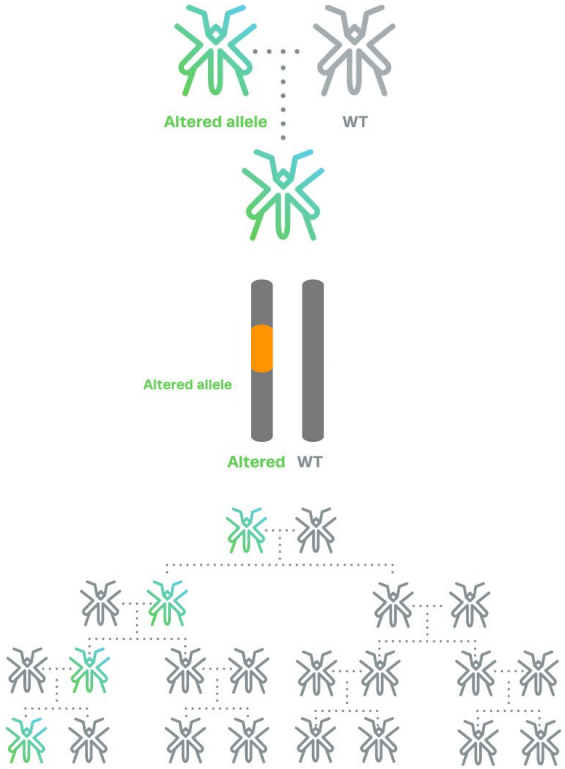
- cut
- where to cut
- gene to spread



Enzmann, 2018

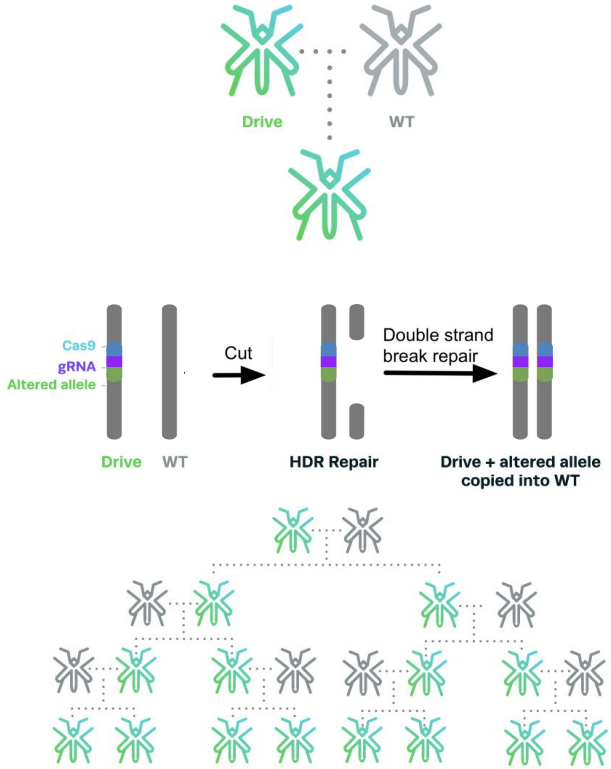
Gene drives spread fast in a population

Altered gene spread by **normal inheritance**



50% chance of passing altered gene via normal inheritance

Altered gene spread by **gene drive**

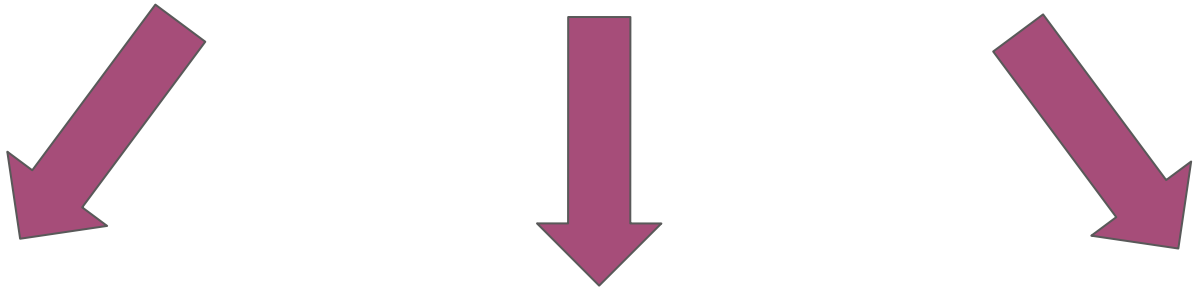


>50% chance of passing altered gene via gene drive

Enzmann, 2018

Gene drive importance and purpose

- Can edit a wild population
- Self-sustaining and cost-effective
- Highly versatile



