2016 Invasive Species Webinar Series

ENVIRONMENTAL LAW • INSTITUTE®

Gene Editing: A Next Generation Tool for Invasive Species Management?

Thursday, February 18, 2016
2:00pm – 4:00pm Eastern Time
(speaking will begin at 2:03)

Co-hosted by the Environmental Law Institute &
The National Invasive Species Council

To join the ELI Invasive Species Seminar Series mailing list, please email lerner@eli.org

2016 Invasive Species Webinar Series

ENVIRONMENTAL LAW • INSTITUTE®

Gene Editing: A Next Generation Tool for Invasive Species Management?

Thursday, February 18, 2016 • 2:00pm – 4:00pm ET

NOW SPEAKING:

Stas Burgiel

Assistant Director for Prevention and Budgetary Coordination,
National Invasive Species Council (NISC)

Stas Burgiel serves as the NISC policy lead on issues related to preventing the introduction and spread of invasive species with a focus on the pathways for their movement. He coordinates a prevention committee convened jointly with the Aquatic Nuisance Species Task Force and also oversees the collation of information on NISC member agency budgets related to invasive species issues. Key areas of interest and activity include the role of trade agreements, links to climate change and multi-level stakeholder coordination.

Stas received his Ph.D. in international service from the American University and a B.A. in political science from Swarthmore College. He has worked and consulted for a range of nongovernmental, governmental and intergovernmental organizations, including the Global Invasive Species Programme, the Nature Conservancy, the UNEP/World Conservation Monitoring Centre and the New Zealand government, on invasive species and other environmental policy issues.

2016 Invasive Species Webinar Series

ENVIRONMENTAL LAW • INSTITUTE®

Gene Editing: A Next Generation Tool for Invasive Species Management?

Thursday, February 18, 2016 • 2:00pm – 4:00pm ET

INTRODUCING:

Karl Campbell

Project Director, Island Conservation, Galapagos

Karl Campbell is a Project Director for Island Conservation in the Galapagos. Mr. Campbell has a Ph.D. from the University of Queensland, Australia. As part of his doctoral work, he developed advanced Judas goat methods involving sterilization, pregnancy termination and hormone therapy, which he applied to increase the effectiveness of Judas goats in large scale campaigns he was managing in the Galapagos Islands. Mr. Campbell has worked for 17 years on some of the world's largest and most complex eradication campaigns of invasive mammals, preventing the extinction of hundreds of species. His role typically involves identifying sites and partners, detailing a strategy, plan and budget, fundraising, managing field operations and refining strategies as required. In projects he's been involved with, new techniques or refinements to existing techniques have been made in aerial hunting, dog training, toxic baiting, trapping, Judas animals, detection probability tools, and the use of GPS, GIS and digital data collection and management technologies. Scalability and cost effectiveness are two key philosophies that he takes to each project. In 2011, Mr. Campbell initiated Island Conservation's Innovation Program and chairs the committee that oversees this initiative. He has worked on restoration projects in over a dozen countries and has published over 50 scientific and popular articles.

Genetic Biocontrol of Invasive Rodents Program

ATM

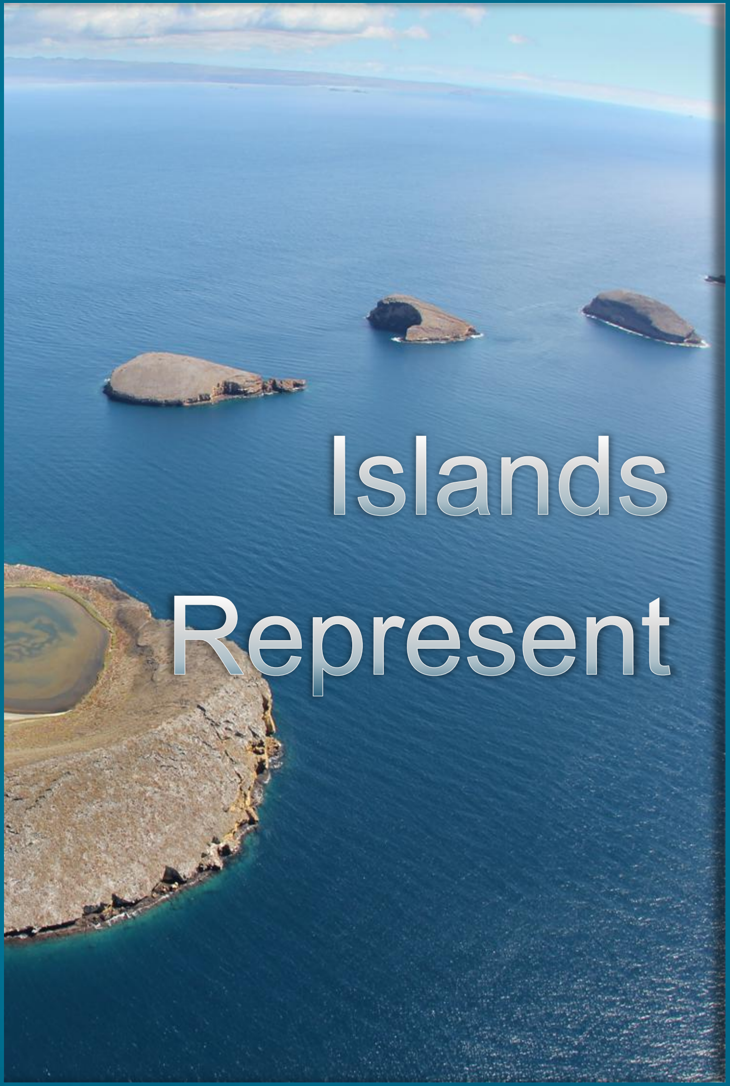
NC STATE UNIVERSITY

USDA

CSIRO

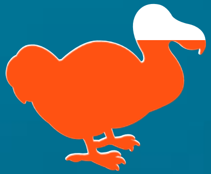
ISLAND CONSERVATION

Preventing Extinctions



Less than 5% of land mass

40% of endangered species



80% of extinctions since 1500

Invasive Species

Predation

Competition

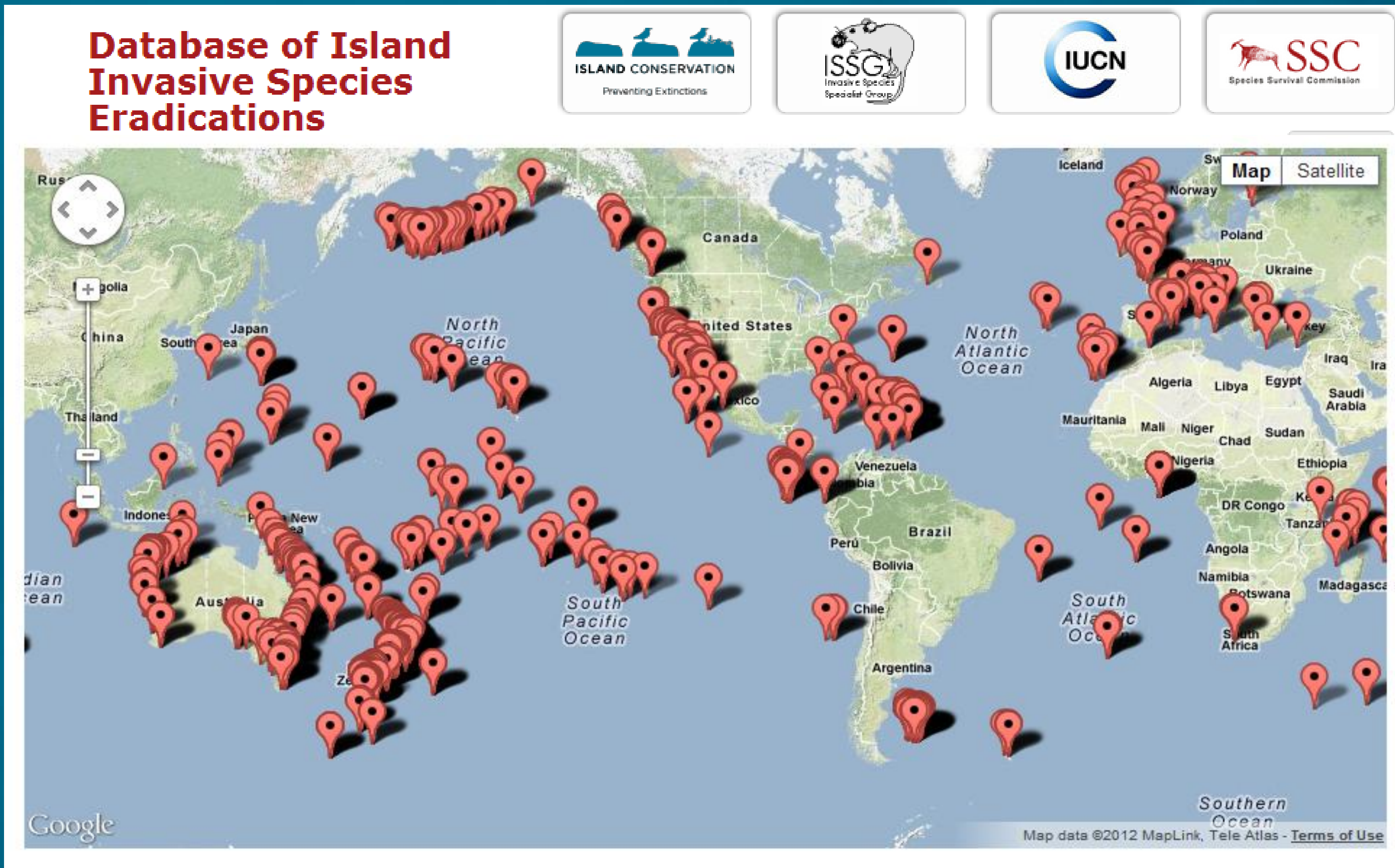
Disrupt ecological function

IAV Eradications

One of the most effective ways to:

Protect IUCN Red List Species

1100 successful eradications to date…



http://diise.islandconservation.org/

Assessing the global need...

...2000 islands, 1100 species

http://tib.islandconservation.org

ISLAND CONSERVATION

Mission: to prevent extinctions by removing invasive species from islands

Parque Nacional
GALAPAGOS
Ecuador

ISLAND CONSERVATION

Pinzon Giant Tortoise

Pinzon Island, Galapagos

Current methods

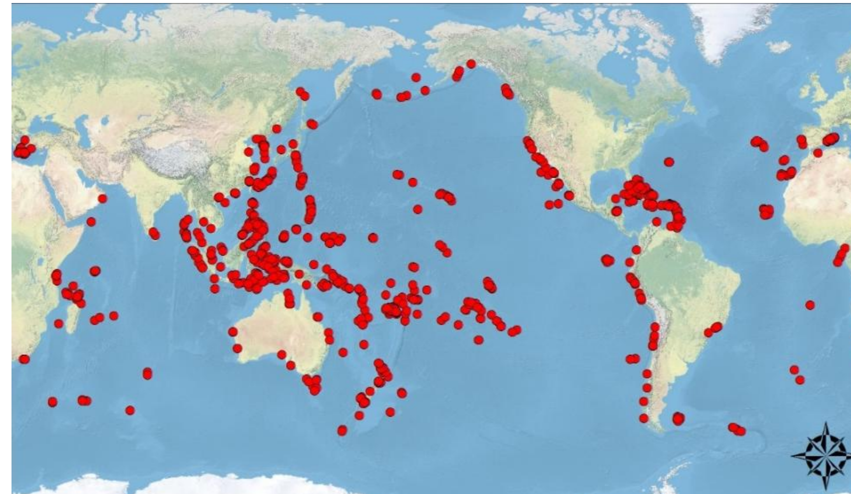
- Reliant on application to every rodent territory
- Not species specific
- Humane issues
- Inhabited islands
- Perception of poisons

Limitations of today’s methods

	Mice	Black rat
GTIB species impacted	555	638

Innovation Strategy

- Identify point of greatest impact
  - Invasive rodents
- Match technology to the need
  - Horizon scanning
- Select investment targets
  - Incremental
  - Transformative
- How might we catalyze?



Biological Conservation 185 (2015) 47–58

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Special Issue Article: Tropical rat eradication

The next generation of rodent eradications: Innovative technologies and tools to improve species specificity and increase their feasibility on islands

Karl J. Campbell[a,b,*], Joe Beek[a], Charles T. Eason[c,d], Alistair S. Glen[e], John Godwin[f], Fred Gould[g], Nick D. Holmes[a], Gregg R. Howald[a], Francine M. Madden[h], Julia B. Ponder[i], David W. Threadgill[j,k], Alexander S. Wegmann[a], Greg S. Baxter[b]

[a] Island Conservation, 2161 Delaware Ave Suite A, Santa Cruz, CA 95060, USA
[b] School of Geography, Planning & Environmental Management, The University of Queensland, St Lucia 4072, Australia
[c] Cawthron Institute, Private Bag 2, Nelson 7042, New Zealand
[d] Centre of Wildlife Management and Conservation, Lincoln University, PO Box 84, Lincoln, Canterbury, New Zealand
[e] Landcare Research, PO Box 69040, Lincoln 7640, New Zealand
[f] Department of Biological Sciences, North Carolina State University, Raleigh, NC 27695, USA
[g] Department of Entomology, North Carolina State University, Raleigh, NC 27695, USA
[h] Human-Wildlife Conflict Collaboration, 2020 12th St. NW Suite 506, Washington, DC 20009, USA
[i] The Raptor Center, University of Minnesota, 1920 Fitch Avenue, St. Paul, MN 55108, USA
[j] Department of Veterinary Pathobiology, Texas A&M University, College Station, TX 77843, USA
[k] Department of Molecular and Cellular Medicine, Texas A&M University, College Station, TX 77843, USA

ARTICLE INFO

Article history:
Received 29 April 2014
Received in revised form 1 September 2014
Accepted 10 October 2014
Available online 7 November 2014

Keywords:
Rattus
Mus musculus
Control methods
Pest eradication
Island restoration

ABSTRACT

Rodents remain one of the most widespread and damaging invasive alien species on islands globally. The current toolbox for insular rodent eradications is reliant on the application of sufficient anticoagulant toxicant into every potential rodent territory across an island. Despite significant advances in the use of these toxicants over recent decades, numerous situations remain where eradication is challenging or not yet feasible. These include islands with significant human populations, unreceptive stakeholder communities, co-occurrence of livestock and domestic animals, or vulnerability of native species. Developments in diverse branches of science, particularly the medical, pharmaceutical, invertebrate pest control, social science, technology and defense fields offer potential insights into the next generation of tools to eradicate rodents from islands. Horizon scanning is a structured process whereby current problems are assessed against potential future solutions. We undertook such an exercise to identify the most promising technologies, techniques and approaches that might be applied to rodent eradications from islands. We highlight a *Rattus*-specific toxicant, RNA interference as species-specific toxicants, rodenticide research, crab deterrent in baits, prophylactic treatment for protection of non-target species, transgenic rodents, virus vectored immunocontraception, drones, self-resetting traps and toxicant applicators, detection probability models and improved stakeholder community engagement methods. We present a brief description of each method, and discuss its application to rodent eradication on islands, knowledge gaps, challenges, whether it is incremental or transformative in nature and provide a potential timeline for availability. We outline how a combination of new tools may render previously intractable rodent eradication problems feasible.

* Corresponding author at: Island Conservation, 2161 Delaware Ave Suite A, Santa Cruz, CA 95060, USA. Tel.: +593 984660893.

E-mail addresses: karl.campbell@islandconservation.org (K.J. Campbell), joe.beek@islandconservation.org (J. Beek), Charles.Eason@cawthron.org.nz (C.T. Eason), GlenA@landcareresearch.co.nz (A.S. Glen), godwin@ncsu.edu (J. Godwin), Fred_Gould@ncsu.edu (F. Gould), nick.holmes@islandconservation.org (N.D. Holmes), gregg.howald@islandconservation.org (G.R. Howald), francine@humanwildlifeconflict.org (F.M. Madden), ponde003@umn.edu (J.B. Ponder), dwt@tamu.edu (D.W. Threadgill), alex.wegmann@islandconservation.org (A.S. Wegmann), gbaxter@uqg.uq.edu.au (G.S. Baxter).

http://dx.doi.org/10.1016/j.biocon.2014.10.016
0006-3207/© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Invasive mammal eradications are powerful conservation tools to protect biodiversity and prevent extinctions on islands (Aguirre-Muñoz et al., 2008; Bellingham et al., 2010; Campbell et al., 2011). The opportunity to scale up existing eradication techniques is being realized, with larger and more challenging projects being undertaken (Phillips, 2010; Sutherland et al., 2014). Yet

Opportunity

- No pesticides or killing
- Humane and target specific

- Big picture
  - Reduce risks
  - Increase impact

Genetic Biocontrol of Invasive Rodents Program

- Prevent extinctions on islands
- Agriculture, food security
- Human health




Why might this work?

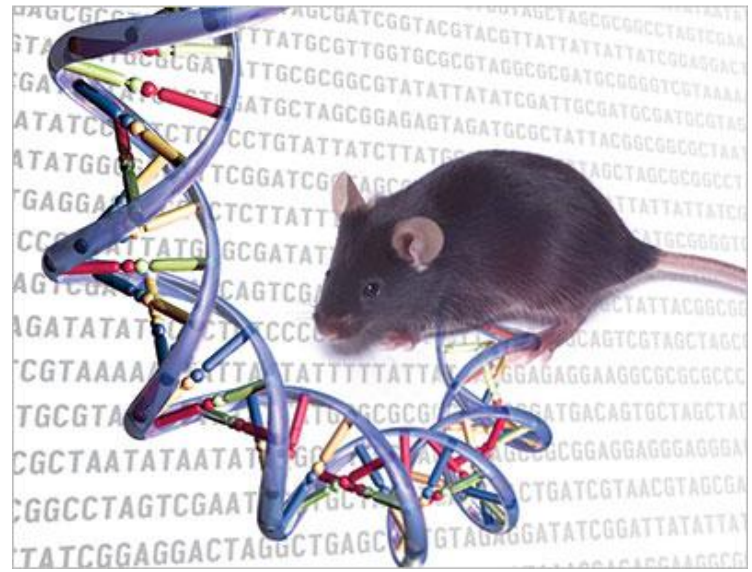
Isle of May, Orkney

- 57 ha
- Population ~1000 house mice
- Released 42 male & 35 female mice from Eday Island
- After 18 months, all mice trapped were hybrids (n=70)
- Males were disproportionately responsible for 'invasion'
- Leverage biology and promiscuity

Berry et al. 1991; Jones et al. 1995; Scriven 1992

Technical approach - Start with mice

- Model vertebrate for genetics
- Possess a short generation-time
- Are small and husbandry is straight-forward
- Invasive and non-native in many countries



Technical approach – Staged

At proof-of-concept

- Sry is master 'switch' for sex determination in most mammals
- Sex reversal possible through translocating 10kb Sry fragment
- Match with gene drive
  - T-complex
  - CRISPR-Cas
- All male population dies out

Koopman et al. 2001; Kashimada & Koopman 2010

Approach

- Interested in pro-actively and transparently identifying any potential risks
- Precedents and lessons learned
- Partnership with policy makers and regulators
- We’re yet to identify any deal-breakers

Opportunity

- No pesticides or killing
- Humane and target specific

- Big picture
  - Reduce risks
  - Increase impact

ENVIRONMENTAL LAW•INSTITUTE®

2016 Invasive Species Webinar Series

Gene Editing: A Next Generation Tool for Invasive Species Management?

Thursday, February 18, 2016 • 2:00pm – 4:00pm ET

INTRODUCING:

Fred Gould

Professor, Department of Entomology, North Carolina State University
Co-director, Genetic Engineering and Society Center

Fred Gould is a Distinguished University Professor in the Entomology Department of North Carolina State University and Co-director of the Genetic Engineering and Society Center. In the past, Dr. Gould has assisted in the development and deployment of insecticidal transgenic crops in ways that suppress the evolution of pest resistance, among other subjects. He is now focused on the potential for engineering insect pests to suppress disease and crop loss, and to protect endangered species. Dr. Gould has served on a number of US National Research Council and EPA committees addressing regulation of genetic technologies in agriculture. Dr. Gould has received the Alexander von Humboldt award for most significant agricultural research over a five-year period, the Sigma Xi George Bugliarello Prize for written communication of science, and the O. Max Gardner Award for the University of North Carolina faculty member with the greatest contribution to human welfare. He was elected to the US National Academy of Sciences in 2011 and serves on the National Research Council Board on Agriculture and Natural Resources. Mr. Gould graduated from Queens College in New York City in 1971 with a BS in Biology and from the State University of New York at Stony Brook in 1977 with a PhD in Ecology and Evolutionary Biology.

Can Genetically Engineered Pests ^ Save Biodiversity?