Eradication

Suppression

Rescue

The promises of gene drives

Public health

Control of vector-borne diseases

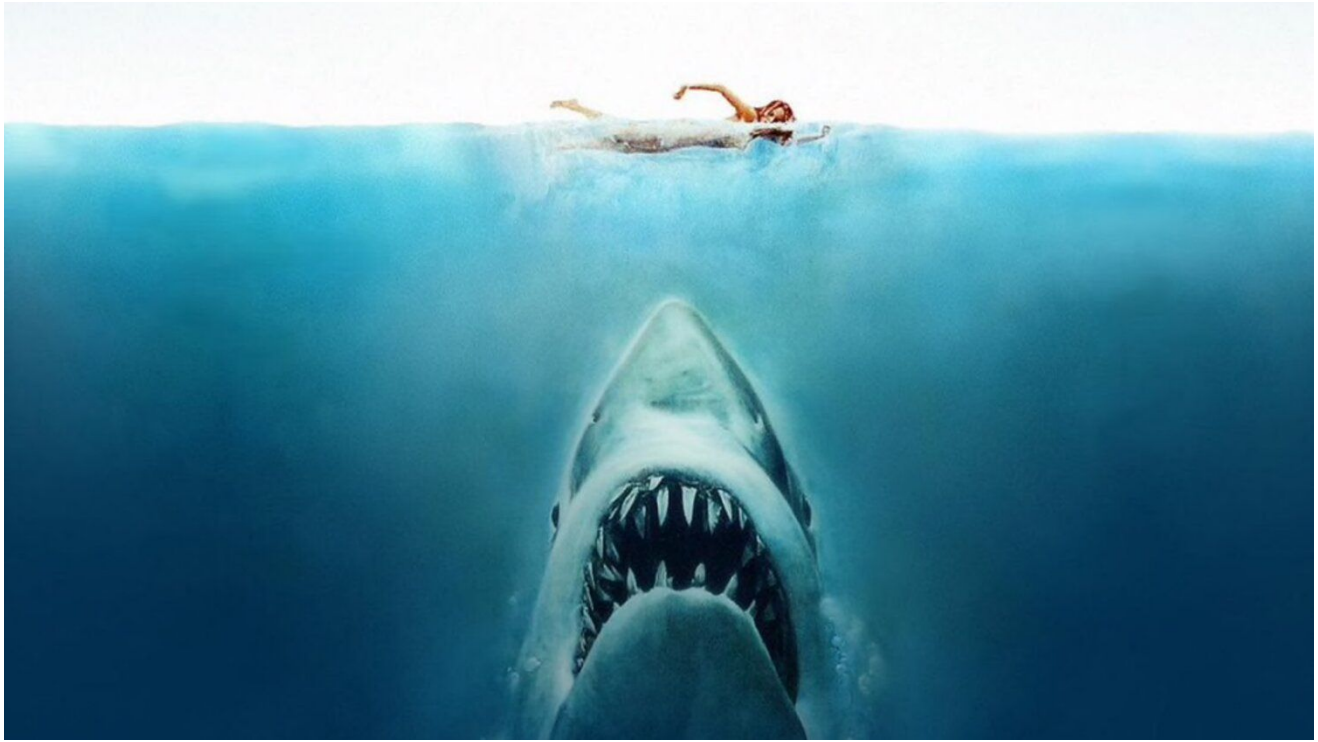
Ecology and environment

Control of invasive animal species

Agriculture

Control of invasive plant species and diseases

World’s deadliest animal



World’s deadliest animal

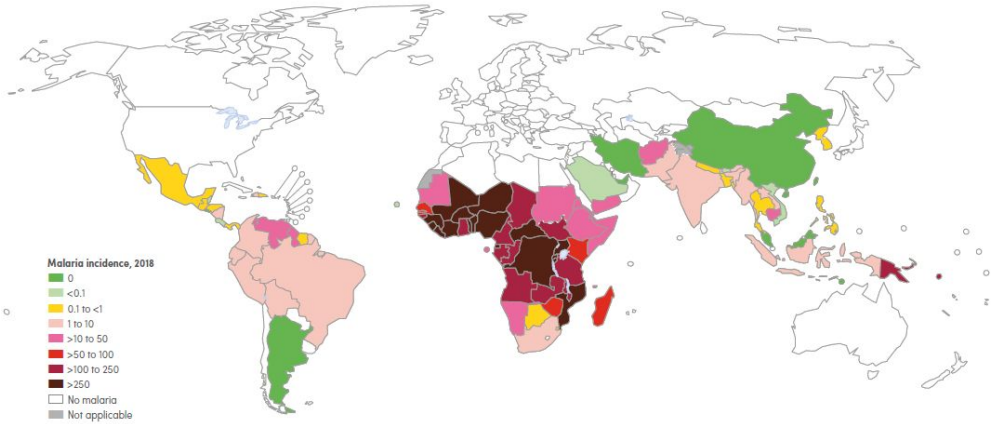
World’s deadliest animal

Mosquitoes directly impact poor communities

- >700,000 deaths every year
- Poor communities and least developed countries
- Aggravates poverty