Fred Gould
NCSU
Genetic Engineering & Society Center

GES CENTER
NC STATE UNIVERSITY

GES CENTER
NC STATE UNIVERSITY

Two General Approaches

Suppression
or
Local Eradication

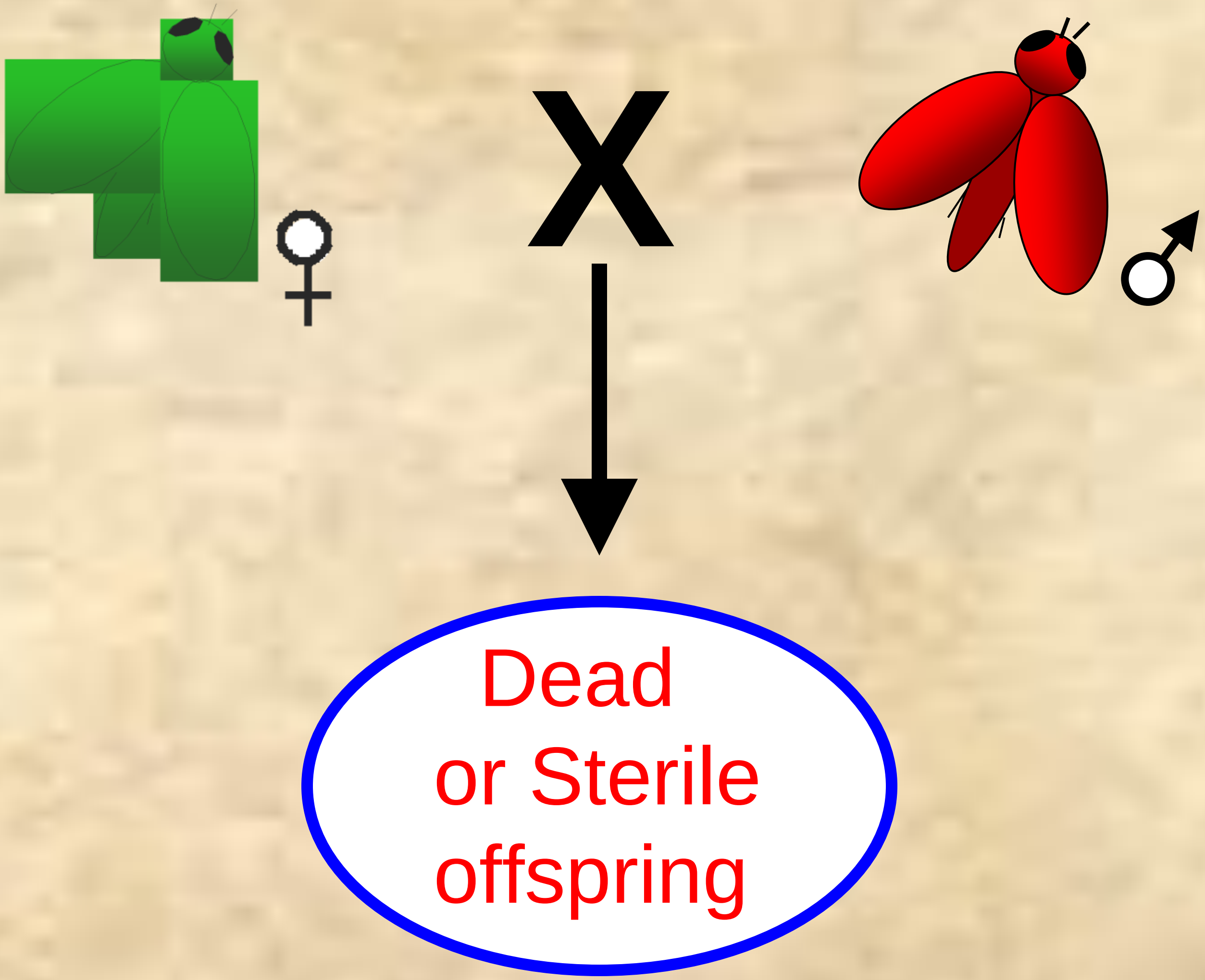
Strain
Replacement

Suppression or Local Eradication

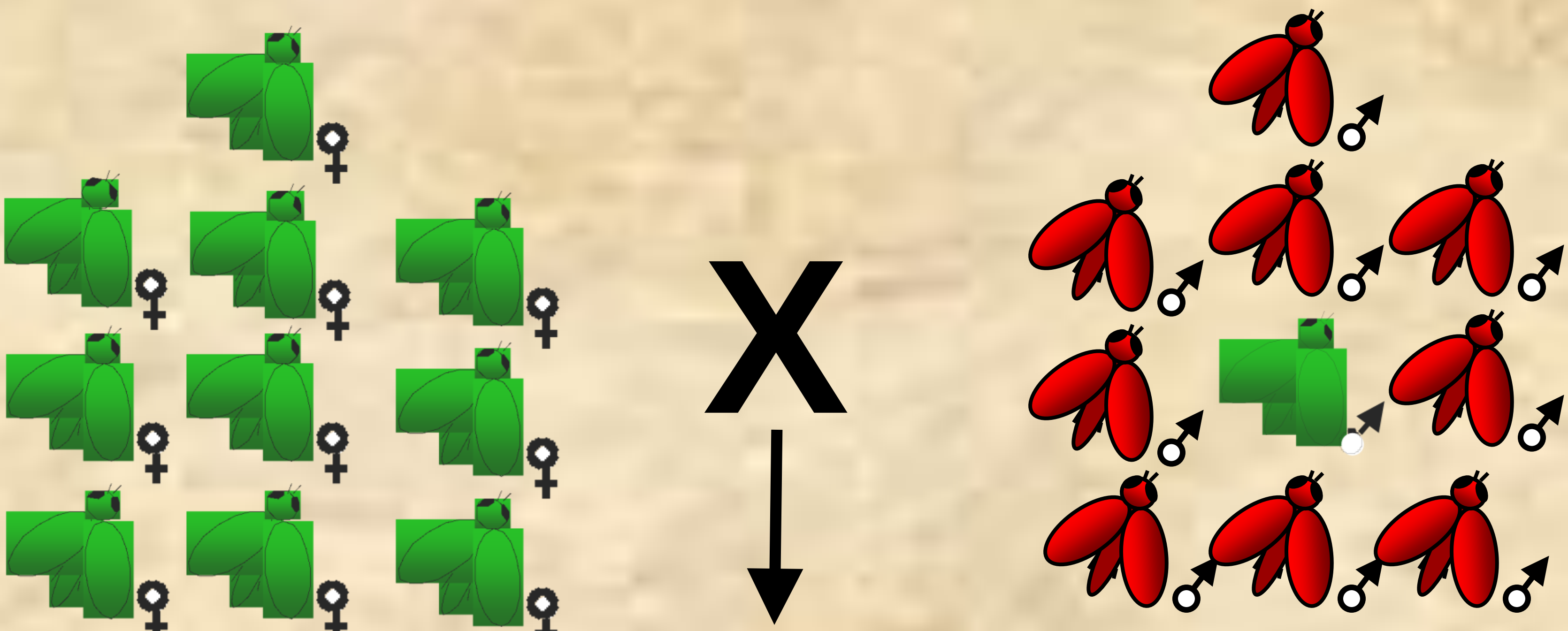
Edward F. Knipling 1950's

1992 World Food Prize

The sterile insect release technique

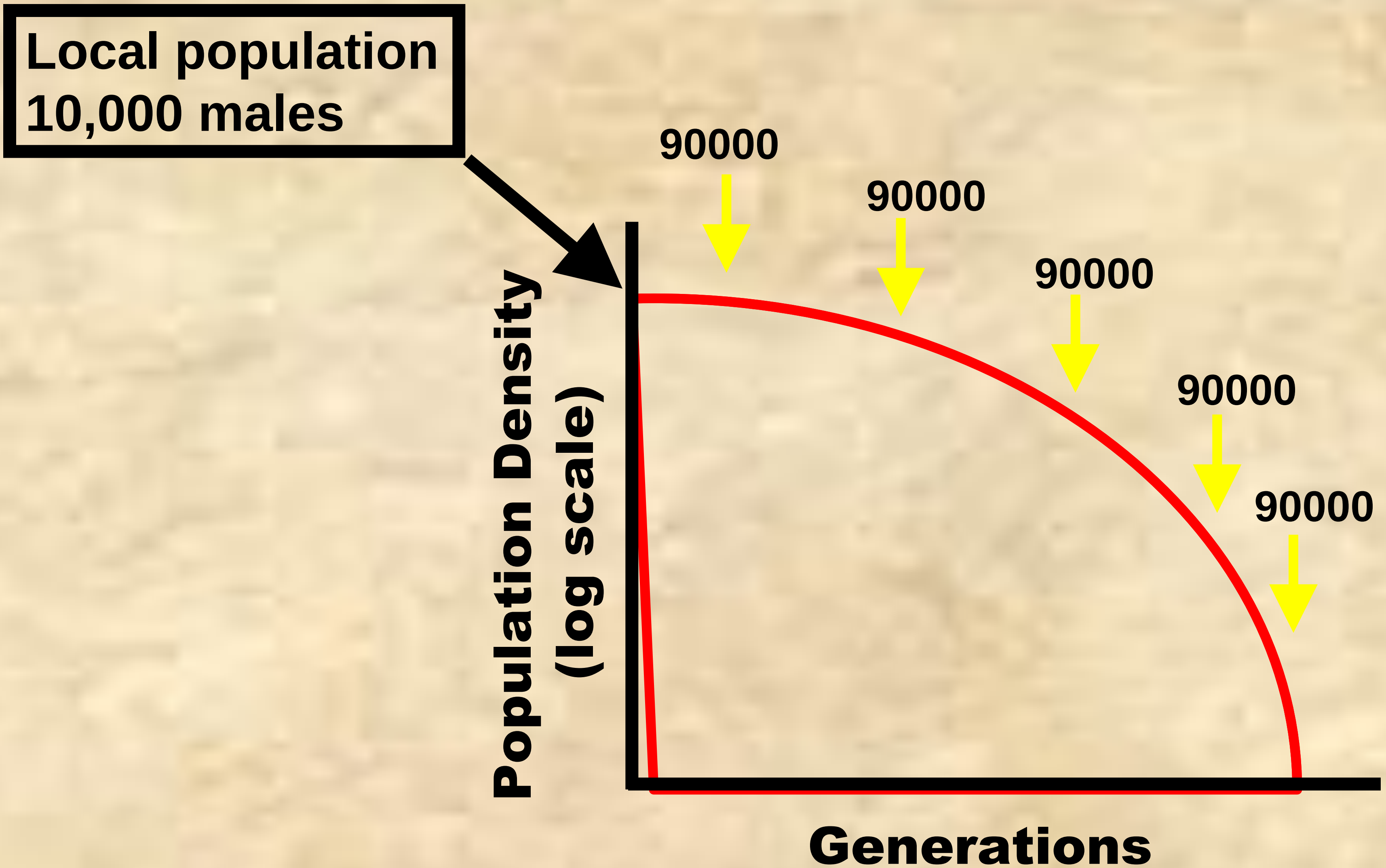


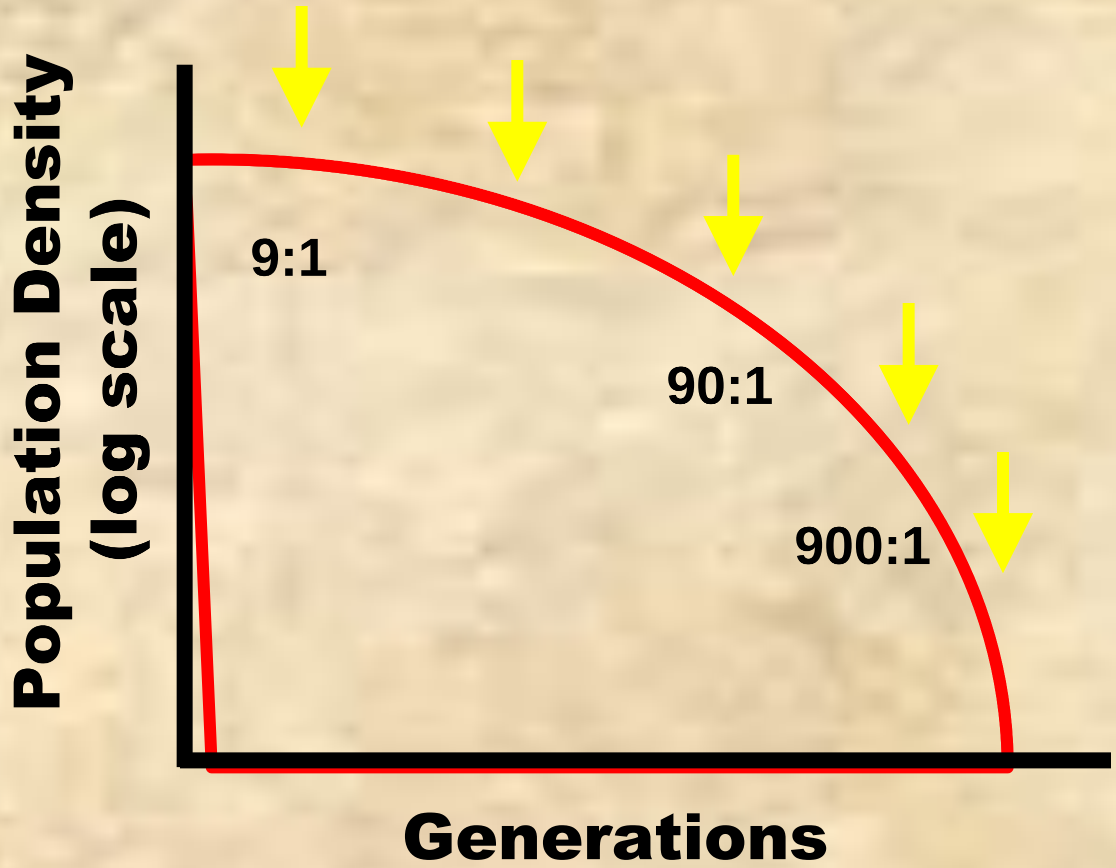
9:1 sterile male release



90%

dead or sterile offspring


Local population
10,000 males
90000
90000
90000
90000
90000
Population Density
(log scale)
Generations



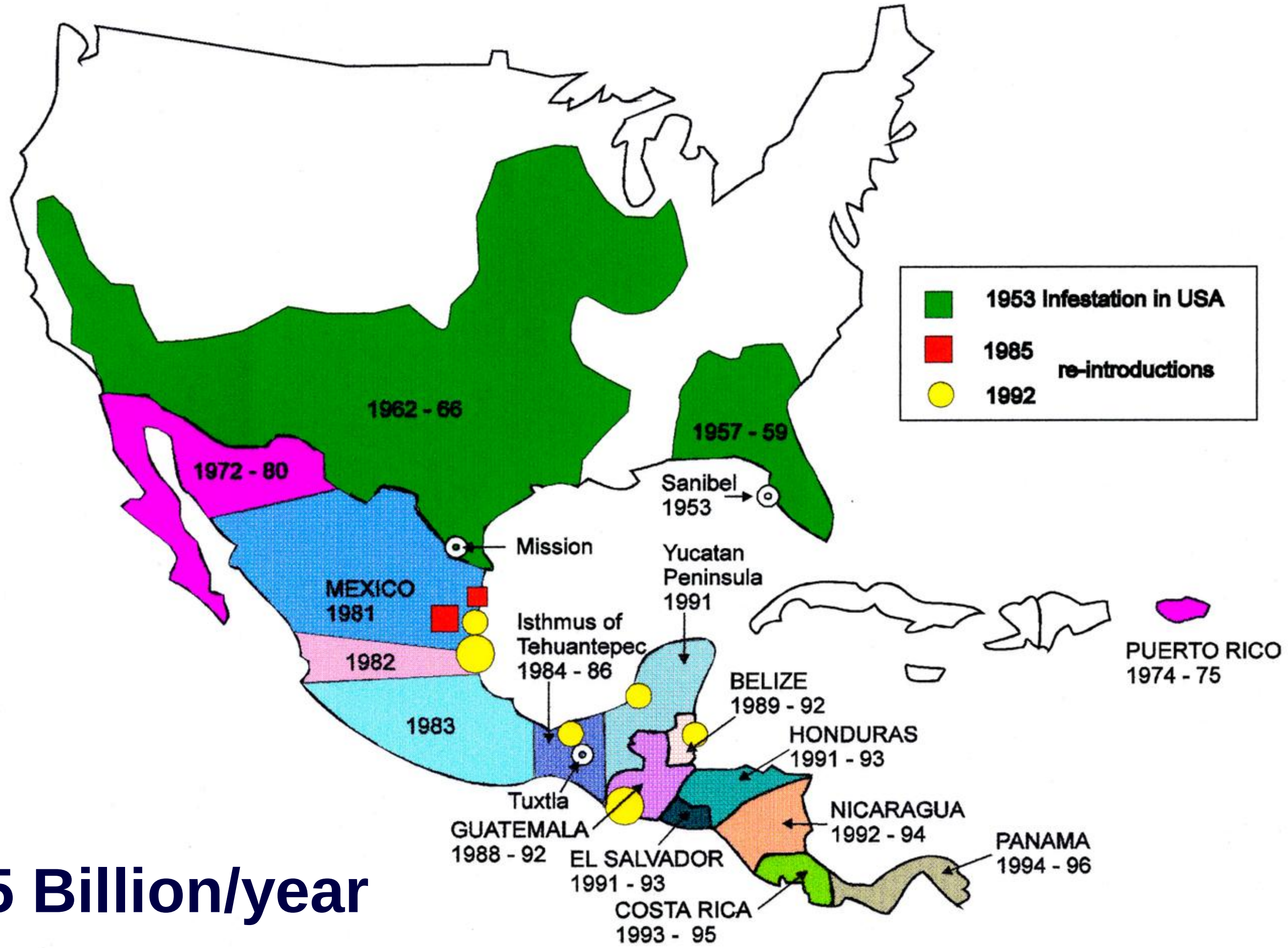
Population Density
(log scale)
9:1
90:1
900:1
Generations

Some Initial Successes:

Screwworm Fly

1960's – 1980's

Screw-worm fly, *Cochliomyia hominivorax*, distribution and eradication

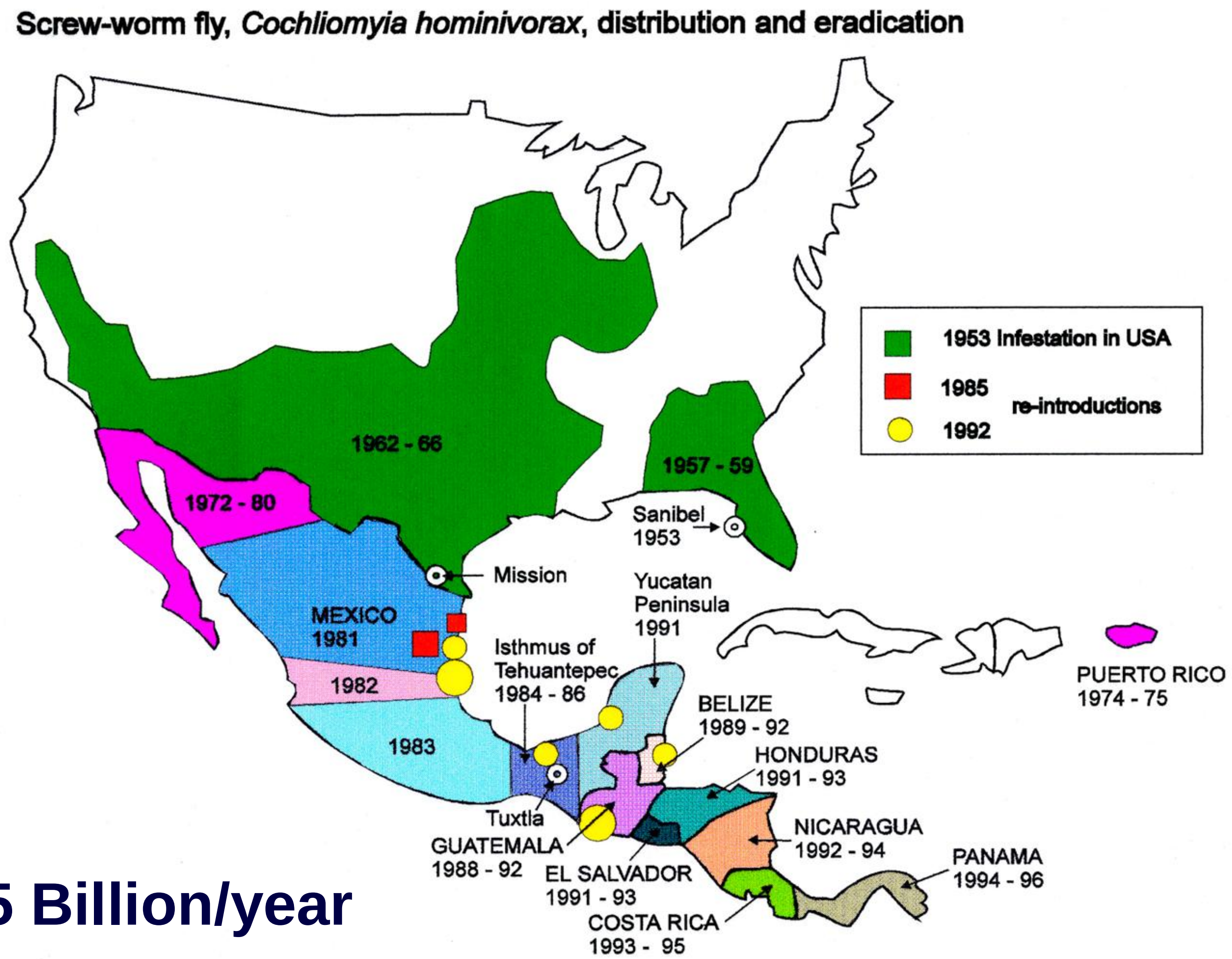


1.5 Billion/year

CSIRO map

USDA-Panama Screwworm Facility

60-120 million per week

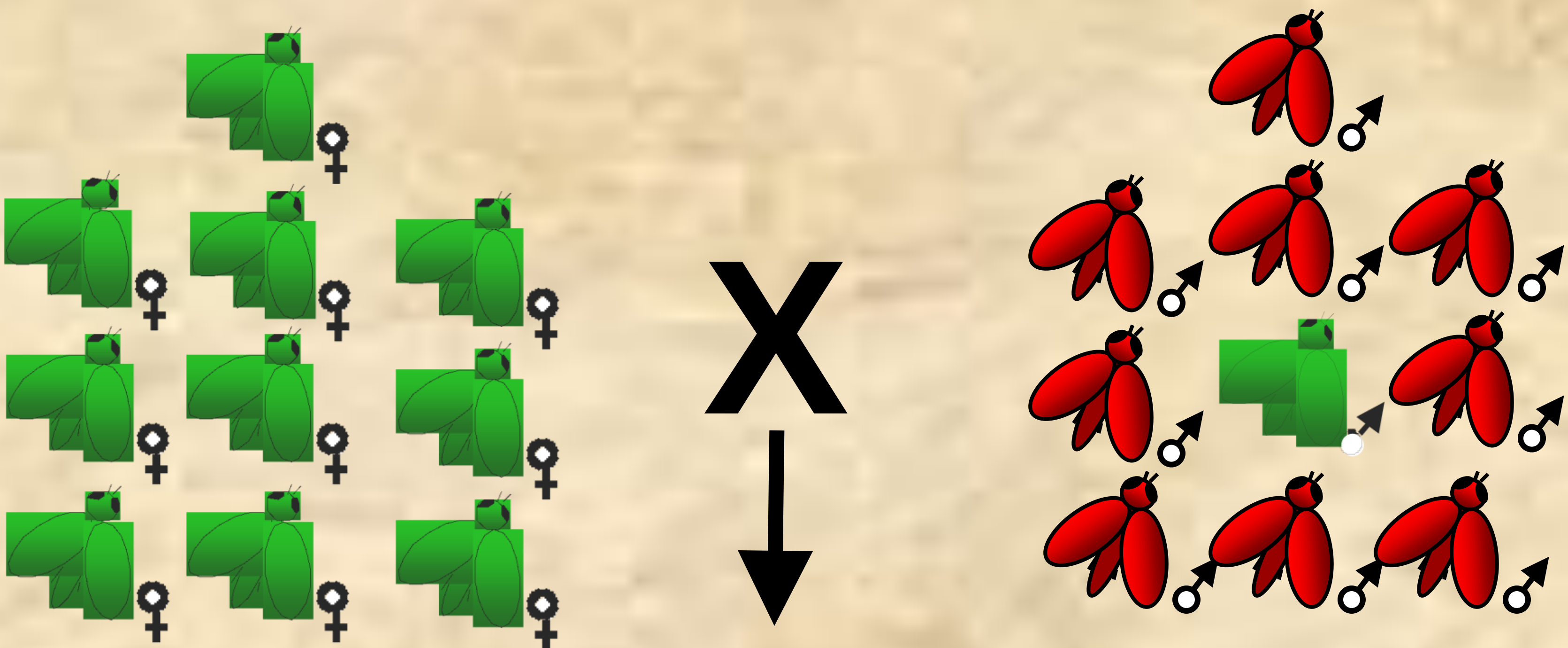


1.5 Billion/year

CSIRO map

Can We Improve Efficiency and Guard Against Environmental Impacts?

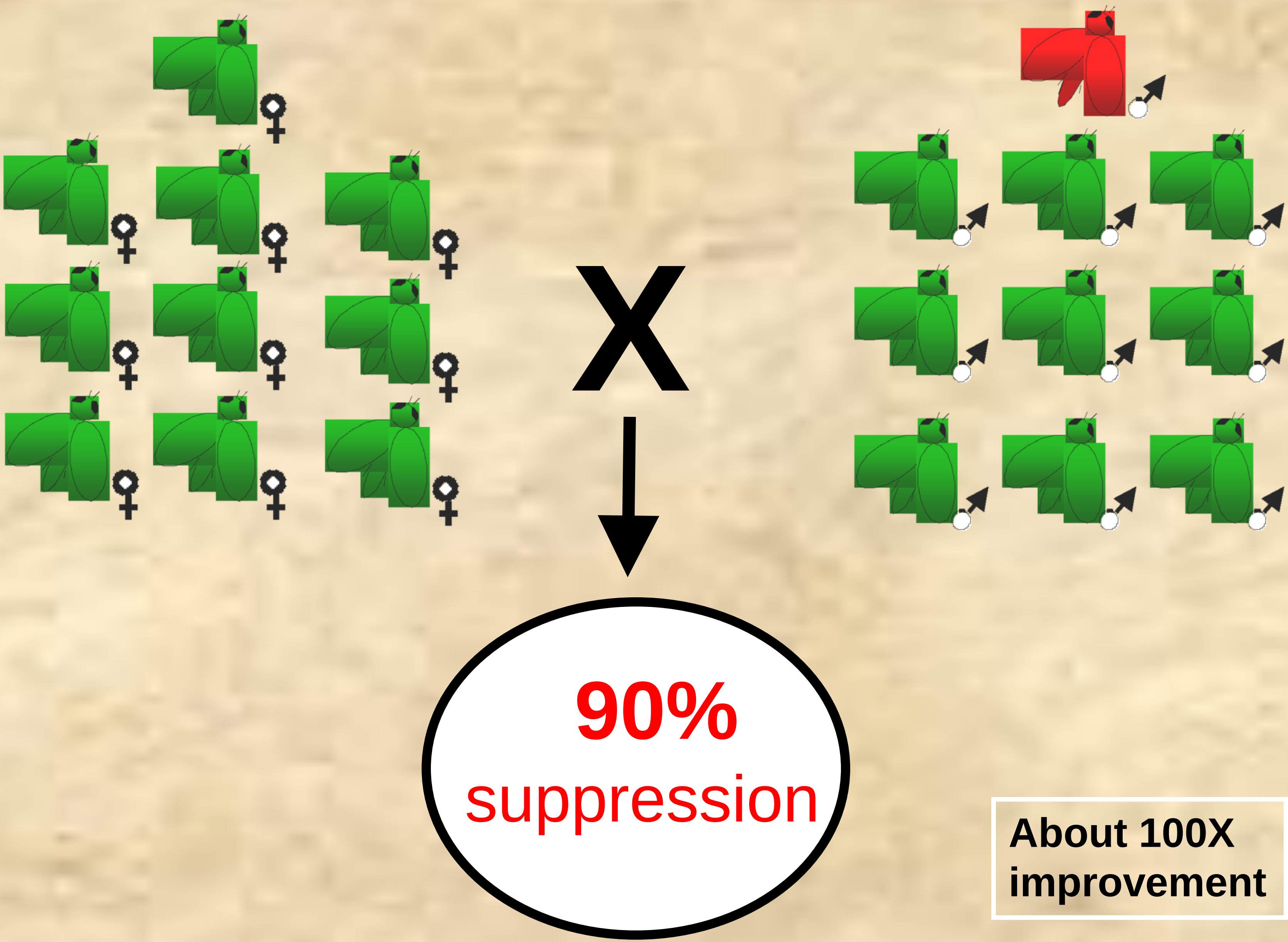
9:1 sterile male release



90%

dead or sterile offspring

Can We Improve Efficiency?

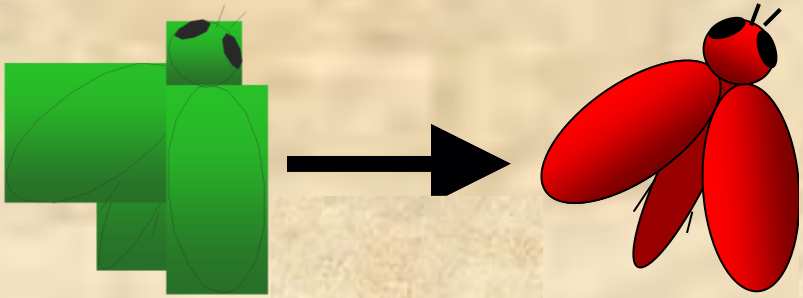


Two General Approaches

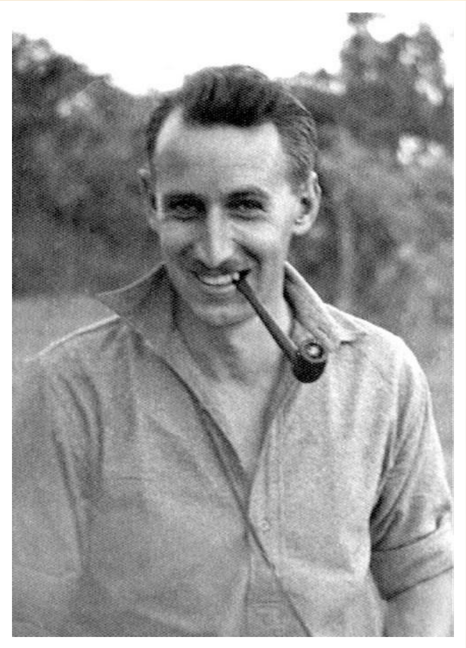
Suppression
or
Local Eradication

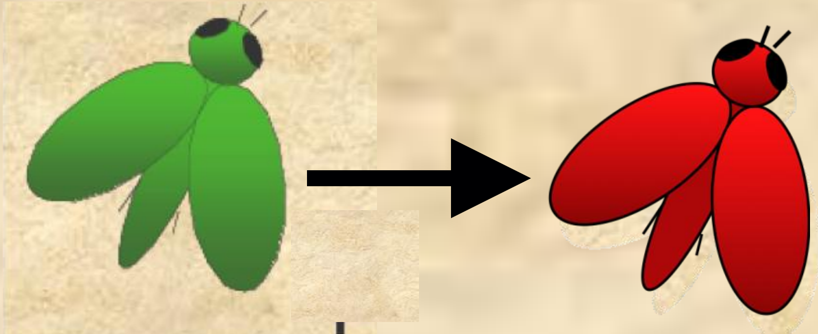
Strain
Replacement

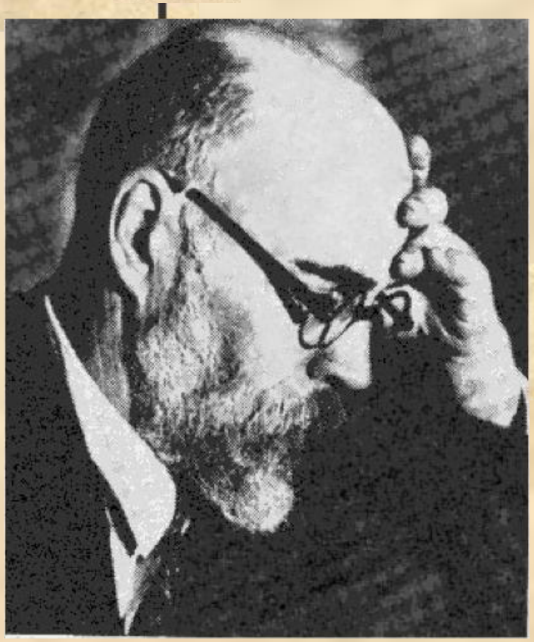
Strain Replacement



Strain Replacement





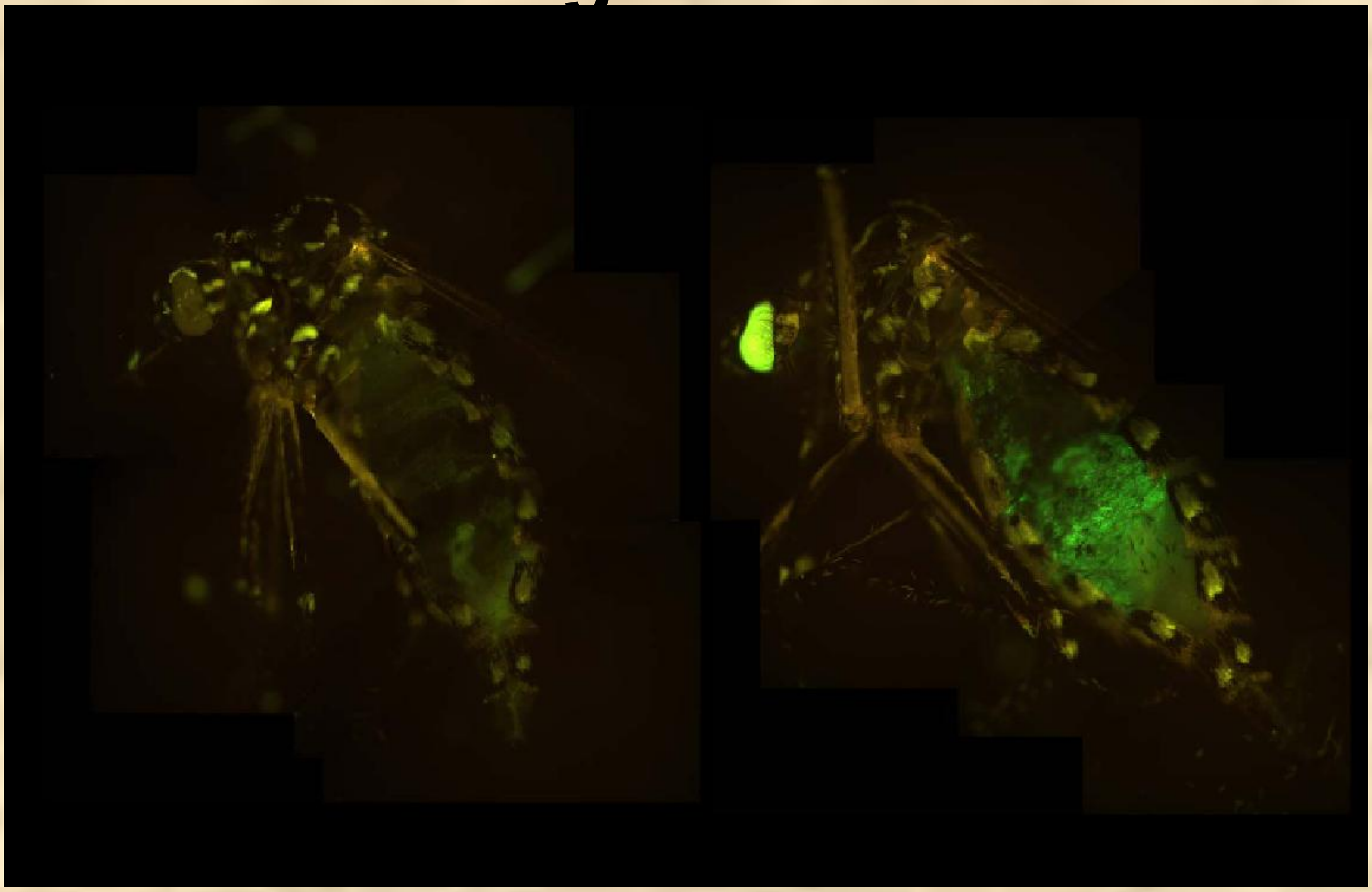


F.L. Vanderplank
Hybrids of Tsetse fly species

A. S. Serebrovski
Soviet Union - Lysenko era
1940's Translocations

Chris Curtis
UK
1960's

Transgenic Pests

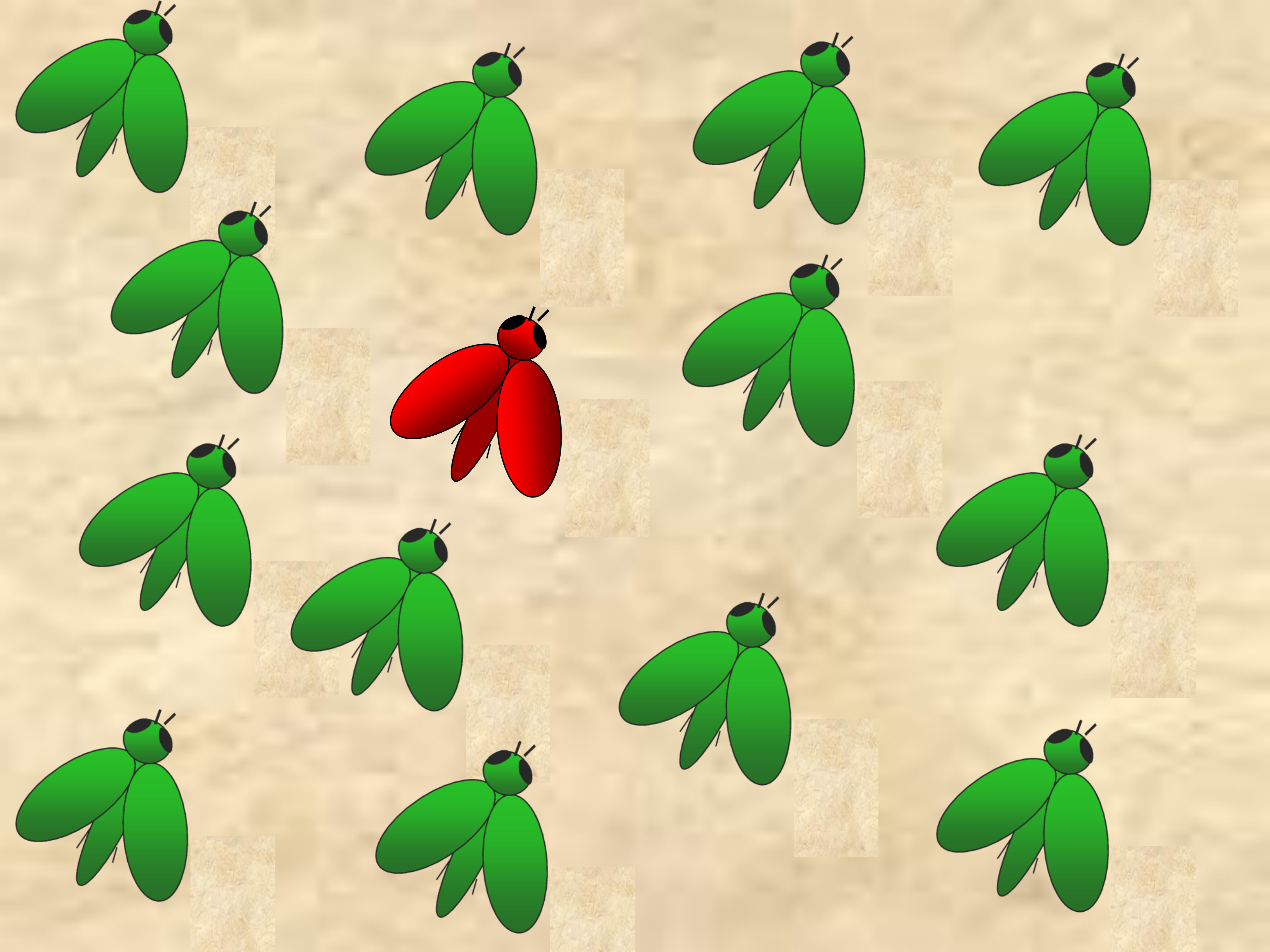


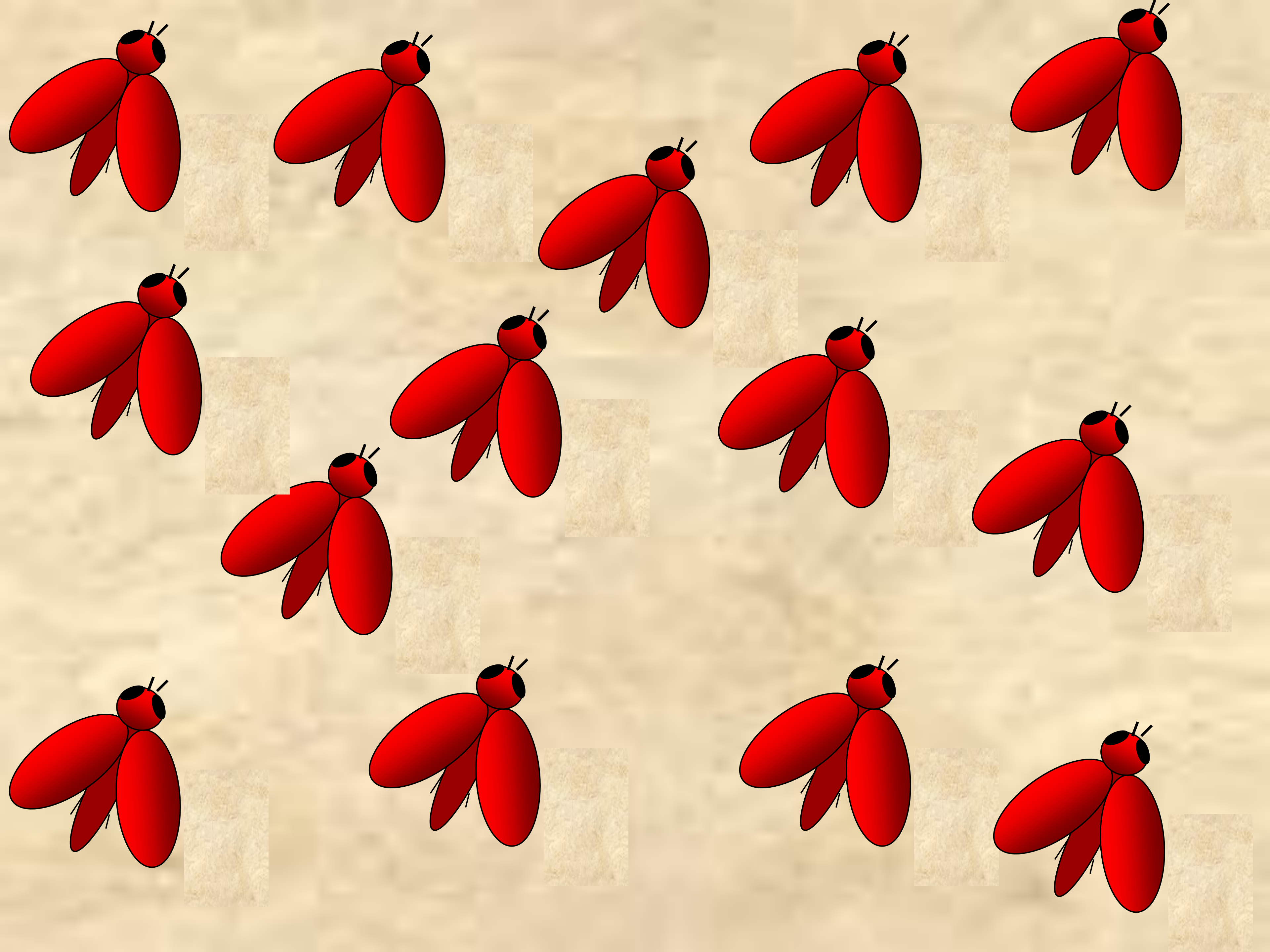
ne

Dengue---Flaviviridae; *Flavivirus*;

Aedes aegypti

by Alexander Franz





Suppression or Local Eradication

1) Sterile insect approach

Strain Replacement

1) Translocations

2) Interspecific underdominance

Suppression or Local Eradication

1) Conditional Lethality
2) Female Killing Systems
3) Sex Ratio Alteration
4) *Medea* elements
5) Homing Endonucleases
6) CRISPRs

Strain Replacement

1) Meiotic Drive
2) Engineered Underdominance
3) Transposons
4) *Wolbachia*
5) *Medea* elements
6) Killer-Rescue
7) Homing Endonucleases
8) CRISPRs

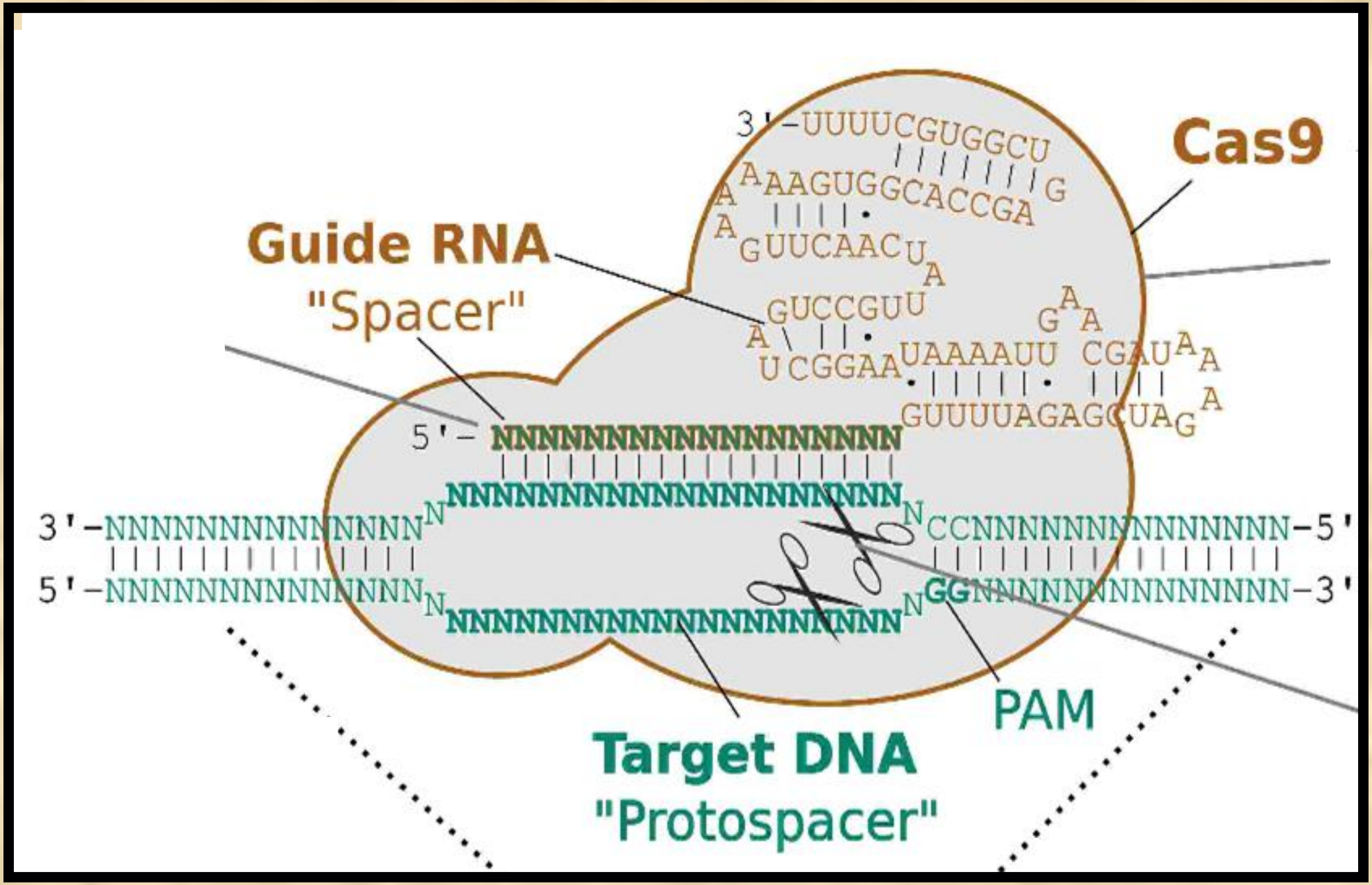
Suppression or Local Eradication

1) Conditional Lethality
2) Female Killing Systems
3) Sex Ratio Alteration
4) *Medea* elements
5) Homing Endonucleases
6) CRISPRs