Malaria is a global burden

- *Plasmodium* parasites
- 435,000 deaths (61% children under 5)
- African region (93% deaths)



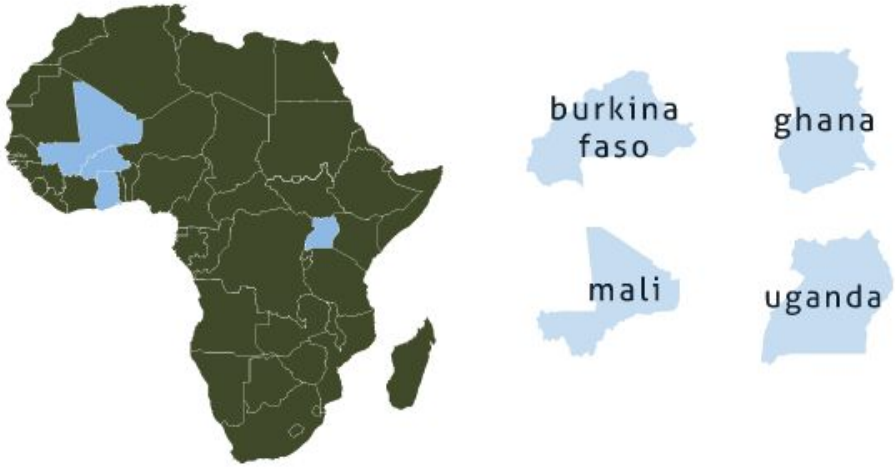
WHO, 2018

Consortium aims to eradicate Malaria

Scientists

TARGET MALARIA

Risk assessment specialists

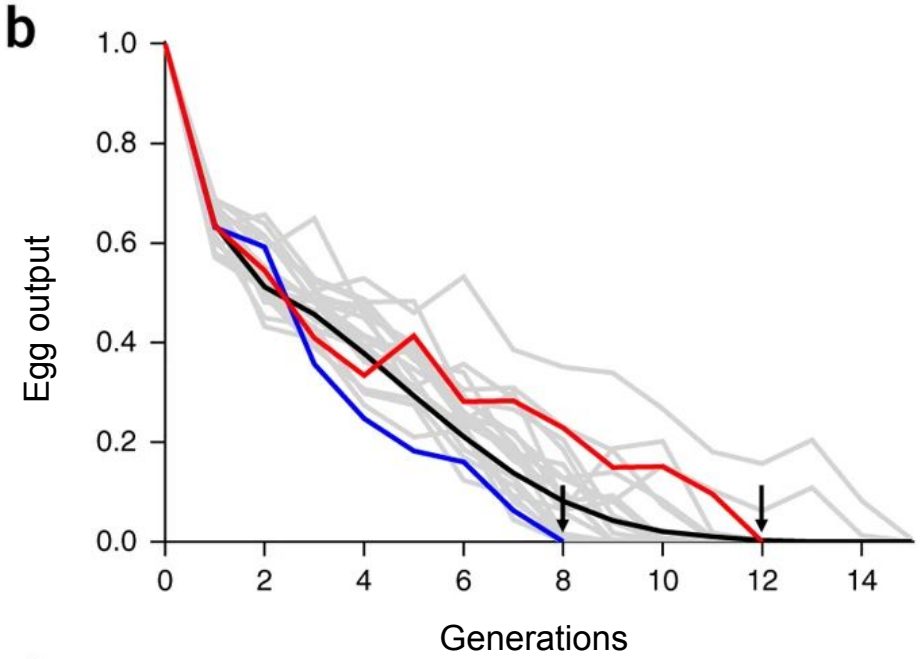


Stakeholder engagement teams

Regulatory experts

Gene drive mosquitoes to fight Malaria

Targeting females to decrease transmission and population



Kyrou et al., 2018

Gene drive mosquitoes to fight Malaria

Creating resistant mosquitoes

CRISPR/Cas9 gene drive construct