Strain Replacement

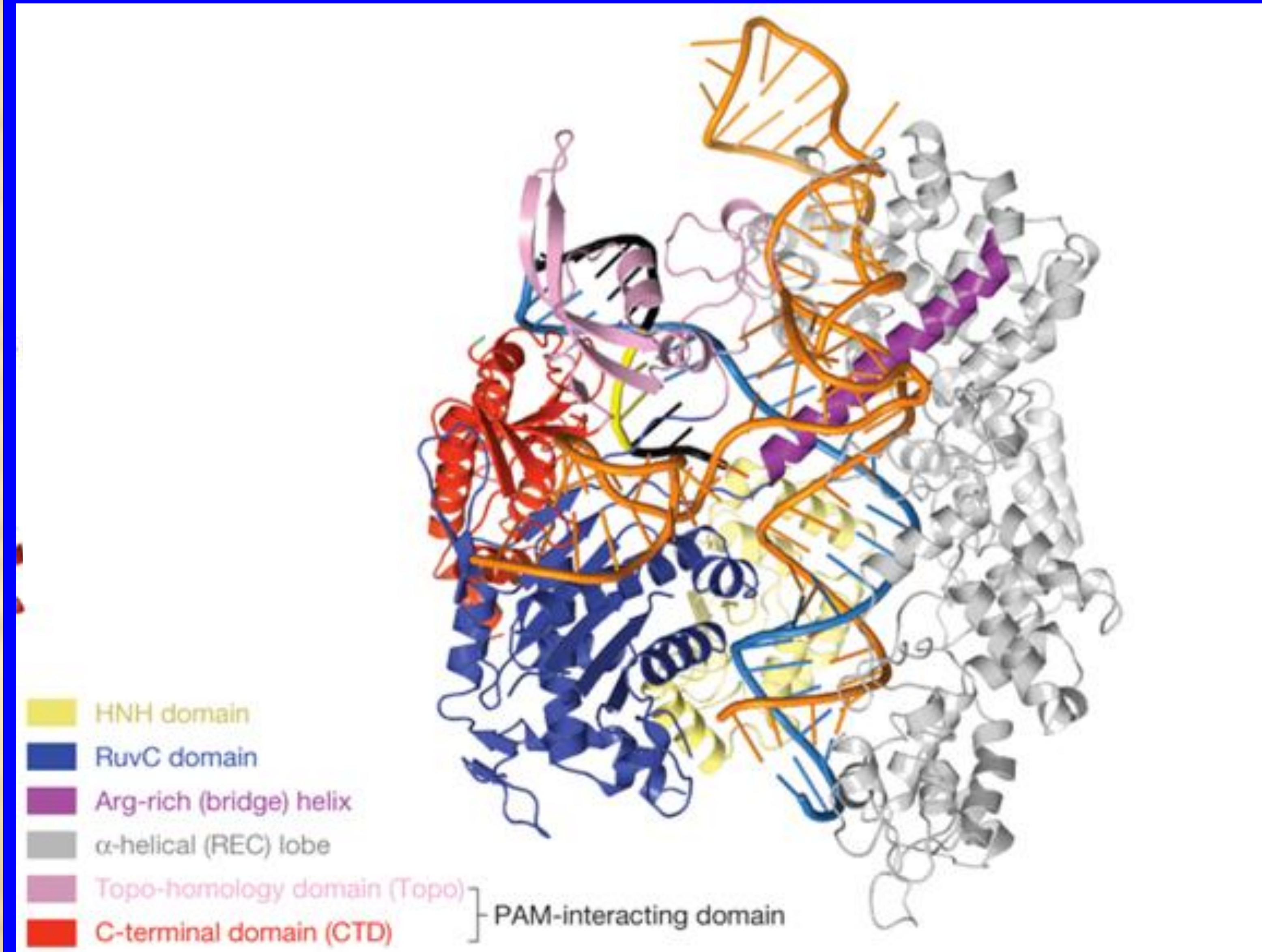
1) Meiotic Drive
2) Engineered Underdominance
3) Transposons
4) *Wolbachia*
5) *Medea* elements
6) Killer-Rescue
7) Homing Endonucleases
8) CRISPRs

CRISPR/Cas9



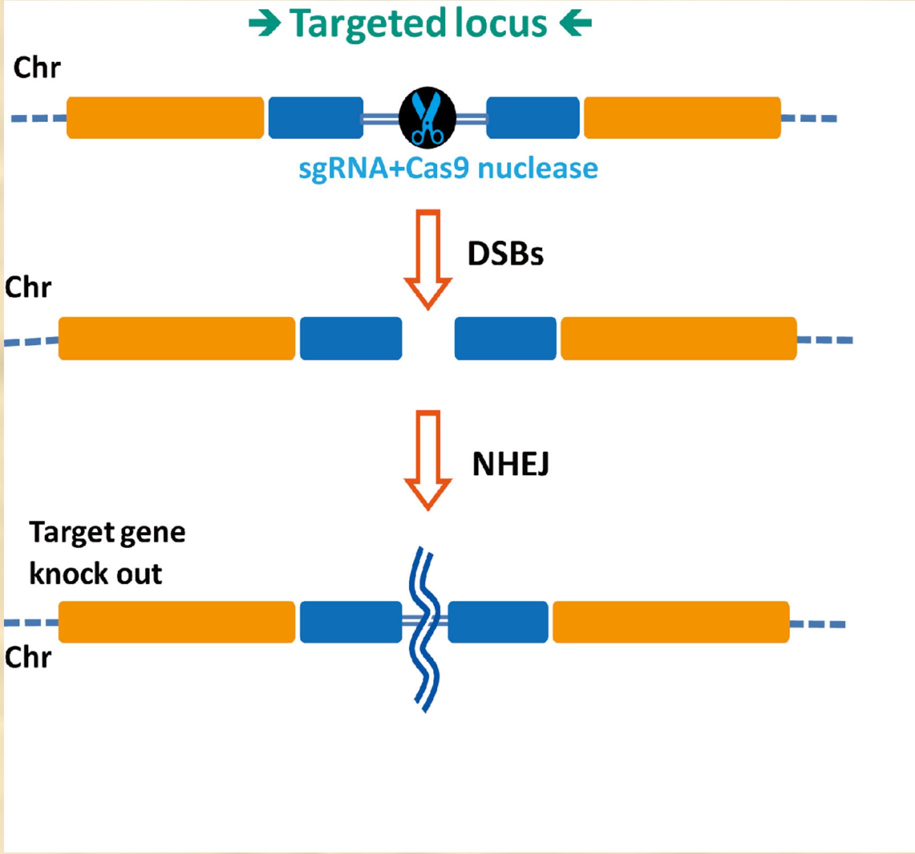
CRISPR/Cas9

CRISPR/Cas9

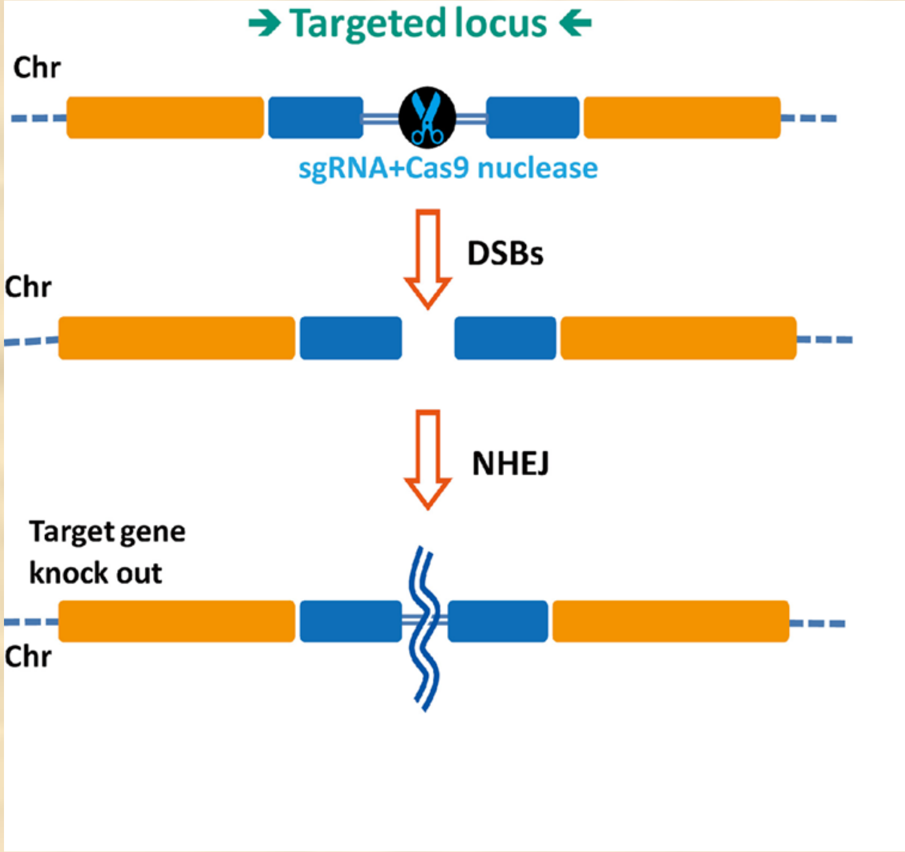


HNH domain
RuvC domain
Arg-rich (bridge) helix
α-helical (REC) lobe
Topo-homology domain (Topo)
C-terminal domain (CTD)
PAM-interacting domain

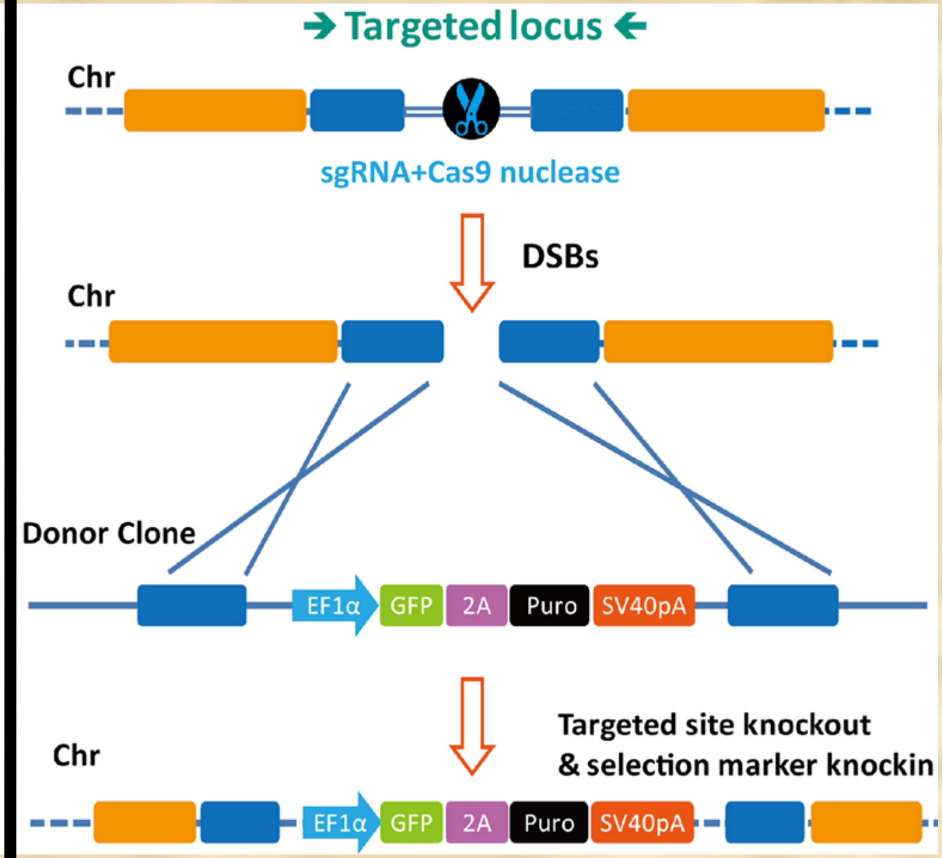
Non-Homologous End-Joining (NHEJ)

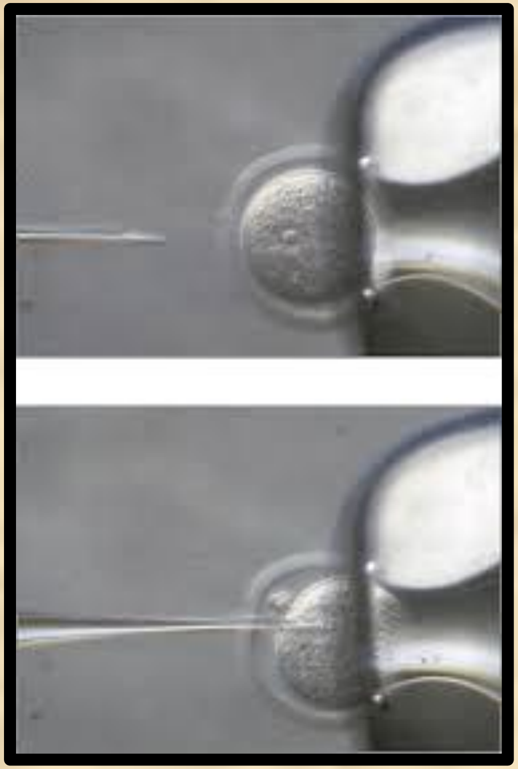


Non-Homologous End-Joining (NHEJ)



Homology-Directed Repair (HDR)




Holder
Injector
Manipulator
mouse
Controller



Sciencexpress

The mutagenic chain reaction: A method for converting heterozygous to homozygous mutations

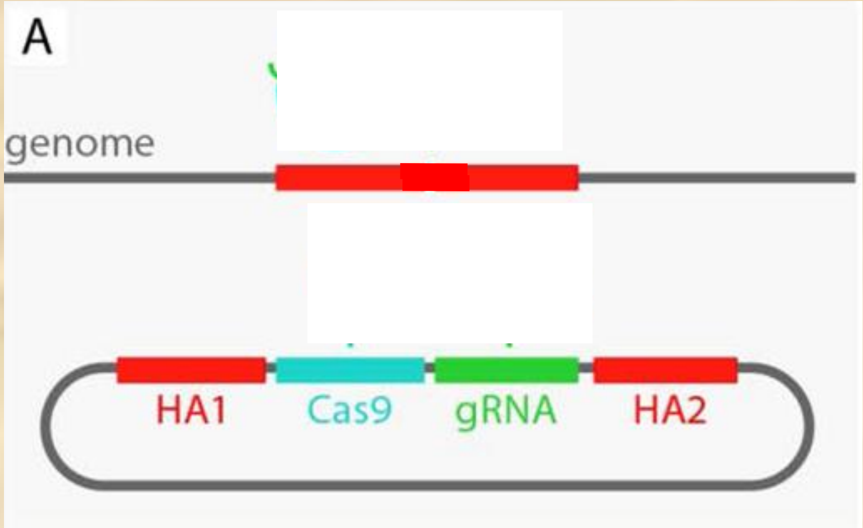
Valentino M. Gantz* and Ethan Bier*

Section of Cell and Developmental Biology, University of California, San Diego, La Jolla, CA 92095, USA.

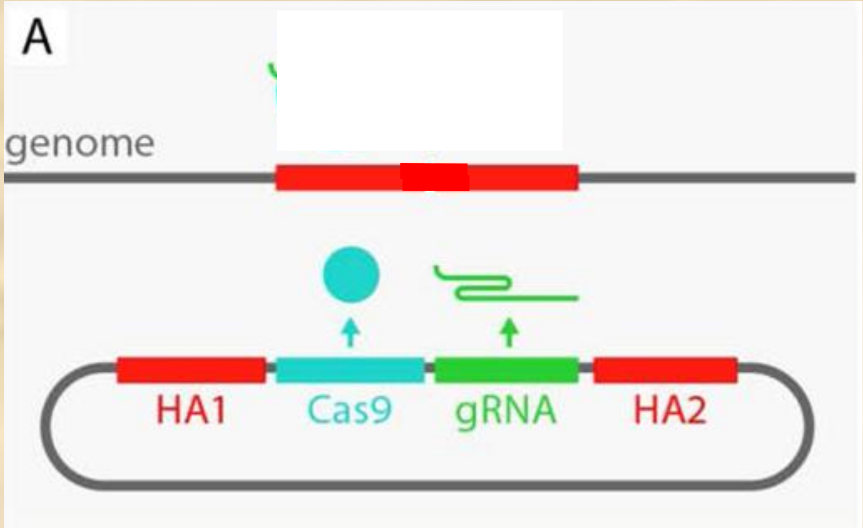
*Corresponding author. E-mail: vgantz@ucsd.edu (V.M.G.); ebier@ucsd.edu (E.B.)

An organism with a single recessive loss-of-function allele will typically have a wild-type phenotype while individuals homozygous for two copies of the allele will display a mutant phenotype. Here, we develop a method that we refer to as the mutagenic chain reaction (MCR), which is based on the CRISPR/Cas9 genome editing system for generating autocatalytic mutations to generate homozygous loss-of-function mutations. We demonstrate in *Drosophila* that MCR mutations efficiently spread from their chromosome of origin to the homologous chromosome thereby converting heterozygous mutations to homozygosity in the vast majority of somatic and germline cells. MCR technology should have broad applications in diverse organisms.