↓

FREP1

↓

Survival of Malaria's parasite

Slower development

Less likely to feed on blood

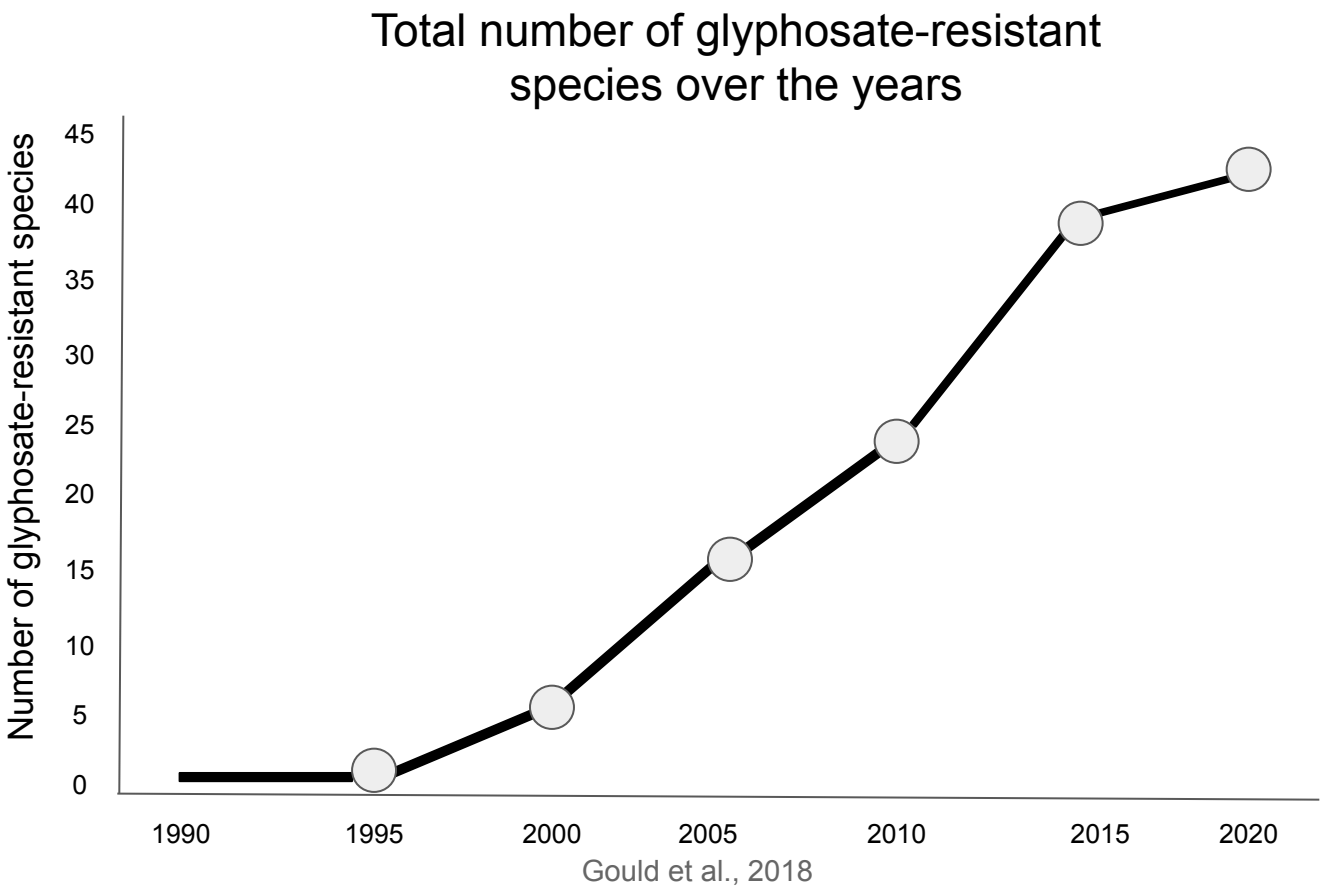
Laid fewer eggs

Kyrou et al., 2018

Weeds threat agriculture and the environment

"A plant that grows in the wrong place"

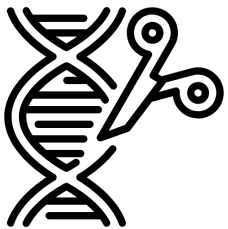
Herbicide resistance is a big problem

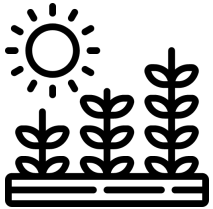
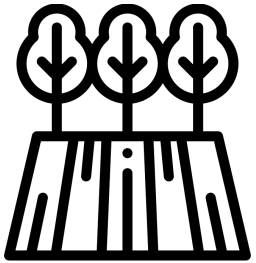


Gould et al., 2018

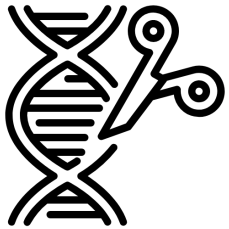
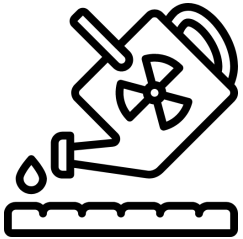
Gene drives can control invasive plants