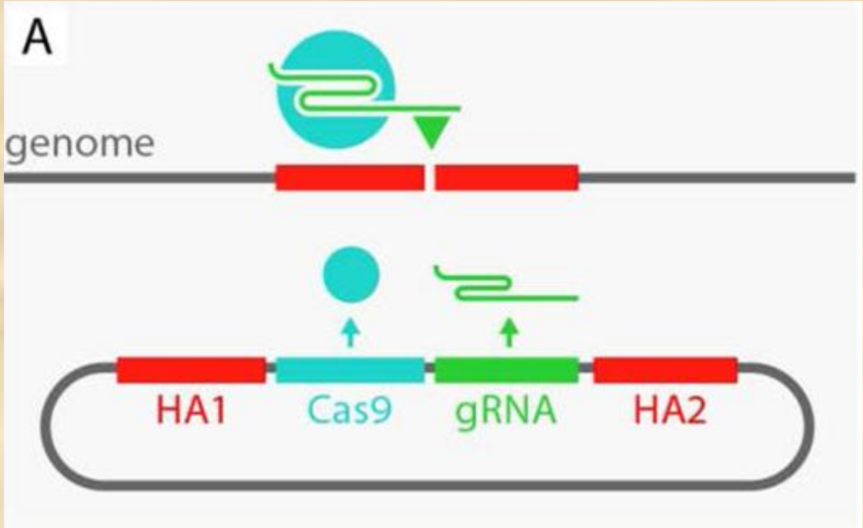
Homologue #1



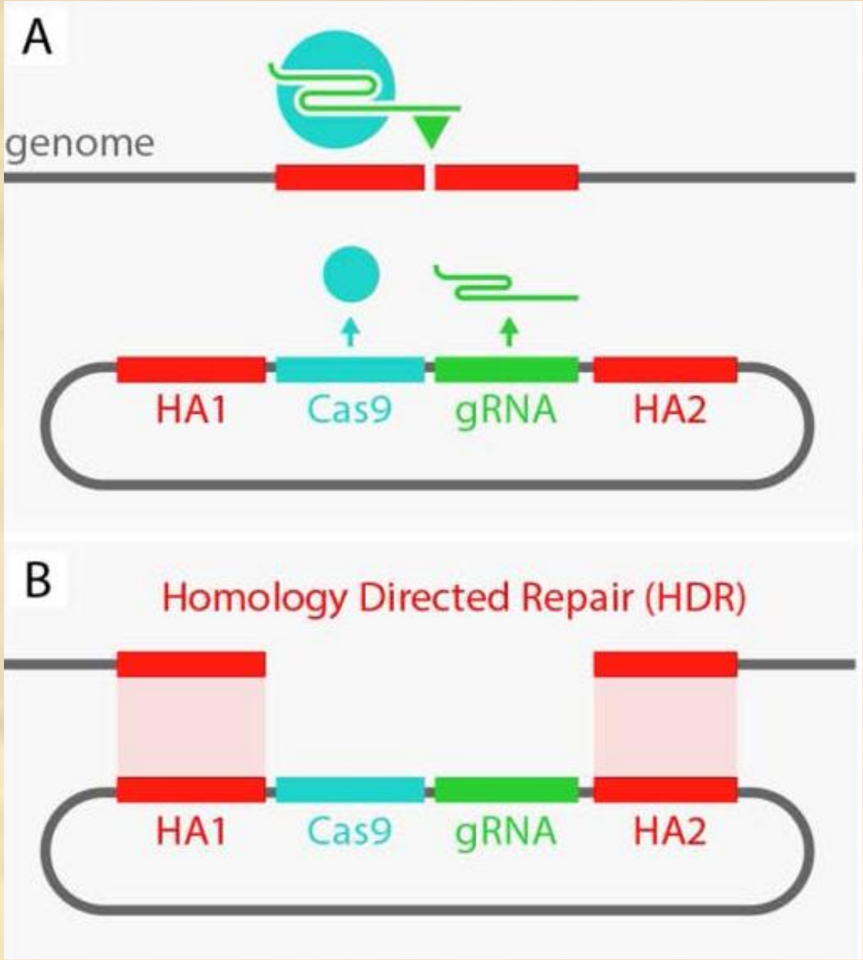
Homologue #1



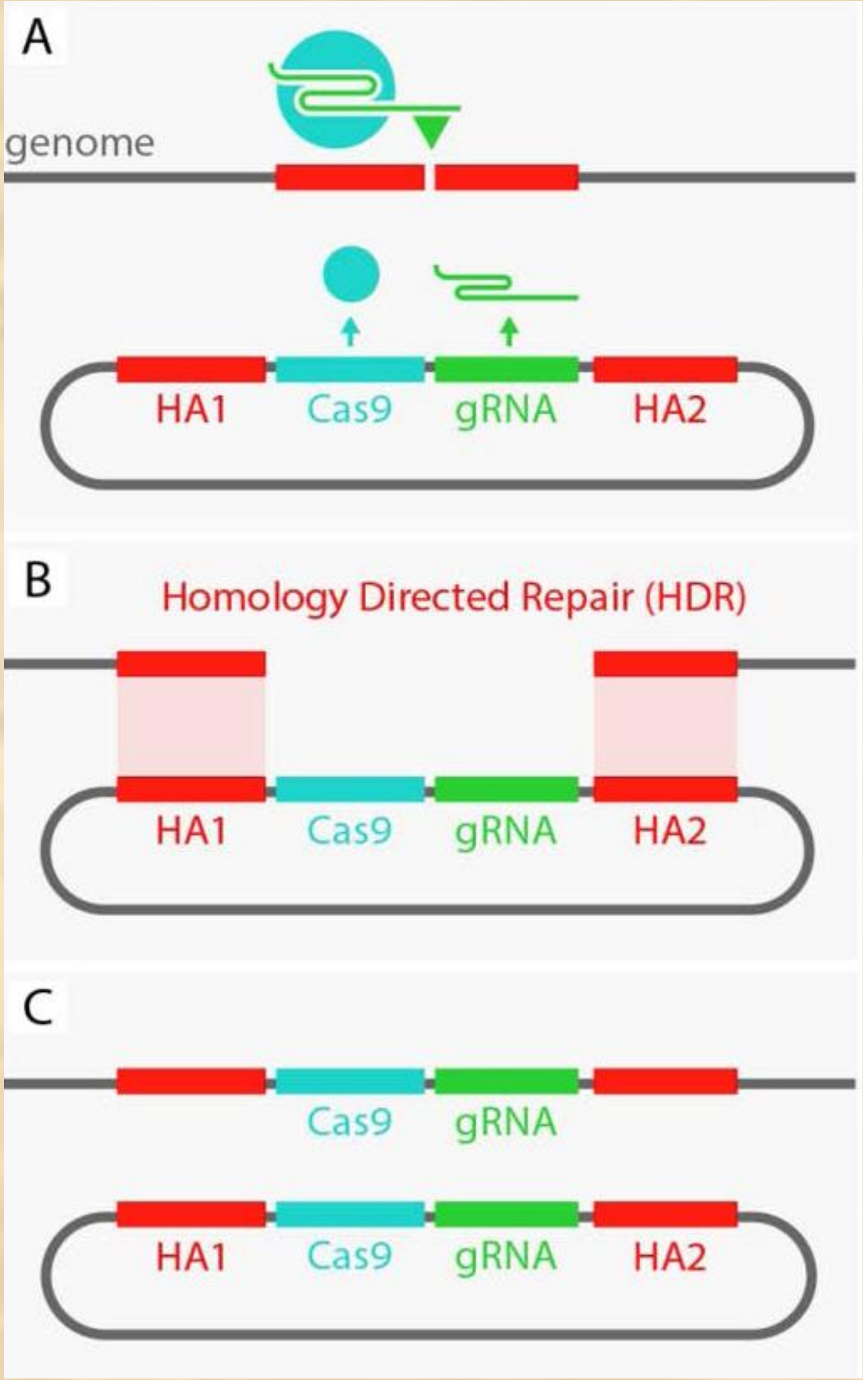
Homologue #1



Homologue #1

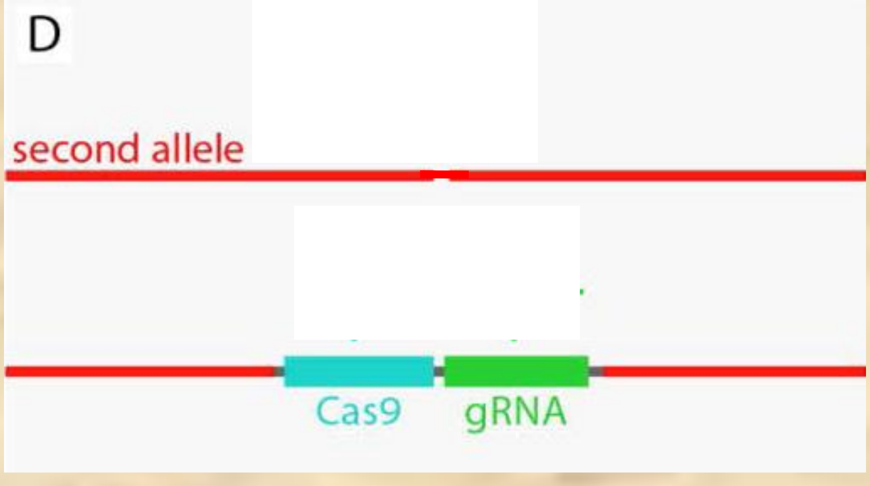

A
genome
HA1
Cas9
gRNA
HA2
B
Homology Directed Repair (HDR)
HA1
Cas9
gRNA
HA2

Homologue #1


A
genome
HA1
Cas9
gRNA
HA2
B
Homology Directed Repair (HDR)
HA1
Cas9
gRNA
HA2
C
Cas9
gRNA
HA1
Cas9
gRNA
HA2

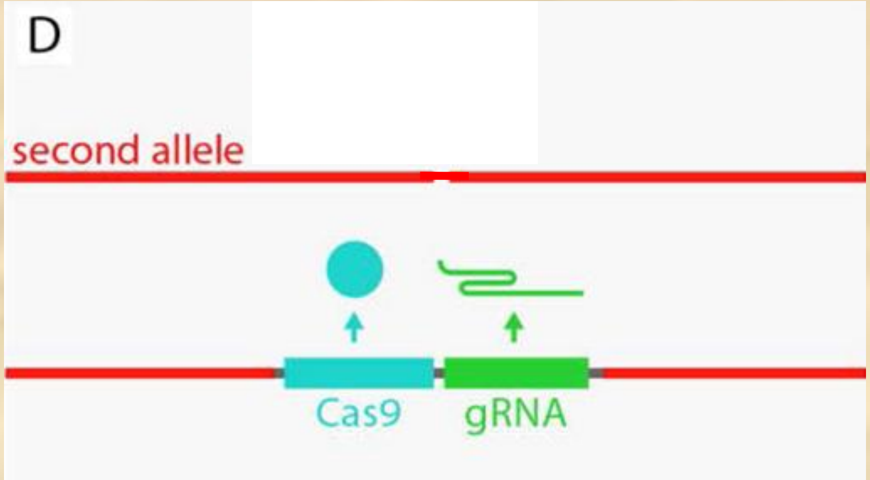
Homologue #2

Homologue #1



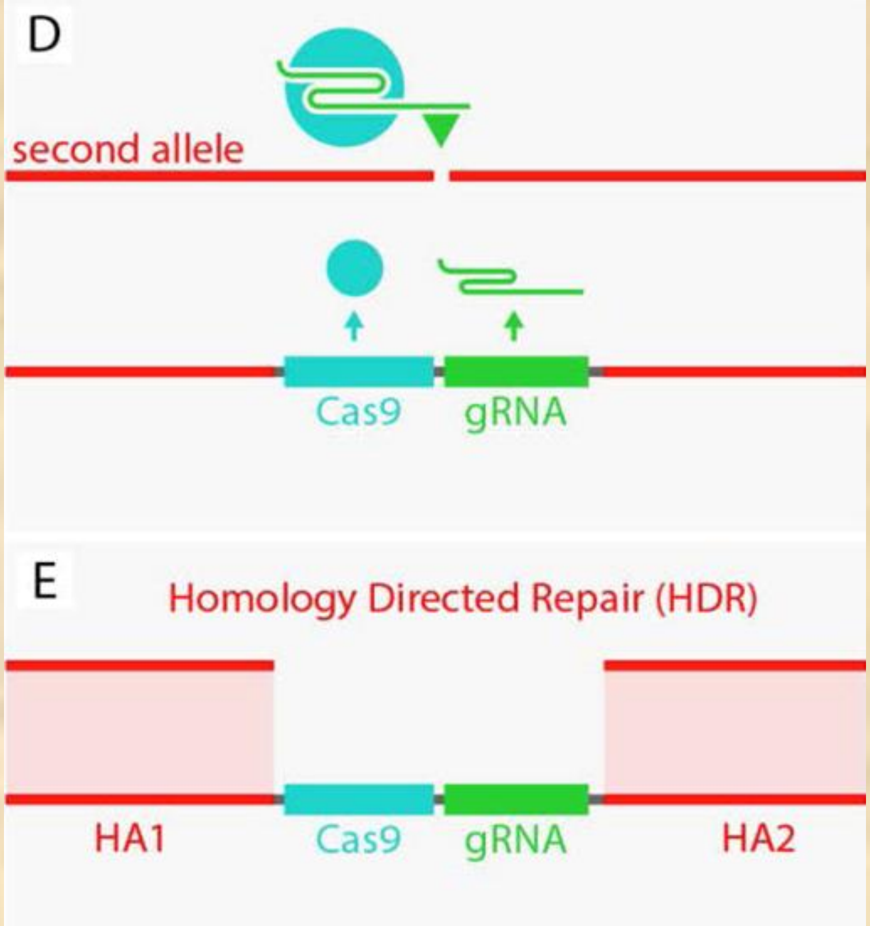
Homologue #2

Homologue #1



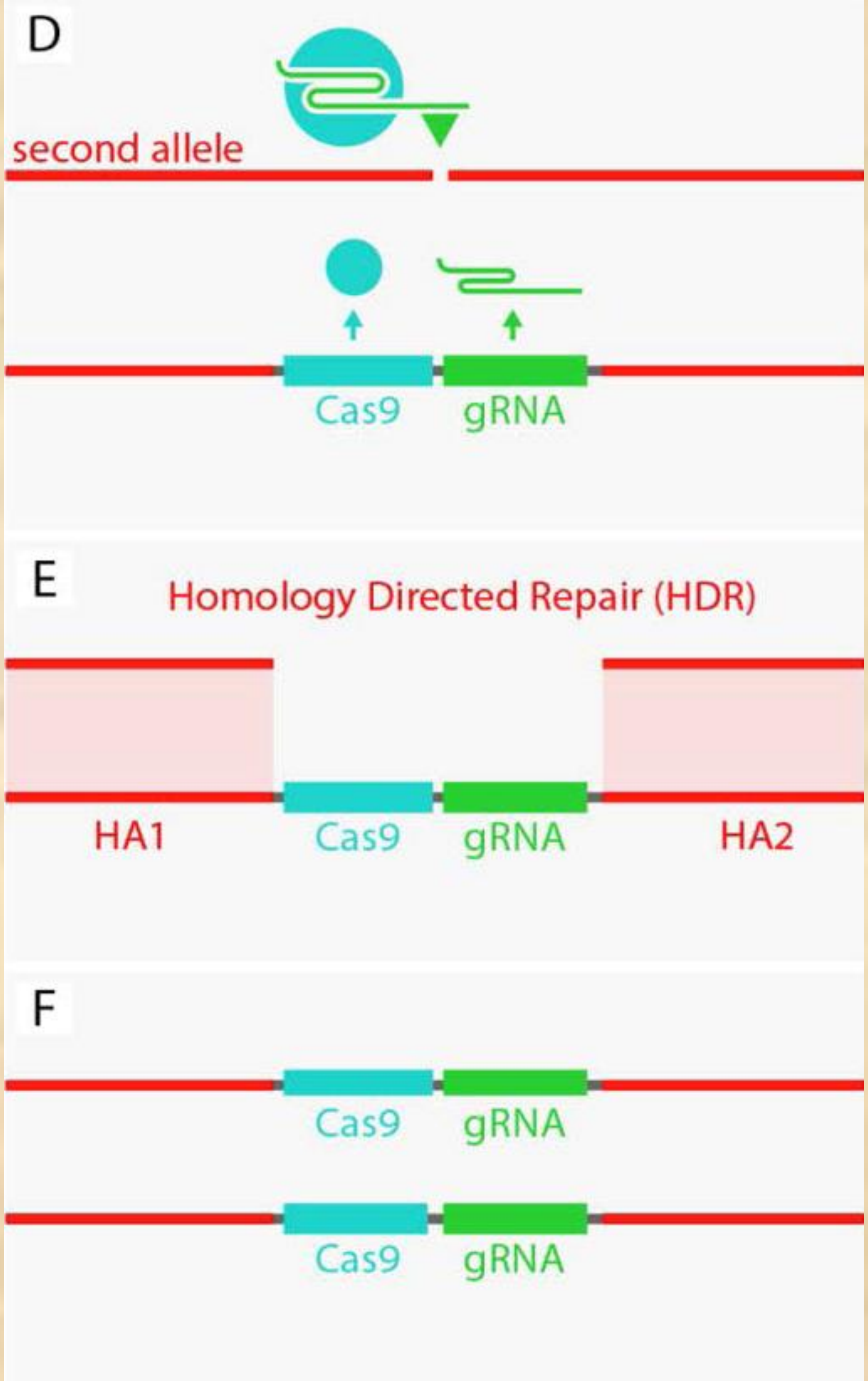
Homologue #2

Homologue #1



Homologue #2

Homologue #1



Homologue #2

Homologue #1

Sciencexpress

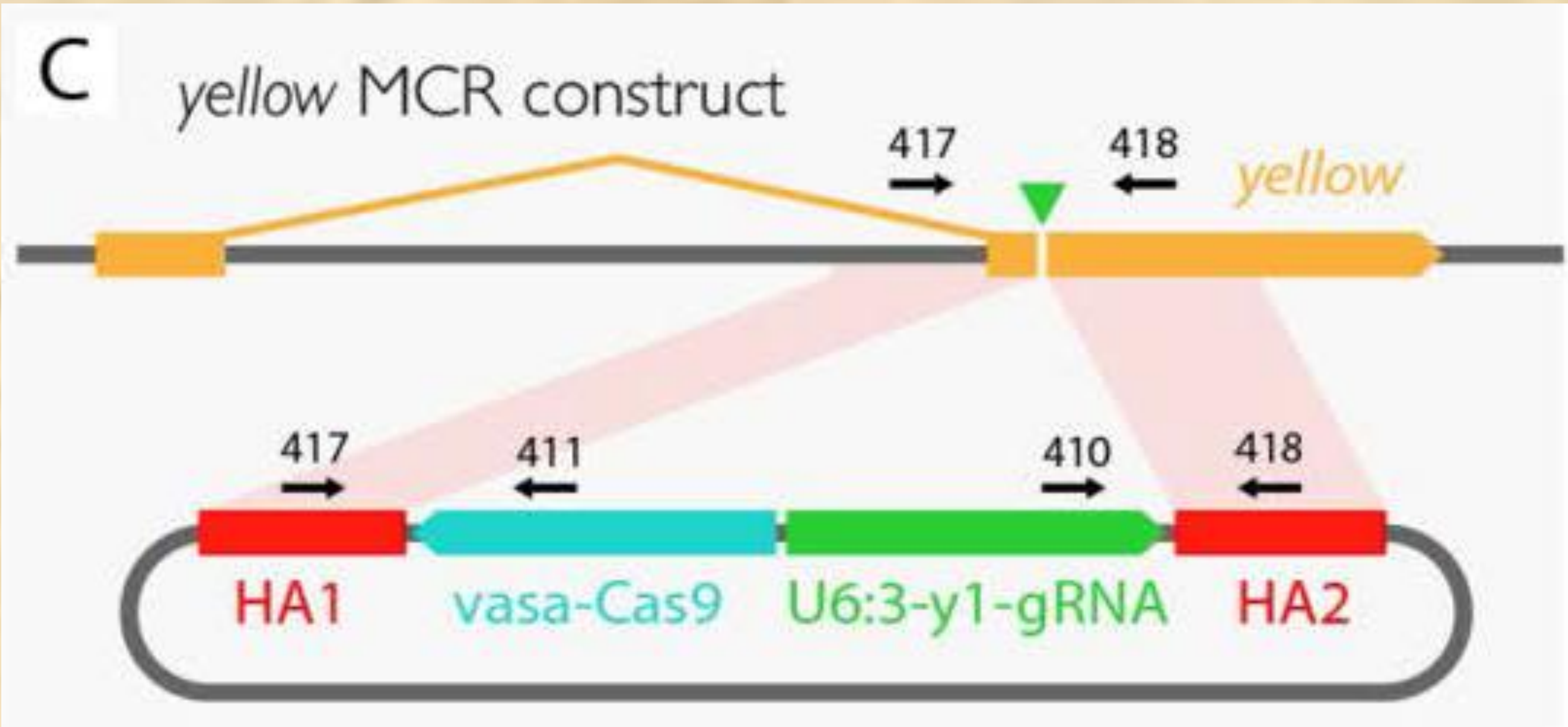
The mutagenic chain reaction: A method for converting heterozygous to homozygous mutations

Valentino M. Gantz* and Ethan Bier*

Section of Cell and Developmental Biology, University of California, San Diego, La Jolla, CA 92095, USA.

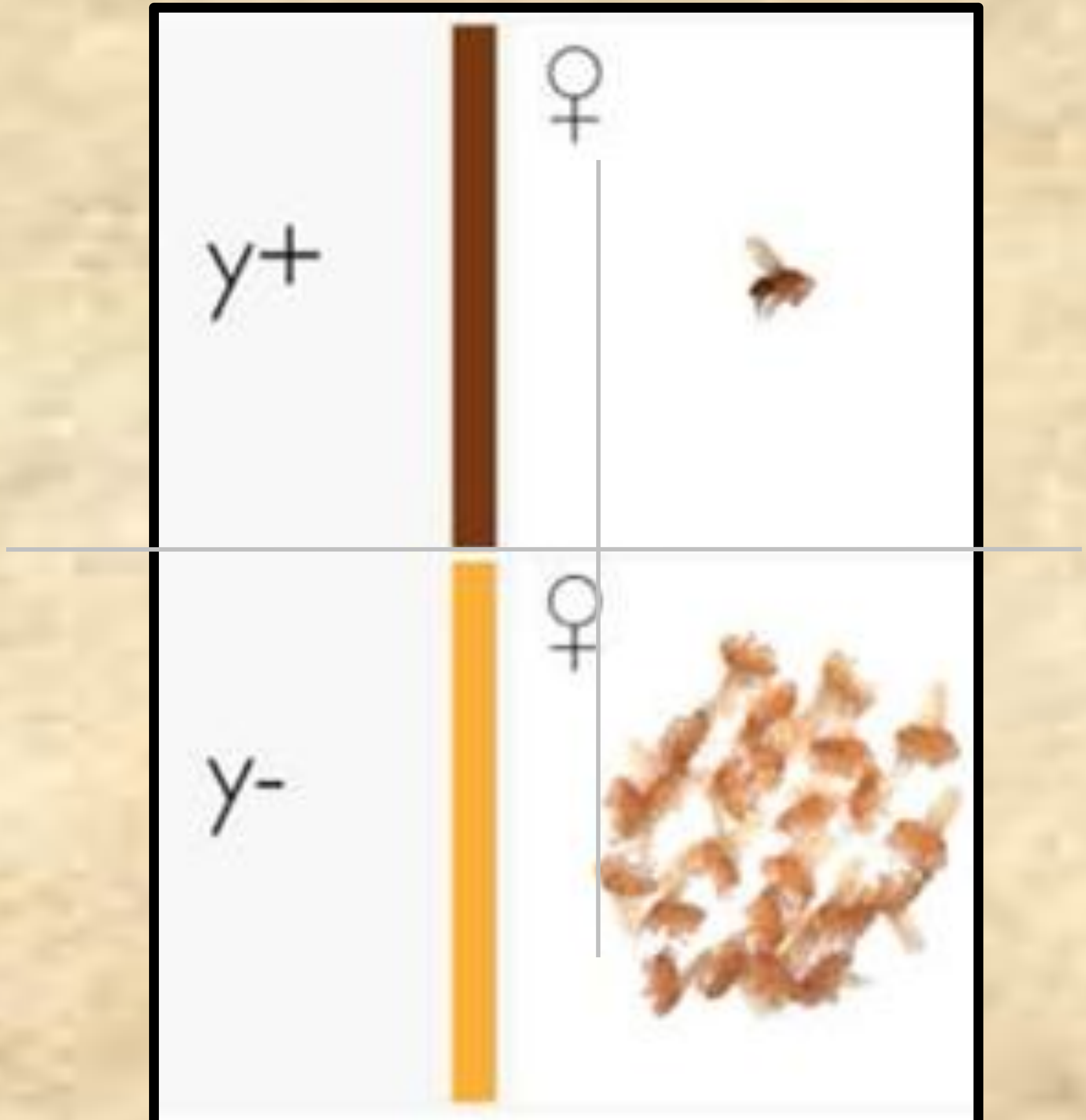
*Corresponding author. E-mail: vgantz@ucsd.edu (V.M.G.); ebier@ucsd.edu (E.B.)

An organism with a single recessive loss-of-function allele will typically have a wild-type phenotype while individuals homozygous for two copies of the allele will display a mutant phenotype. Here, we develop a method that we refer to as the mutagenic chain reaction (MCR), which is based on the CRISPR/Cas9 genome editing system for generating autocatalytic mutations to generate homozygous loss-of-function mutations. We demonstrate in *Drosophila* that MCR mutations efficiently spread from their chromosome of origin to the homologous chromosome thereby converting heterozygous mutations to homozygosity in the vast majority of somatic and germline cells. MCR technology should have broad applications in diverse organisms.