- Population suppression



- Population sensibilization

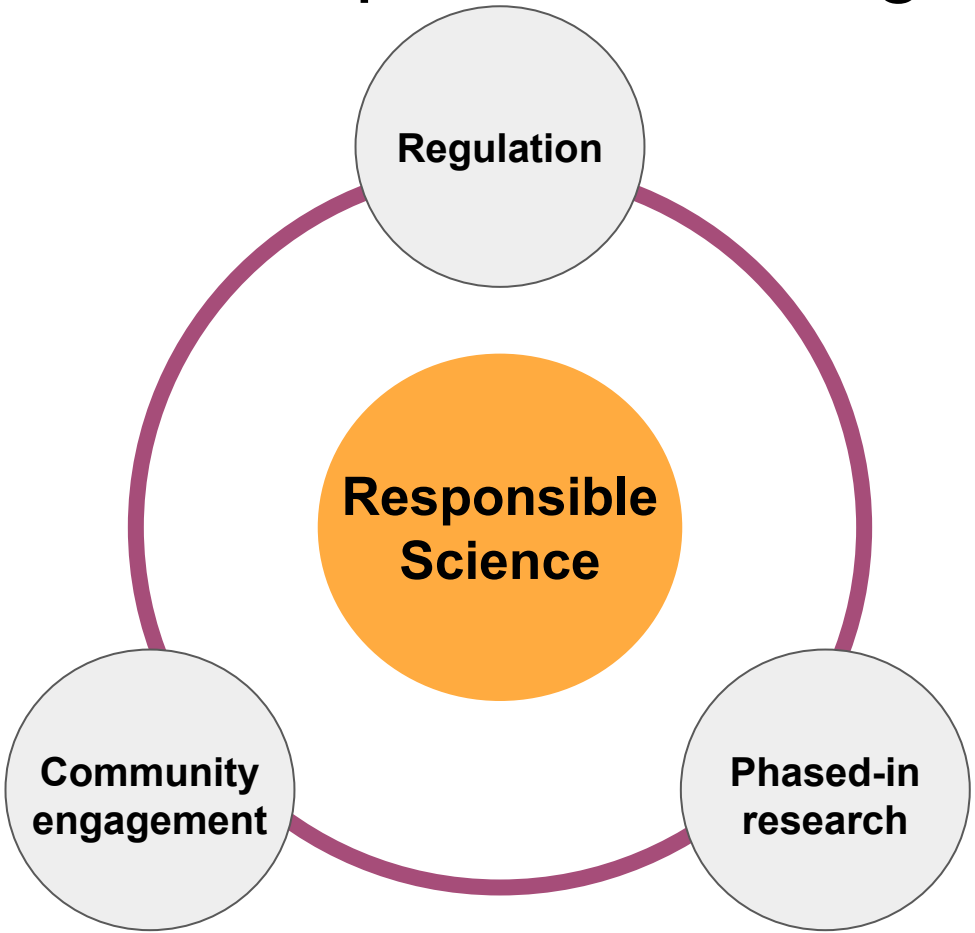
Gene drives can control invasive plants

***Amaranthus palmeri*:**

- Male and female organs separated
- Wind pollinated
- Resistance genes well known

National Academies of Sciences, Engineering, and Medicine. 2016.

Main points for improvement of gene drives

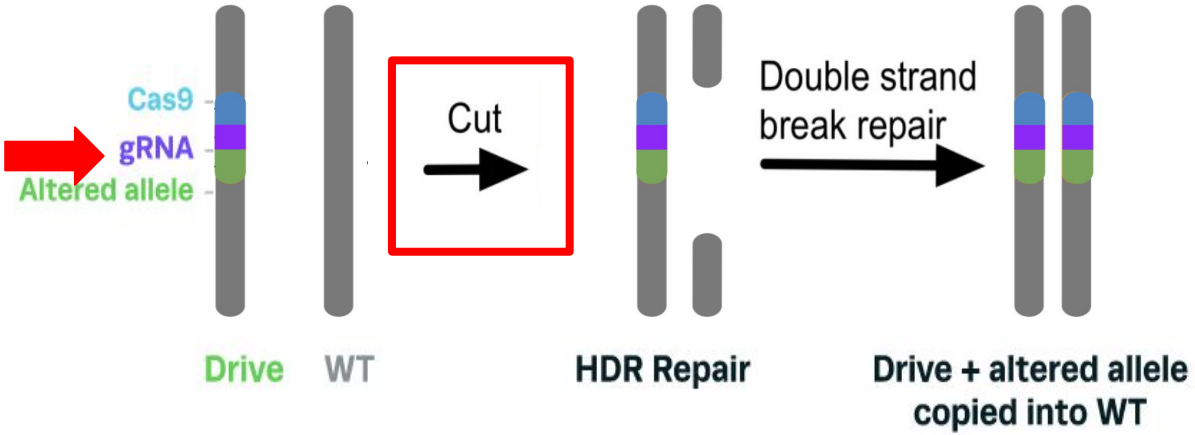


Gene drives call for a regulatory reform

- Research is currently regulated at a national level
- Need for an international regulatory framework

James et al, 2018

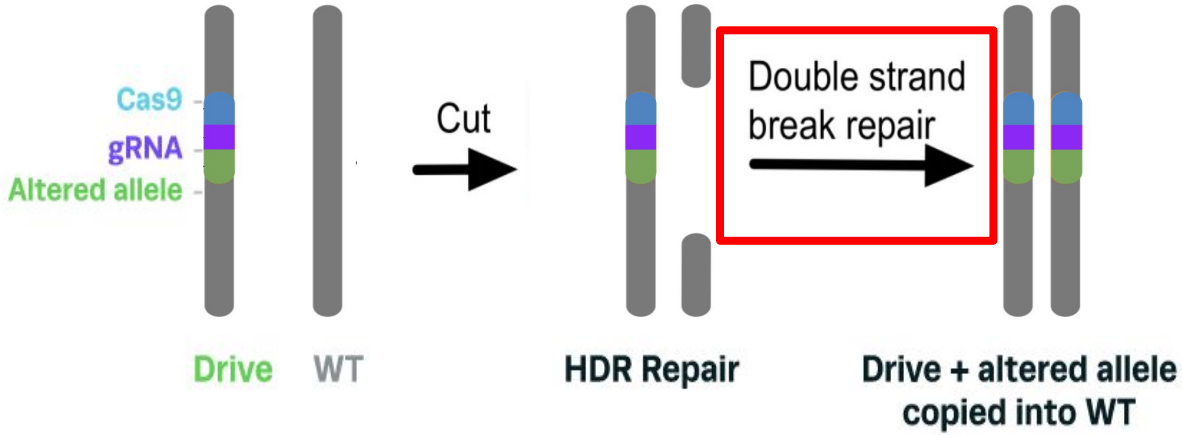
Gene drives can target conserved sites



- Limited by the differences in genetic code
- Target functionally-conserved sites