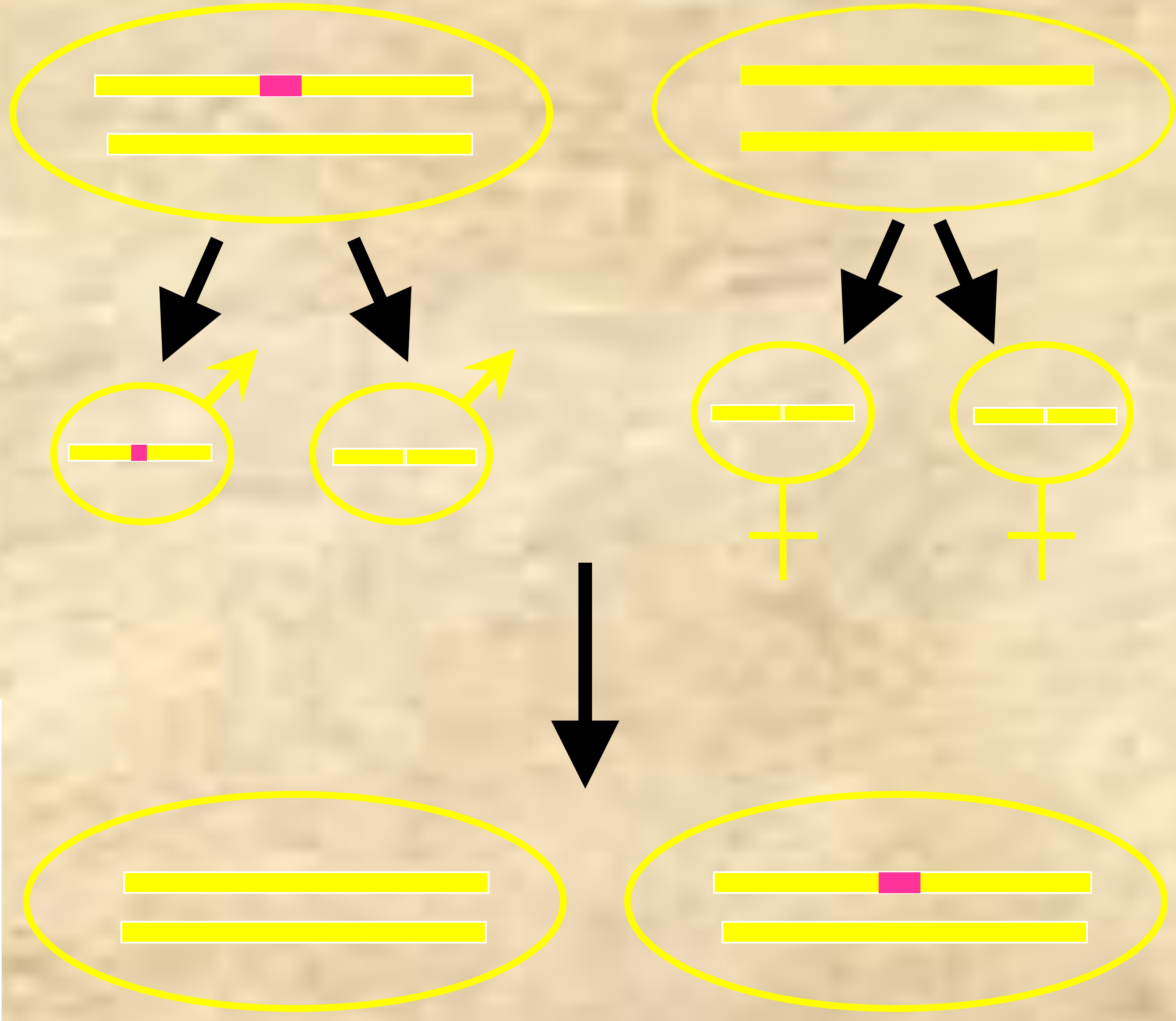

C
yellow MCR construct
417
418
yellow
417
411
410
418
HA1
vasa-Cas9
U6:3-y1-gRNA
HA2


I

G

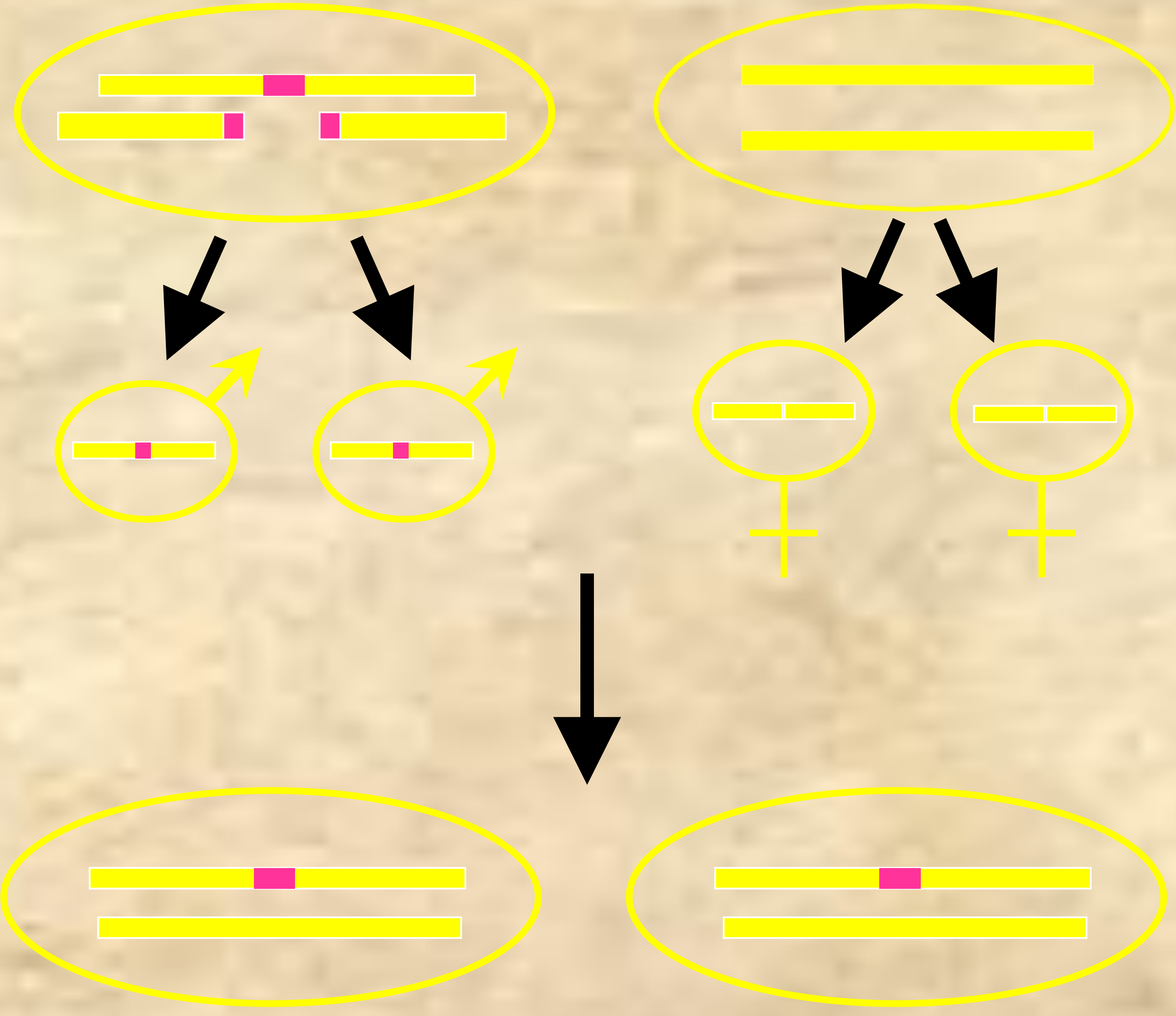

y+
♀
y-
♀

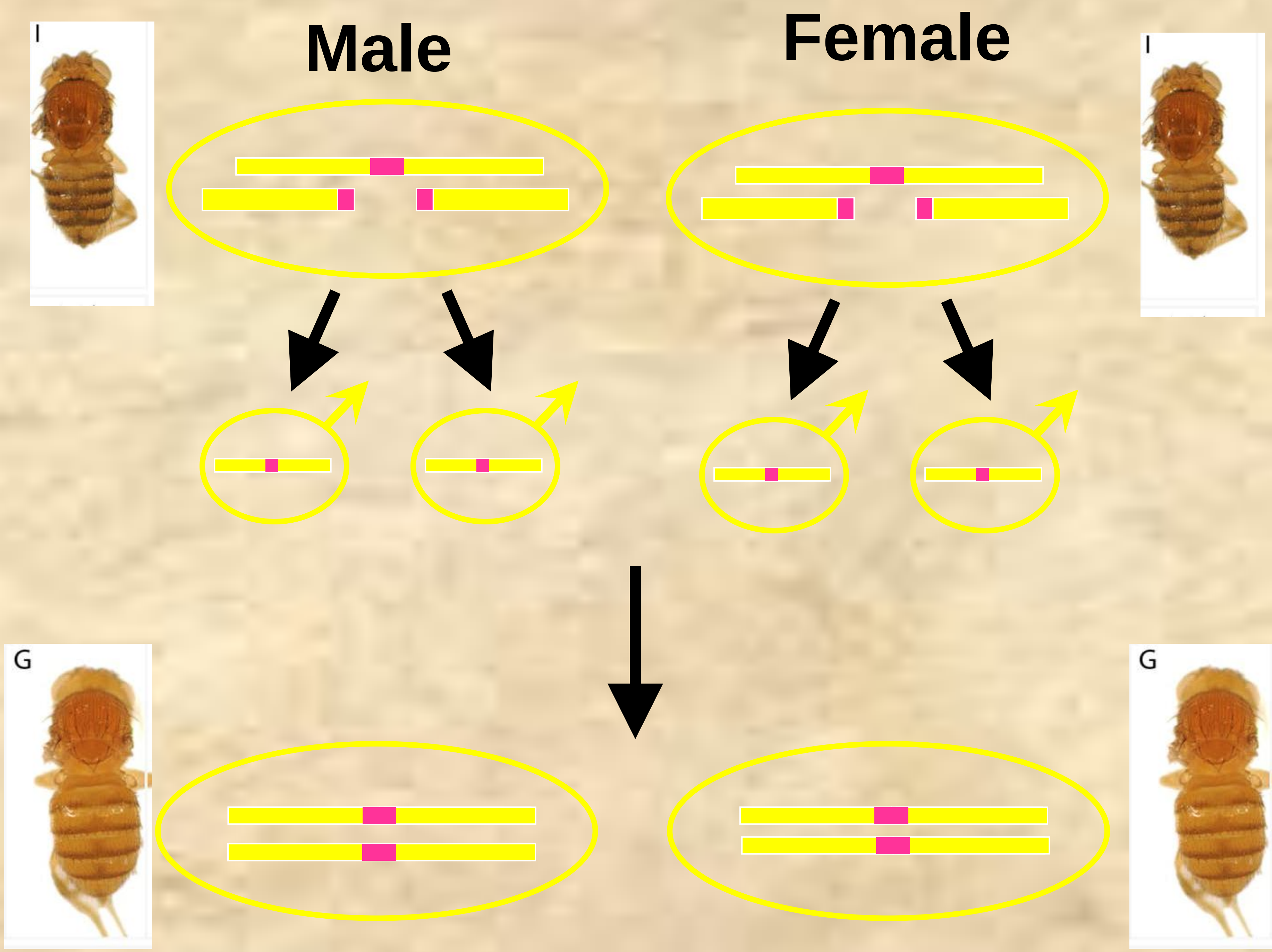
Mendelian Inheritance

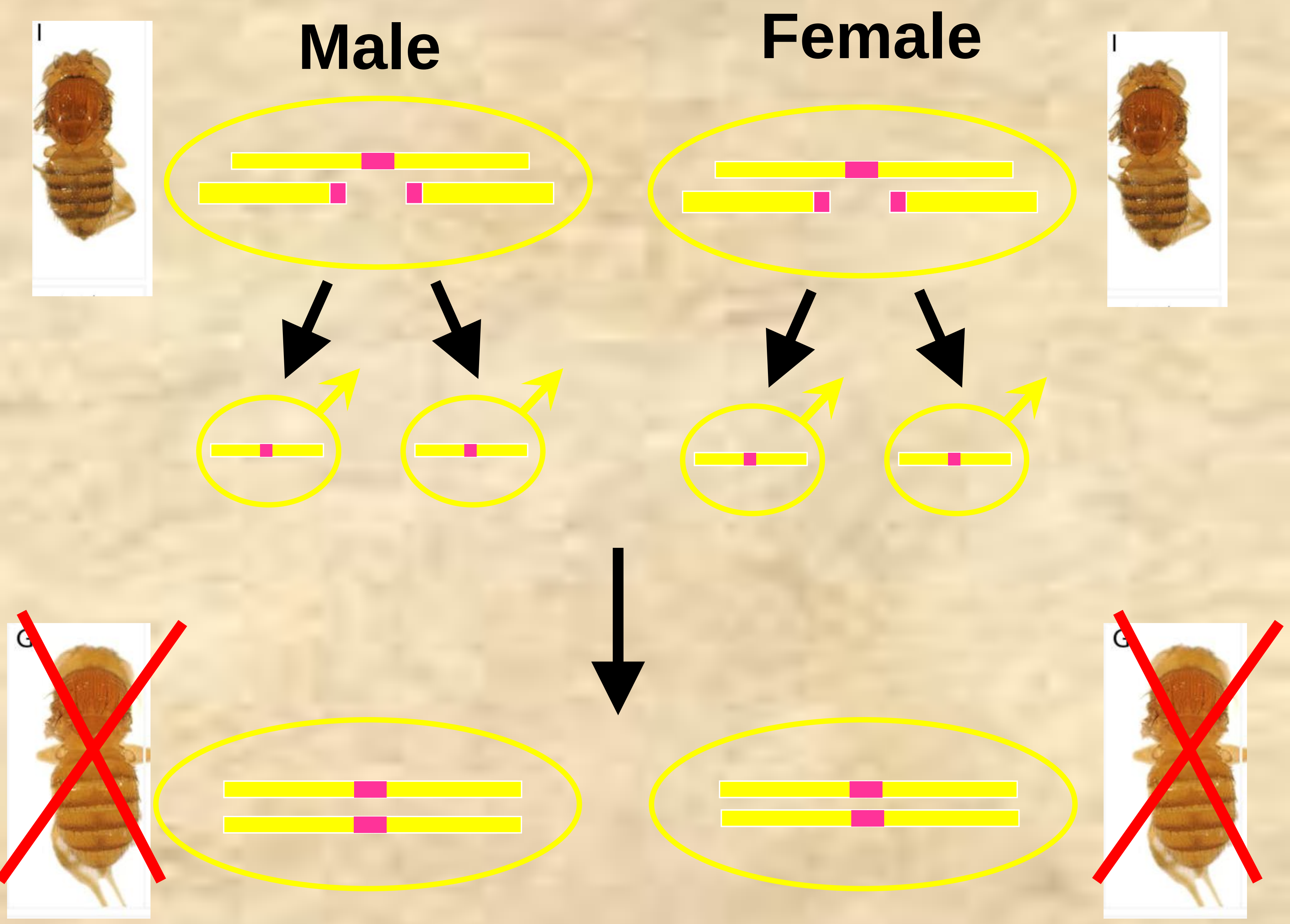


Male

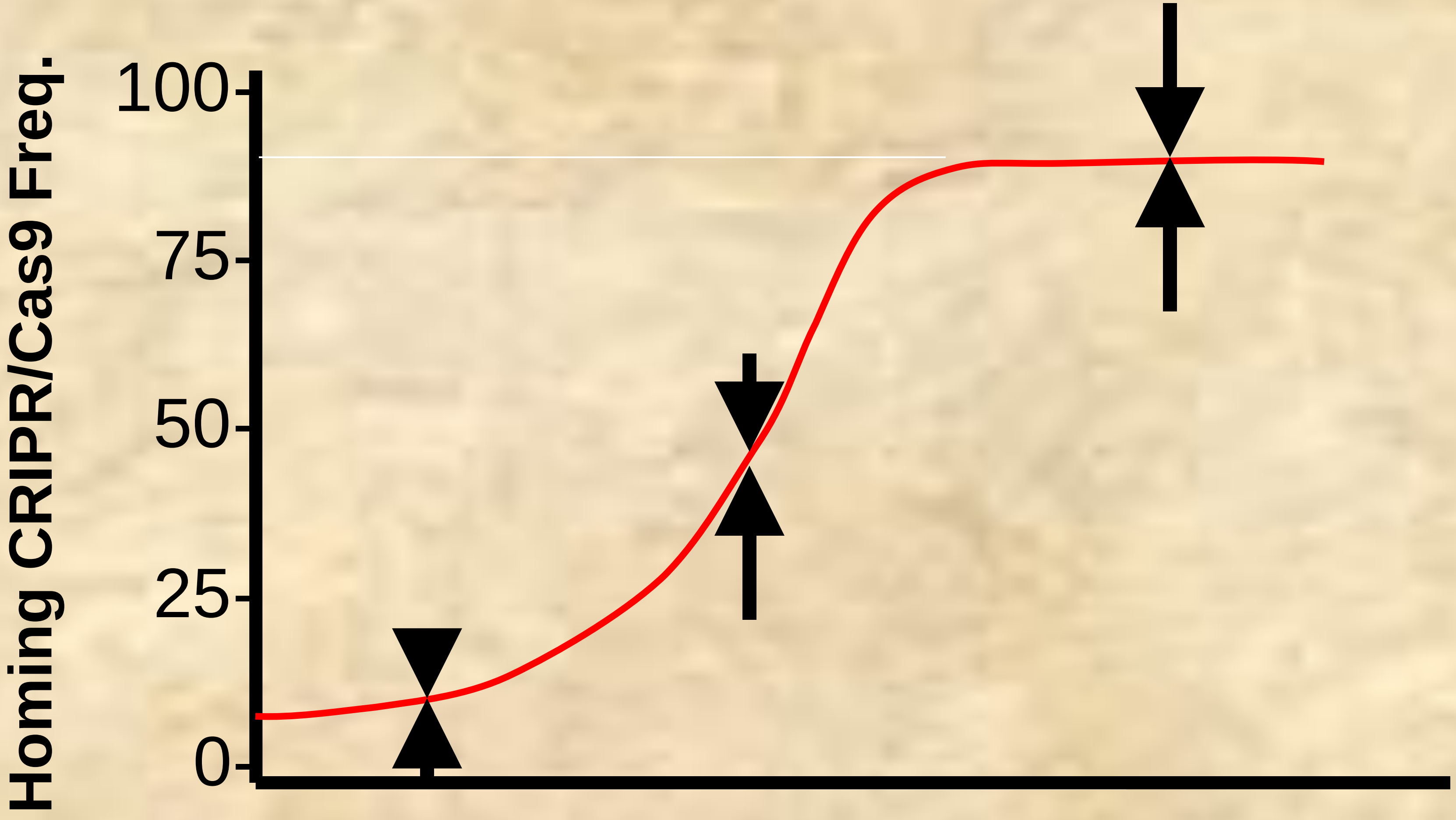
Female



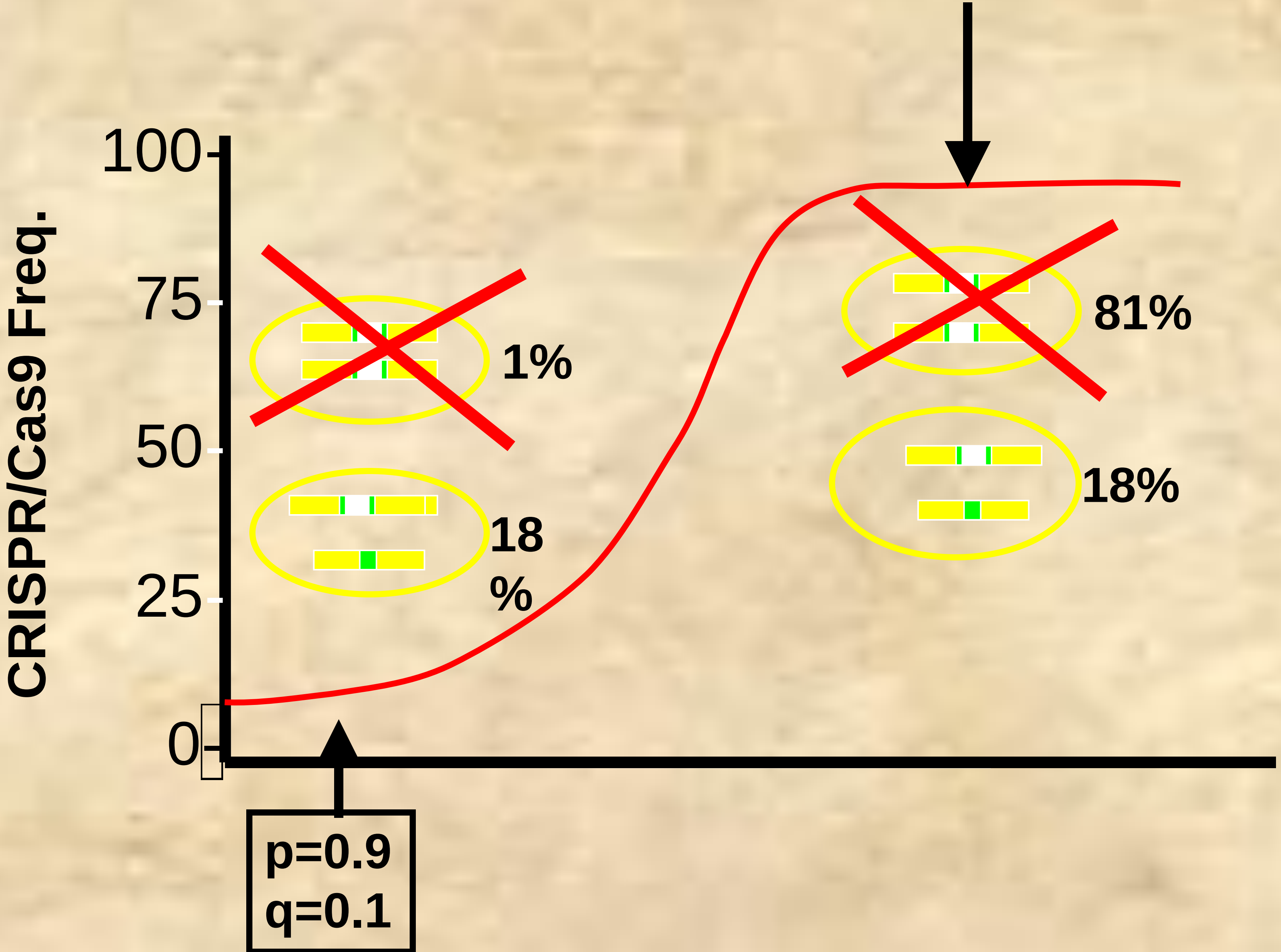

Male
Female
I
I
G
G

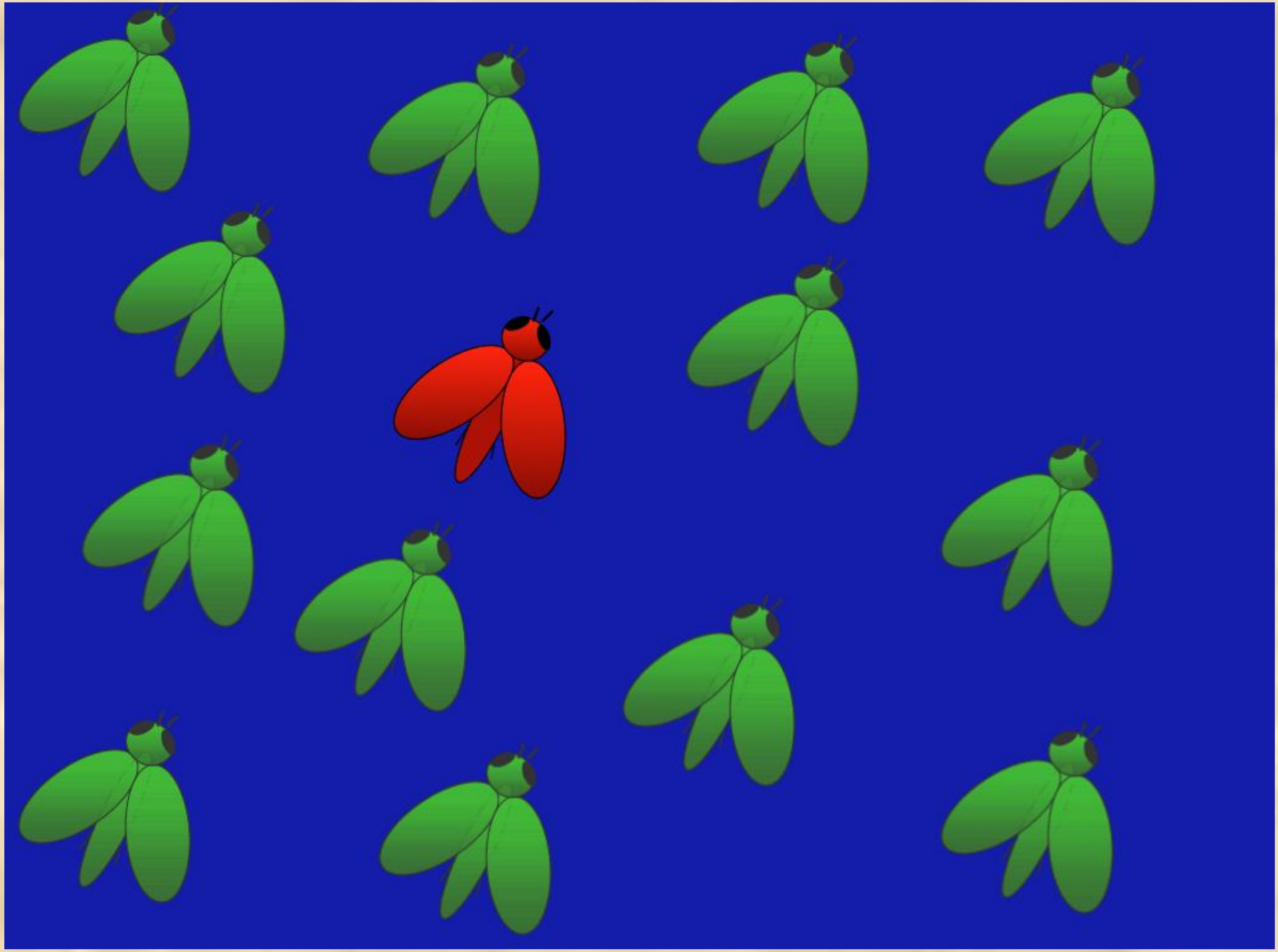

Male
Female

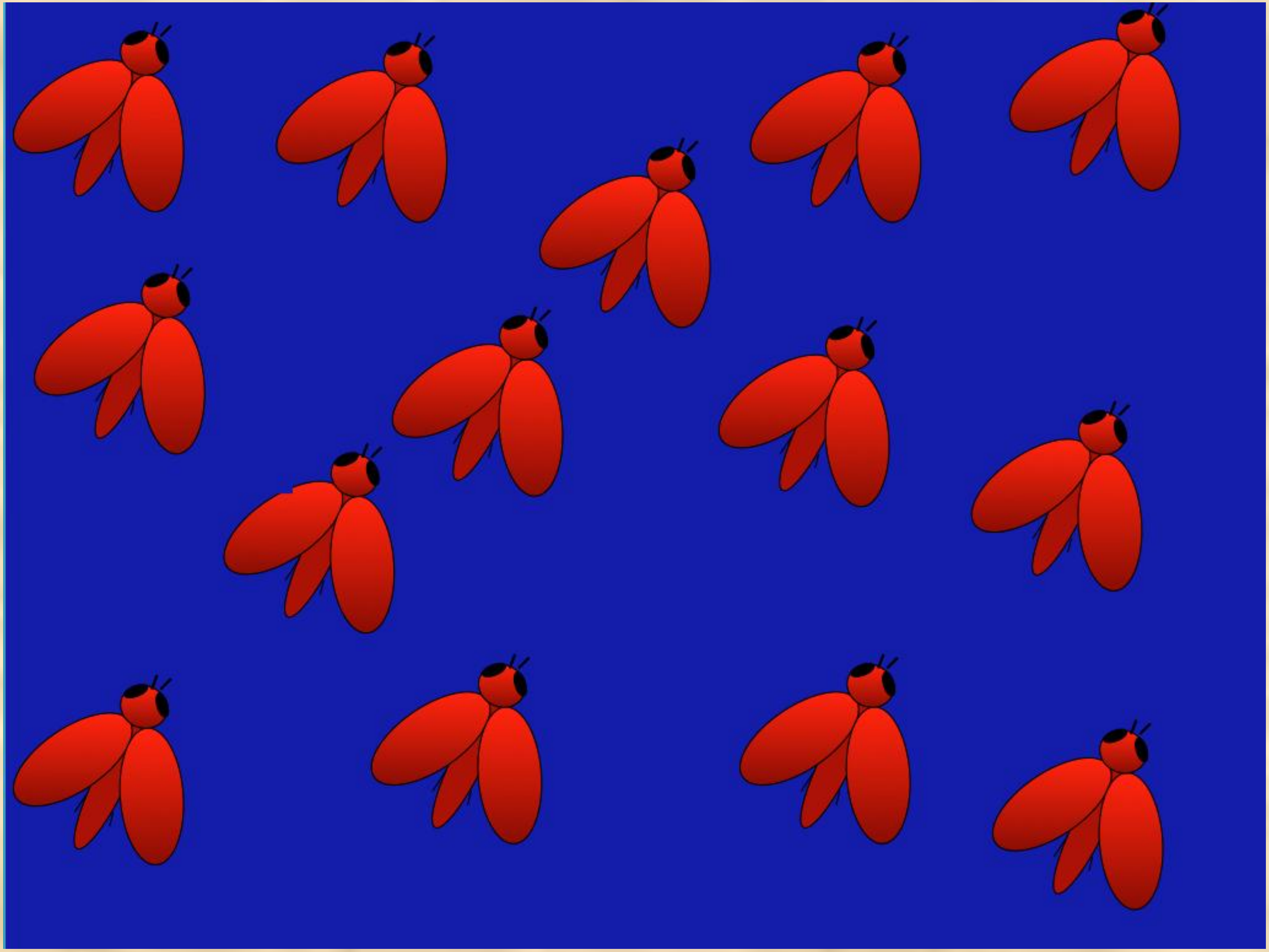
$$1.0 = p^2 + 2pq + q^2$$



$$1.0 = p^2 + 2pq + q^2$$



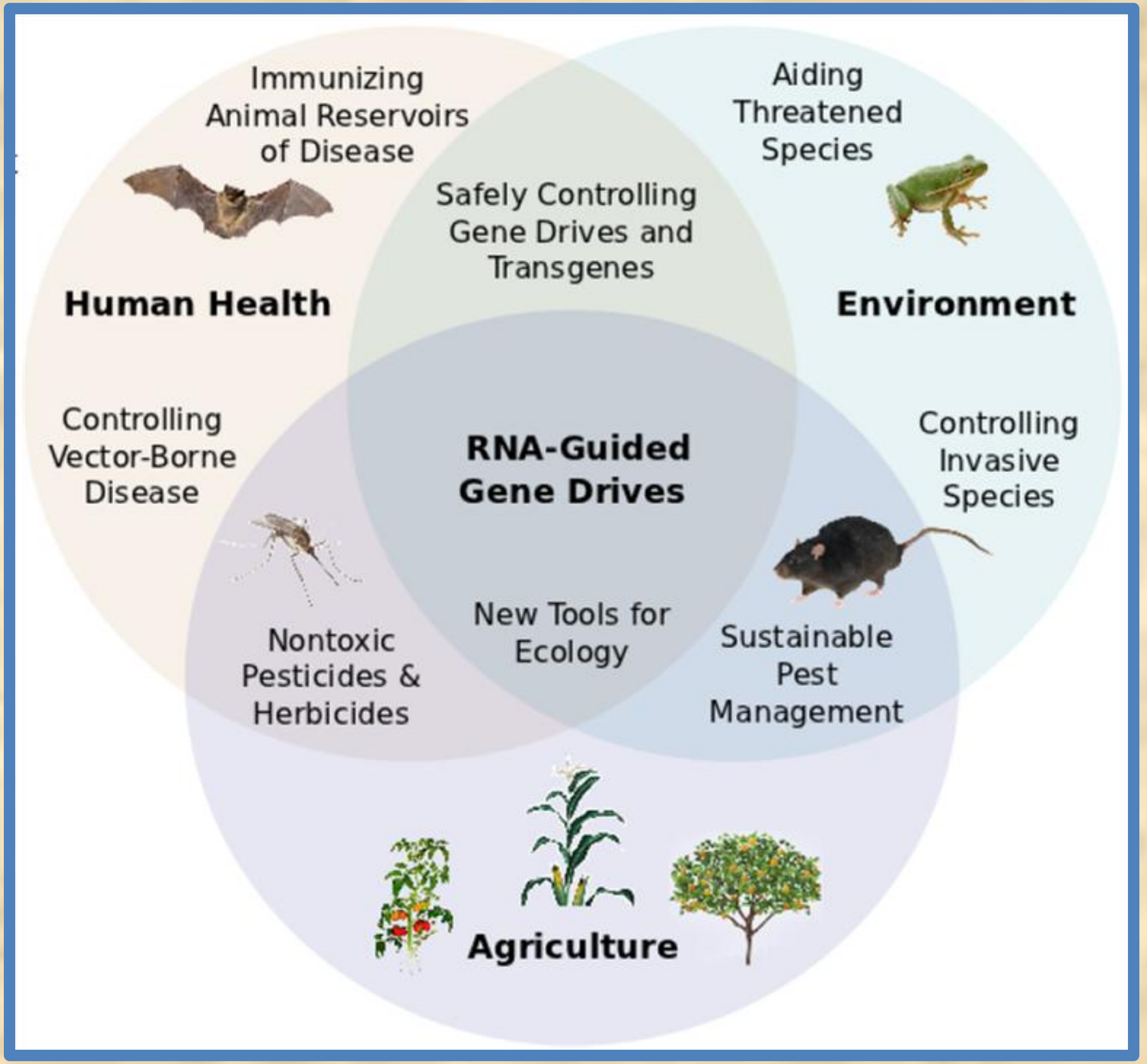




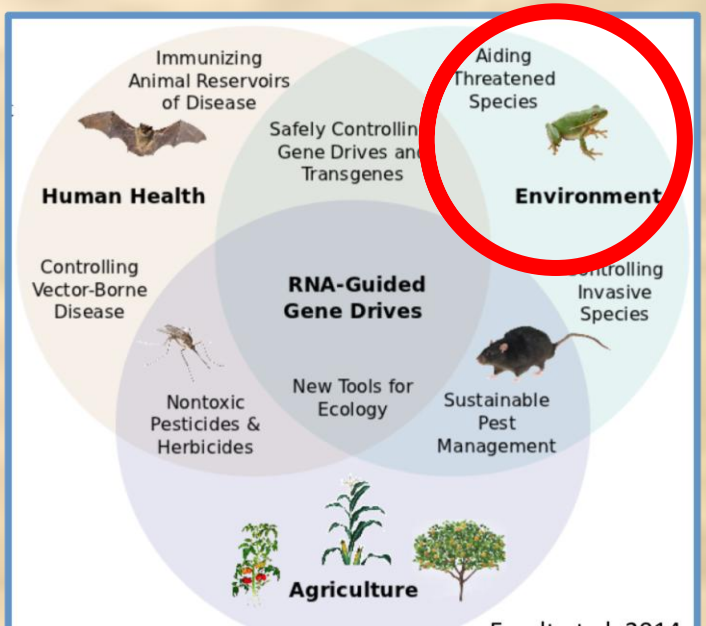
What are good and
Not so good
Targets for
Genetic Pest Management?

http://longnow.org/revive/about-the-workshop-sb/

April 2015

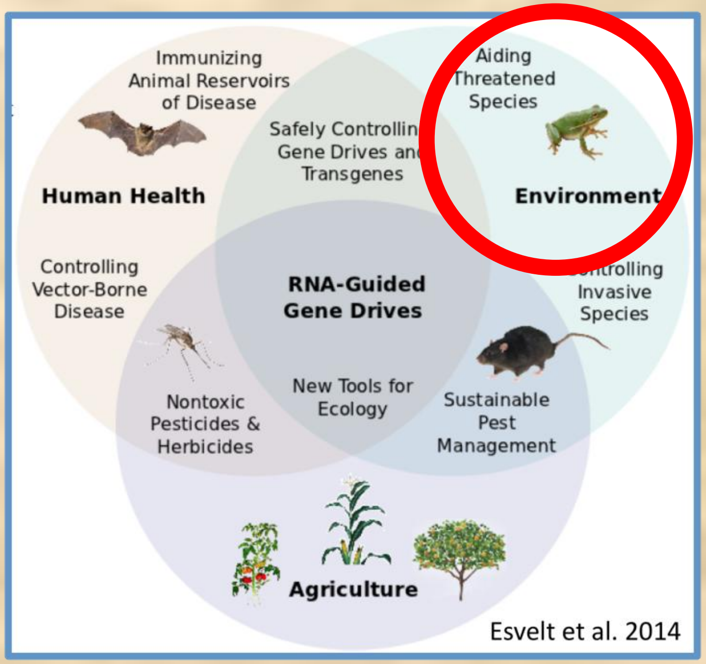


Esvelt et al. 2014

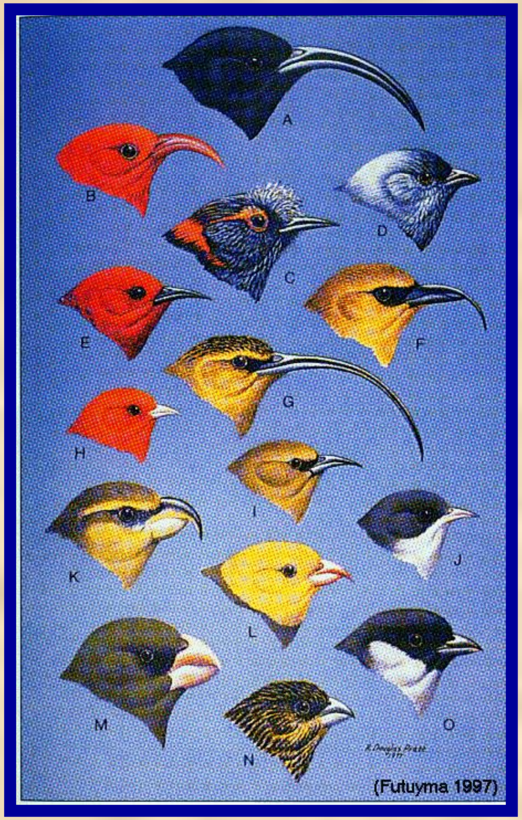


Esvelt et al. 2014

Chytrid Fungus

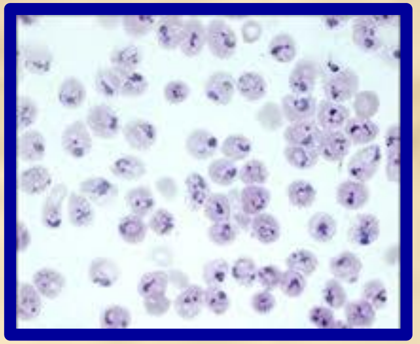



Immunizing Animal Reservoirs of Disease
Aiding Threatened Species
Safely Controlling Gene Drives and Transgenes
Human Health
Environment
Controlling Vector-Borne Disease
RNA-Guided Gene Drives
Controlling Invasive Species
New Tools for Ecology
Nontoxic Pesticides & Herbicides
Sustainable Pest Management
Agriculture
Esvelt et al. 2014



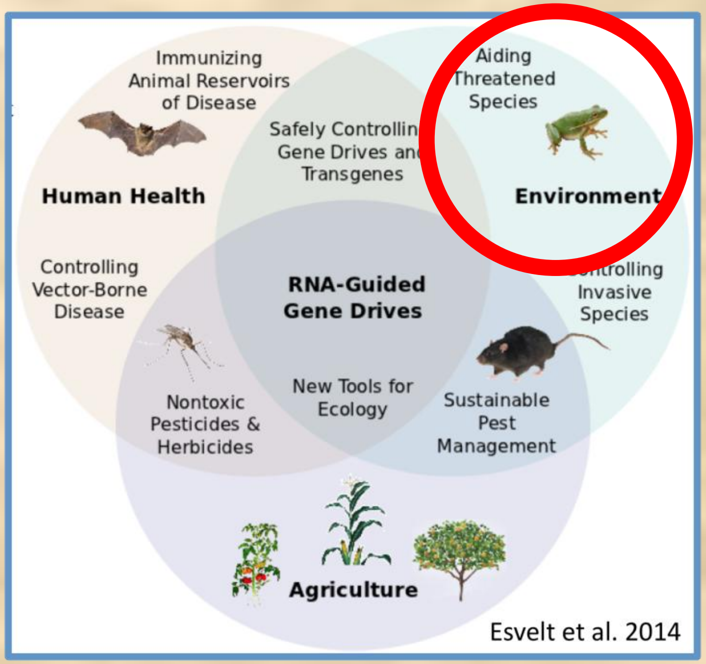
Hawaiian Honeycreepers

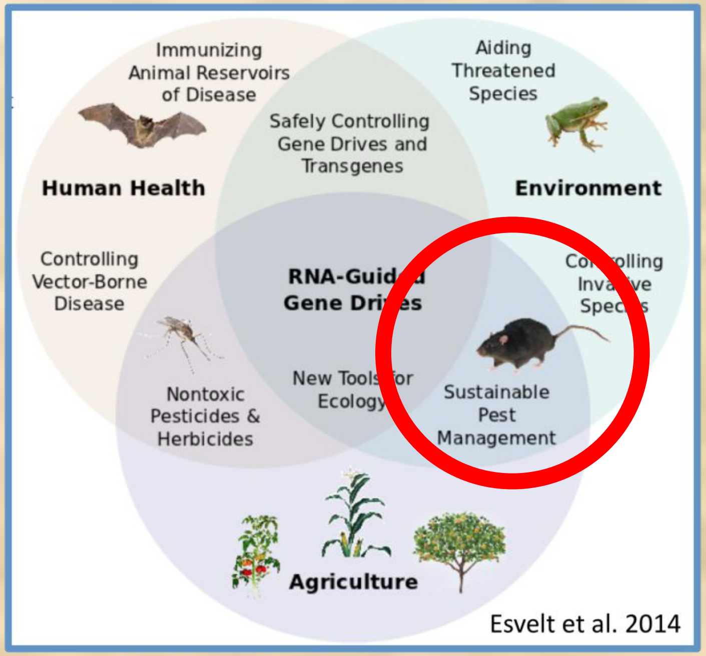
Plasmodium relictum



Culex quinquefasciatus
Southern house mosquito

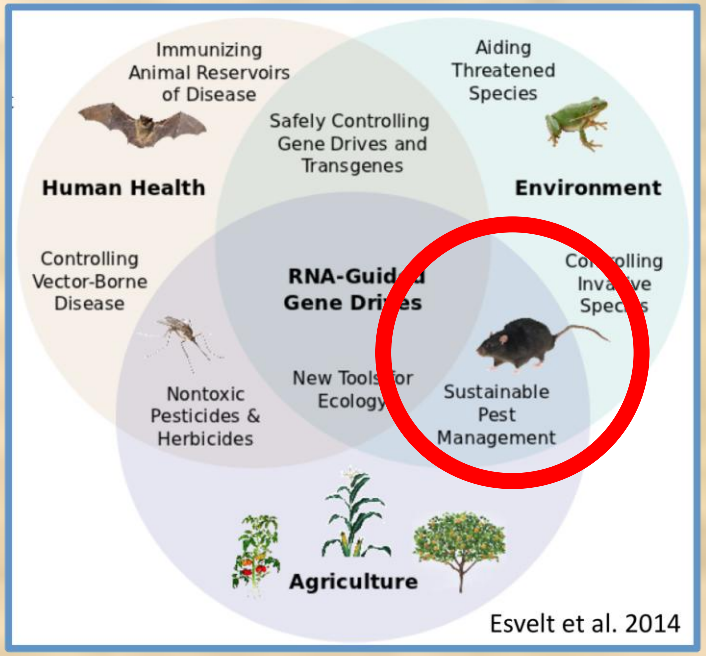
Also transmits West Nile



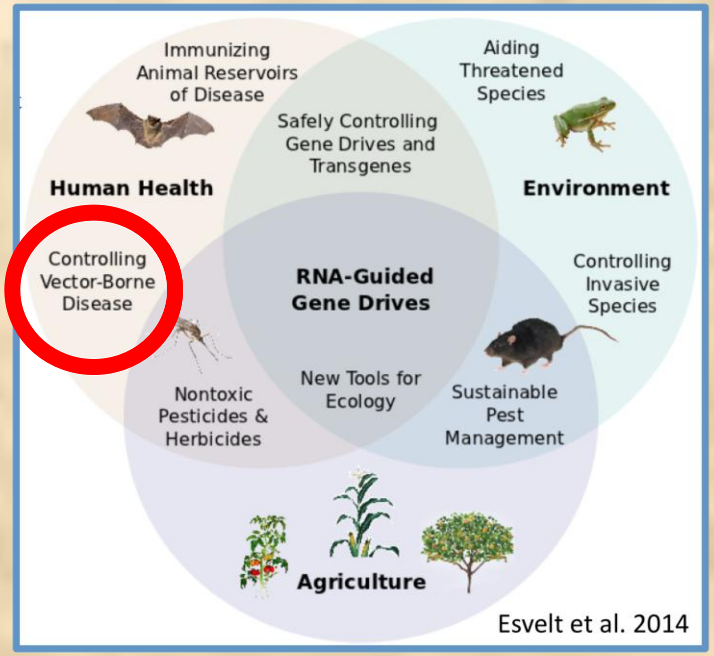

Immunizing
Animal Reservoirs
of Disease
Aiding
Threatened
Species
Safely Controlling
Gene Drives and
Transgenes
Human Health
Environment
Controlling
Vector-Borne
Disease
Sustainable
Pest
Management
Nontoxic
Pesticides &
Herbicides
Agriculture
Esvelt et al. 2014