Enzmann, 2018

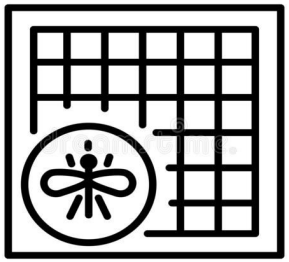
Gene drives can target multiple sites



- Cell repair is error-prone
- Target multiple sites in the same gene

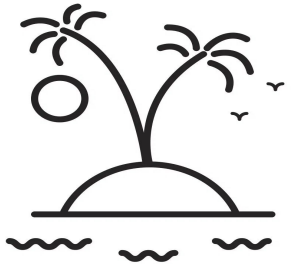
Enzmann, 2018

Four ways to restrict gene drive trials

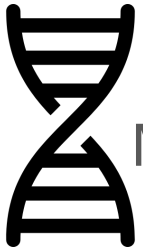


Physical

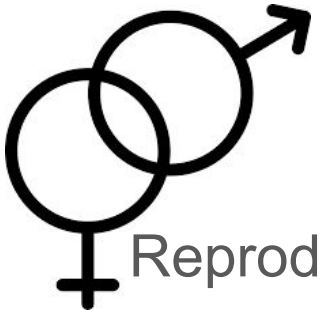
Gene drive trials must be confined



Ecological

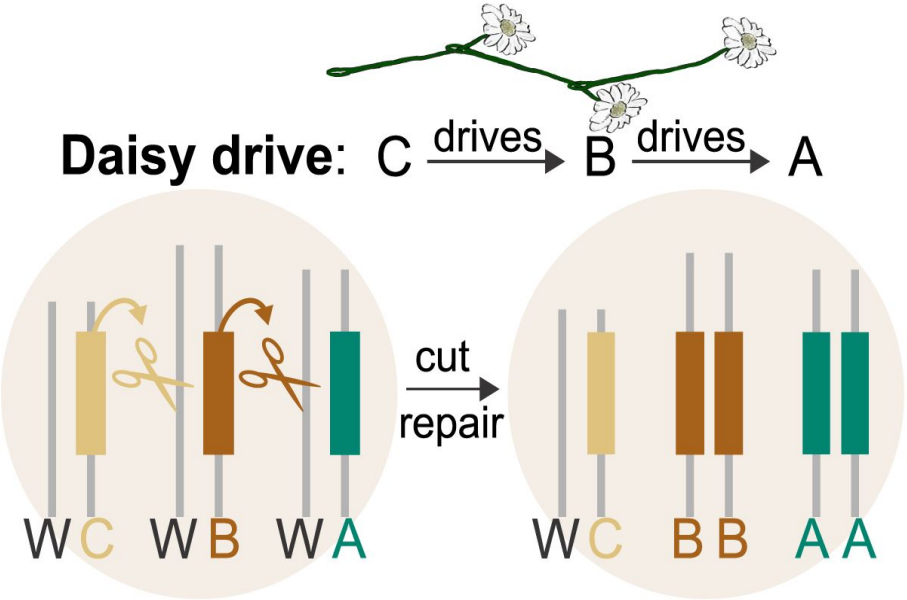


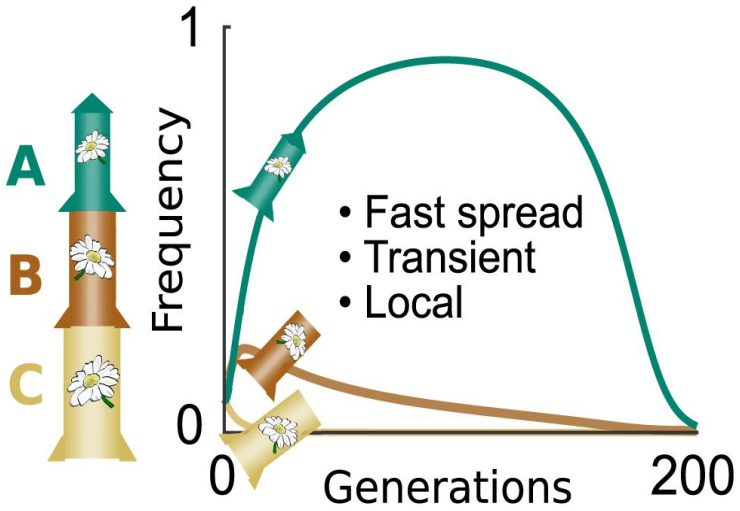
Molecular



Reproductive

Daisy drives limit spread

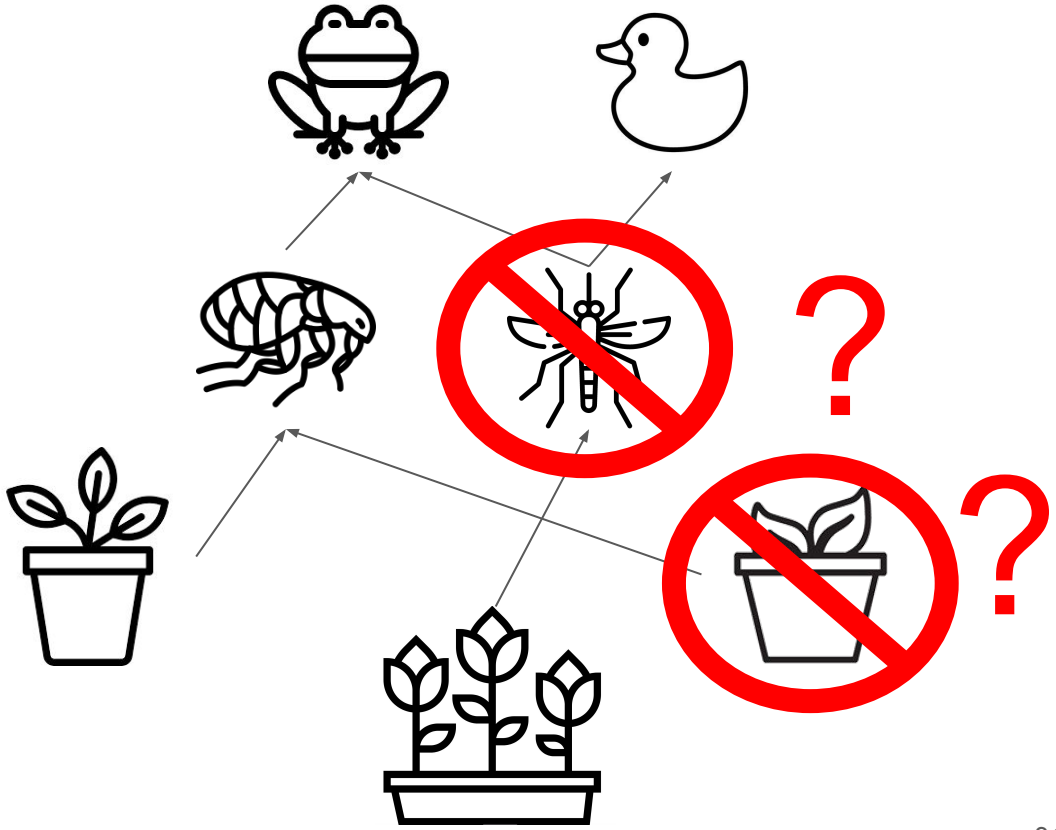




Esvelt and Gemmell, 2018

Open release = effects on the food web

- Complicated relationships
- Can have an adverse effect
- May not go back to normal



Target Malaria: consults with diverse experts

"We **cannot win** the fight against malaria **alone**…

We aim to **achieve excellence in all areas** of our work, creating a path for **responsible research** and development of genetic technologies."

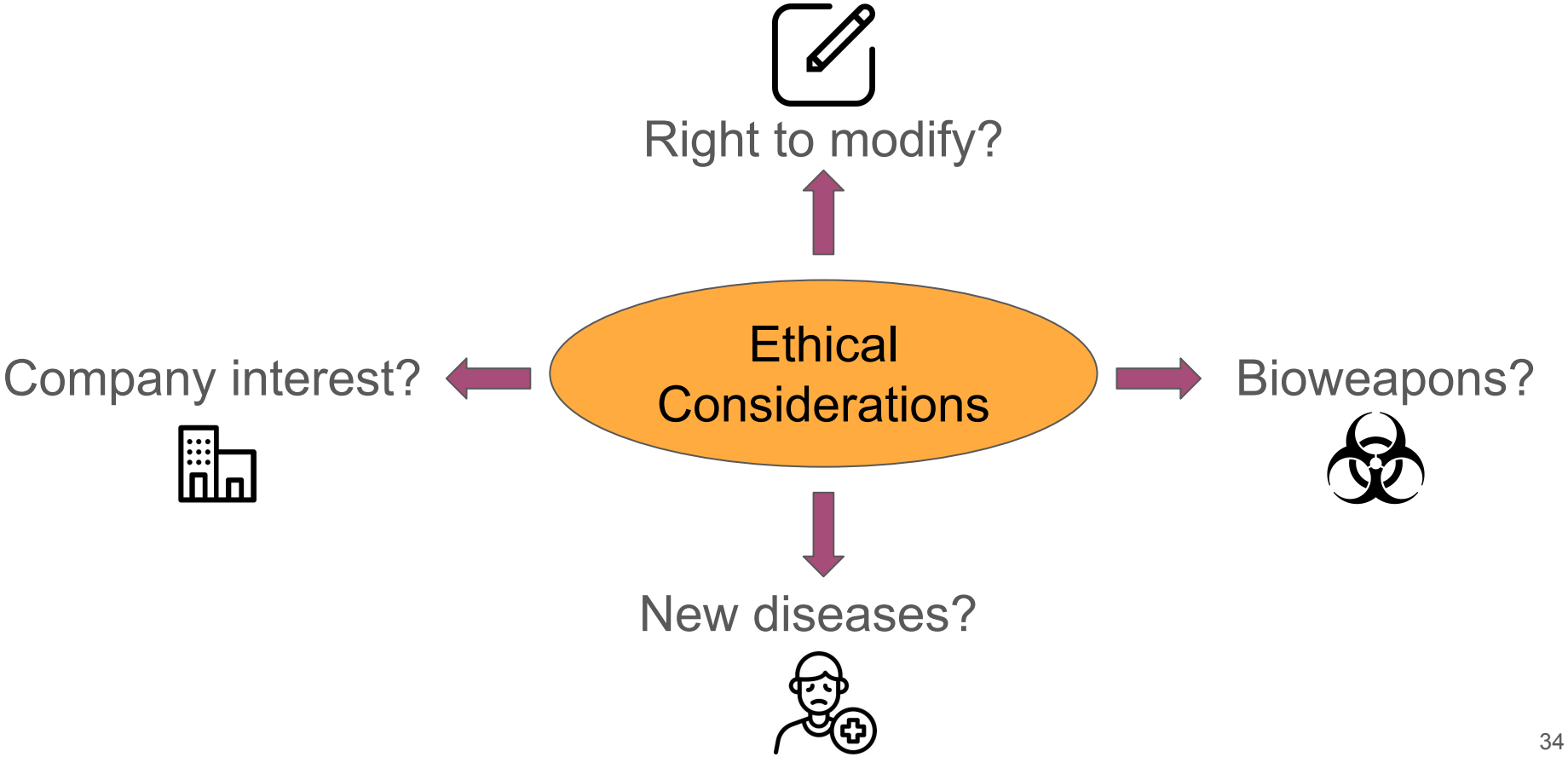
Community engagement is key

Successful Projects:

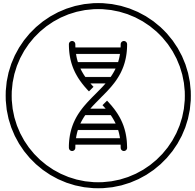
- Open discussion
- Engagement
- Risks and benefits

Esvelt and Gemmell, 2018

Ethical considerations of gene drives

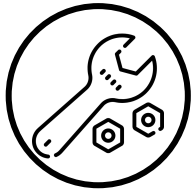


Summary



How natural and synthetic gene drives work

Potential applications for malaria and agriculture



Suggestions for improvement of design and implementation

Gene drives can bring a lot of benefits, but at what cost?

Acknowledgements

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McGill

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CRSNG

GEFSES

Genome Editing for Food Security
and Environmental Sustainability

Questions?

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