ISLAND CONSERVATION

Preventing Extinctions

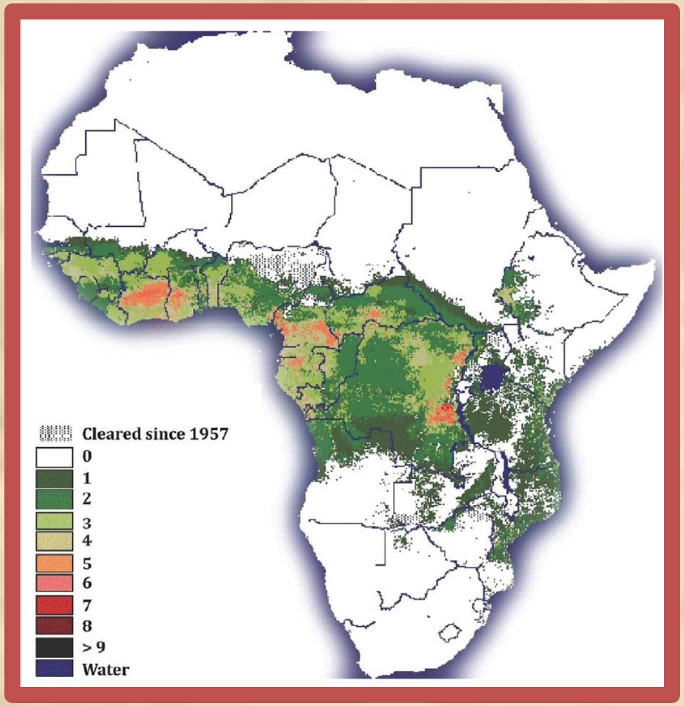


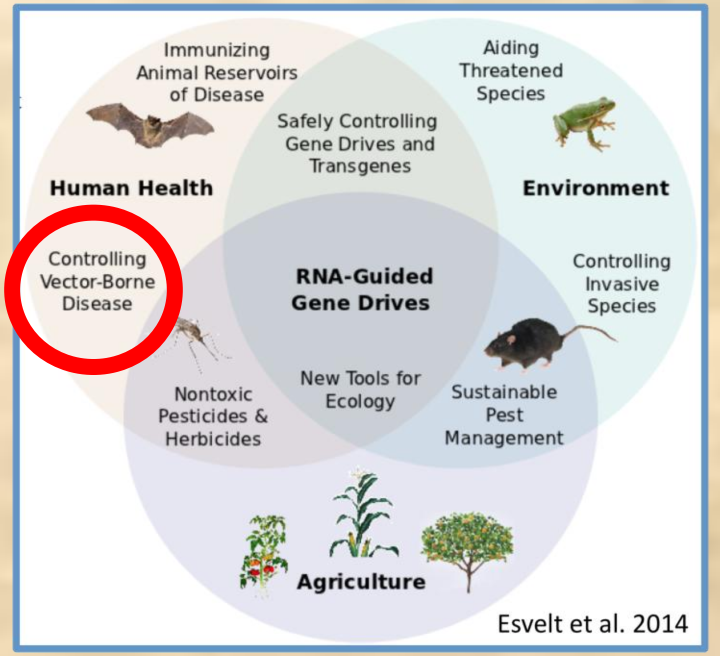
Esvelt et al. 2014

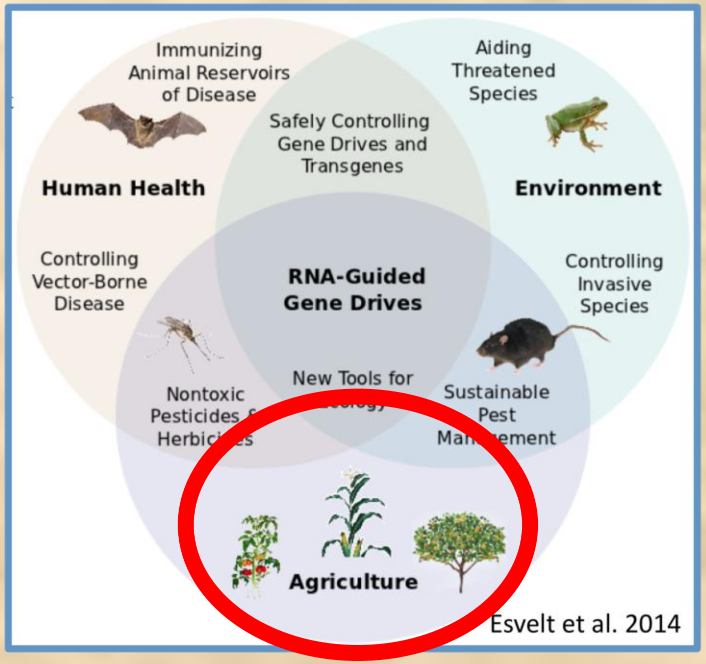

Immunizing
Animal Reservoirs
of Disease
Aiding
Threatened
Species
Safely Controlling
Gene Drives and
Transgenes
Human Health
Environment
Controlling
Vector-Borne
Disease
RNA-Guided
Gene Drives
Controlling
Invasive
Species
New Tools for
Ecology
Nontoxic
Pesticides &
Herbicides
Sustainable
Pest
Management
Agriculture
Esvelt et al. 2014

African Trypanosomiasis

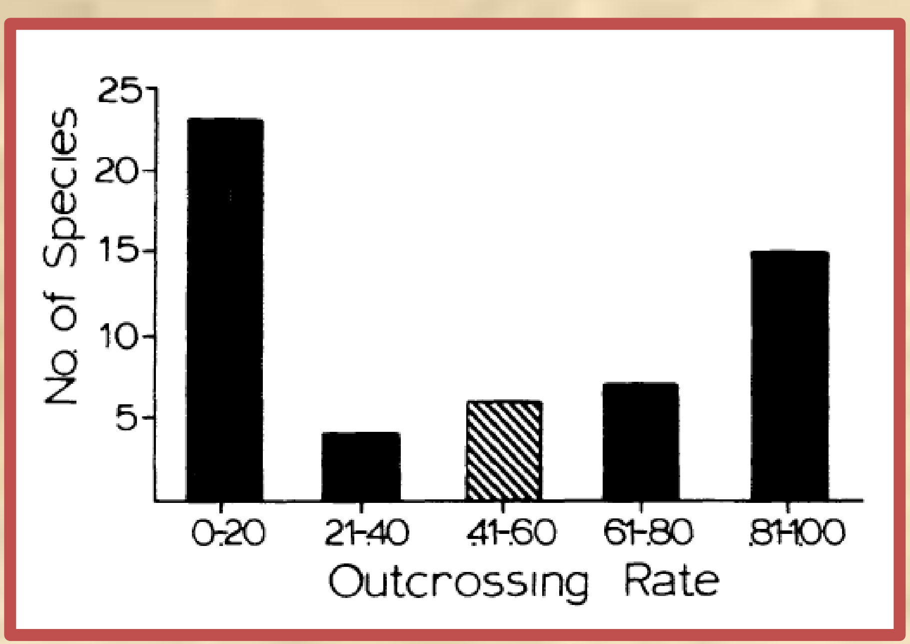
Tsetse fly



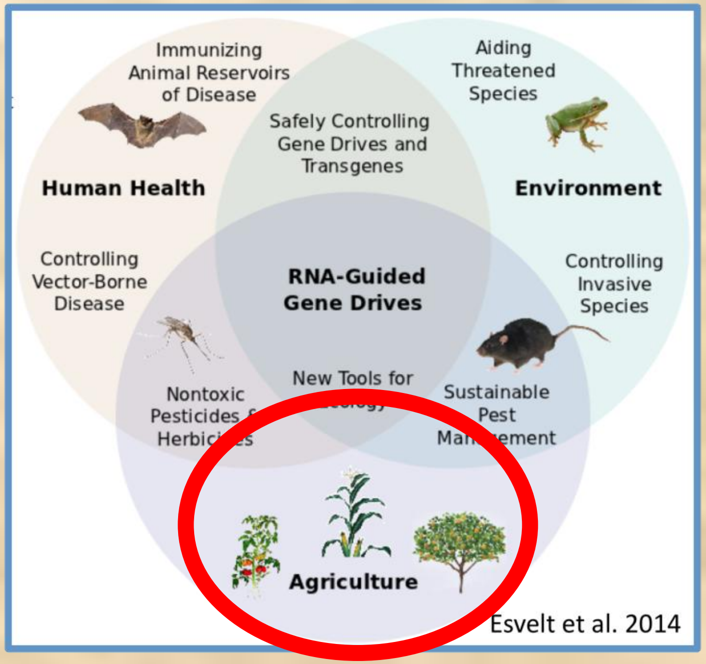



Immunizing
Animal Reservoirs
of Disease
Aiding
Threatened
Species
Safely Controlling
Gene Drives and
Transgenes
Human Health
Environment
Controlling
Vector-Borne
Disease
RNA-Guided
Gene Drives
Controlling
Invasive
Species
New Tools for
Nontoxic
Pesticides
Sustainable
Pest
Agriculture
Esvelt et al. 2014

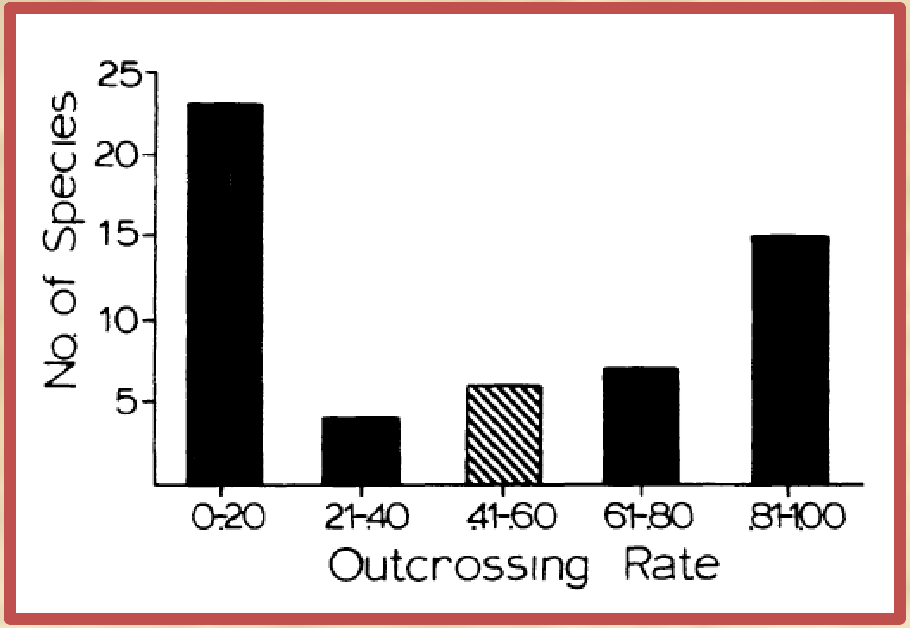
Scotch broom, *Cytisus scoparius*



Schemske and Lande 1985

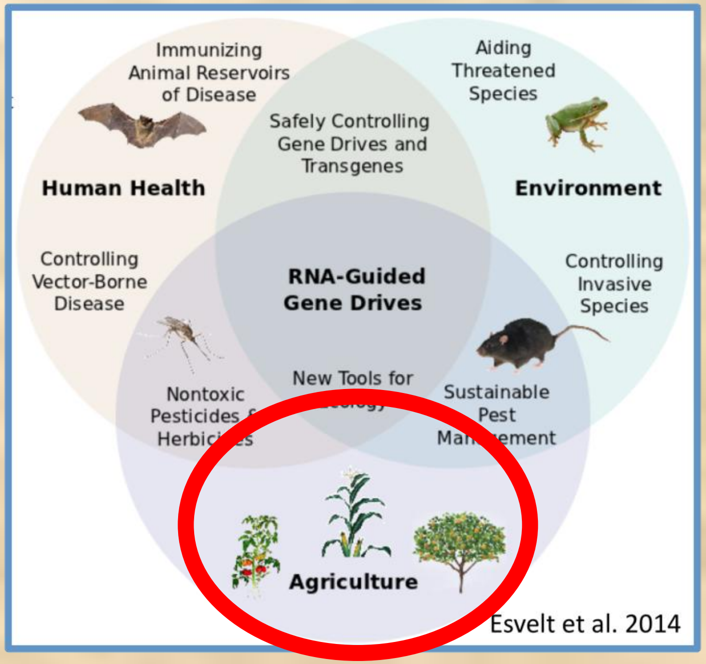


Scotch broom, *Cytisus scoparius*



Schemske and Lande 1985

Amaranth



Morning glory

Genetic Engineering and Society: The case of transgenic pests

NSF

IGERT
INTEGRATIVE GRADUATE
EDUCATION AND
RESEARCH TRAINEESHIP

Jennifer Kuzma

Jason Delborne **Zack Brown**

Bill Kinsella

David Berube

Jade Berry-James

Andrew Binder

Mike Cobb

Mary Kath Cunningham

Jane Hoppin

Marce Lorenzen

Max Scott

Jim Mahaffey

Mike Roe

David Threadgill

Nora Haenn

Nils Peterson

Carolyn Miller

Matthew Booker

Wally Thurman

Will Kimler

Alun Lloyd

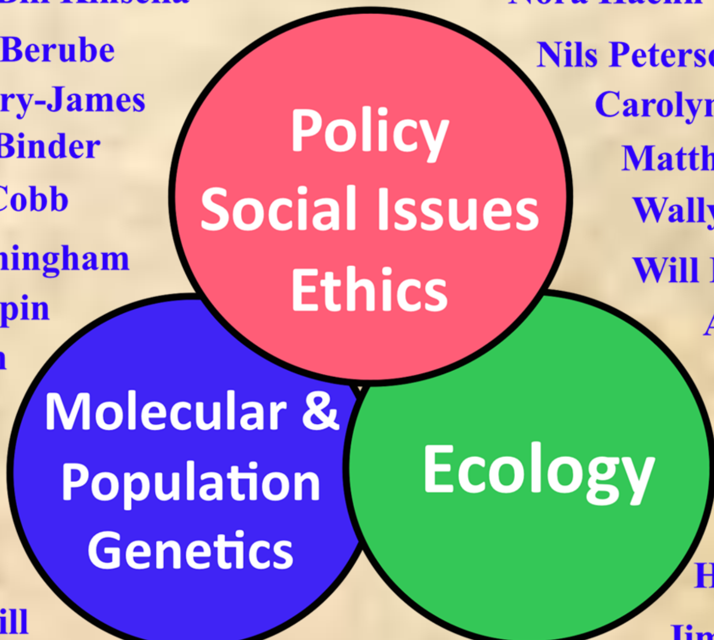
Nick Haddad

Kevin Gross

Yasmin Cardoza

Hannah Burrack

Jim Gilliam



Fred Gould

Lisa McGraw

John Godwin

GES CENTER

NC STATE UNIVERSITY

GES CENTER

NC STATE UNIVERSITY

2016 Invasive Species Webinar Series

ENVIRONMENTAL LAW•INSTITUTE®

Gene Editing: A Next Generation Tool for Invasive Species Management?

Thursday, February 18, 2016 • 2:00pm – 4:00pm ET

INTRODUCING:

Dr. Todd Kuiken

Senior Program Associate, Science and Technology Innovation Program,
Woodrow Wilson International Center for Scholars

Dr. Todd Kuiken is the principal investigator on the Wilson Center's Synthetic Biology Project, where he has numerous projects evaluating and designing new research and governance strategies to proactively address the biosafety, biosecurity and environmental risks associated with synthetic biology and bridge the gaps between scientific research, environmental protection, conservation and public policy. He is collaborating with DIYbio.org on a project to ensure safety within the rapidly expanding community of amateur biologists and the growing network of community laboratories. Dr. Kuiken was recently appointed to the United Nations Convention on Biological Diversity Ad-Hoc Technical Expert Group and has provided expert testimony in front of the U.S. National Security Agency Advisory Board, the U.S. National Academies of Science, the United Nations Bioweapons Convention, and the Organization for Economic Co-operation and Development. He earned his B.S. in Environmental Management and Technology at Rochester Institute of Technology a M.A. in Environmental and Resource Policy from The George Washington University and his Ph.D. from Tennessee Tech University where his research focused on the air/surface exchange of mercury associated with forest ecosystems.

CRISPR and Gene Drives: Using nature as a bioweapon/solution?

The Wilson Center

Todd Kuiken, Ph.D.
todd.kuiken@wilsoncenter.org
202-691-4398

Pace

New Actors

PNAS PLUS

eLIFE

About Careers Labs Submit Search Menu

eLife › Feature article › Ecology / Genes and chromosomes

Article | Figures & data | Metrics | Article & author info

ACCEPTED MANUSCRIPT

Concerning RNA-guided gene drives for the alteration of wild populations

Kevin M Esvelt, Andrea L Smidler, Flaminia Catteruccia, George M Church

DOI: http://dx.doi.org/10.7554/eLife.03401
Published July 17, 2014
Cite as eLife 2014;10.7554/eLife.03401
Download PDF

[–] Abstract

Gene drives may be capable of addressing ecological problems by altering entire populations of wild organisms, but their use has remained largely theoretical due to technical constraints. Here we consider the potential for RNA-guided gene drives based on the CRISPR nuclease Cas9 to serve as a general method for spreading altered traits through wild populations over many generations. We detail likely capabilities, discuss limitations, and provide novel precautionary strategies to control the spread of gene drives and reverse genomic changes. The ability to edit populations of sexual species would offer substantial benefits to humanity and the environment. For example, RNA-guided gene drives could potentially prevent the spread of disease, support agriculture by reversing pesticide and herbicide resistance in insects and weeds, and control damaging invasive species. However, the possibility of unwanted ecological effects and near-certainty of spread across political borders demand careful assessment of each potential application. We call for thoughtful, inclusive, and well-informed public discussions to explore the responsible use of this currently theoretical technology.

[–] Comments

Downloads:

Article Figures

Reference tools:

DOWNLOAD OPEN

Categories & tags

Feature article | Ecology | Genes and chromosomes

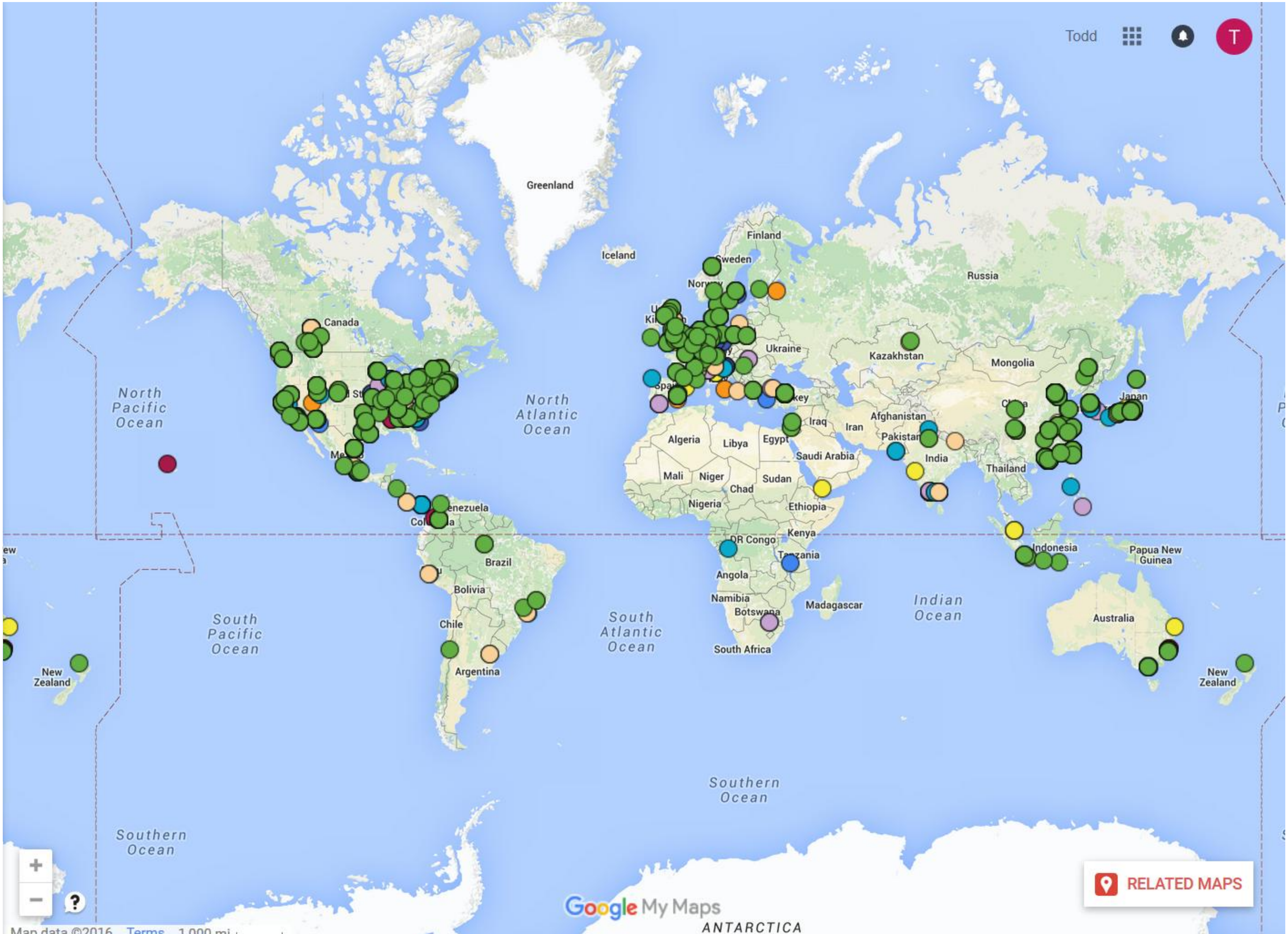
Sign up for *eLife* alerts

type your email address...

SIGN UP

cient conversion in individuals expressing Cas9 only in the germ line, males and females derived from transgenic females, which are expected to have drive component molecules in the egg, produce progeny with a high frequency of mutations in the targeted genome sequence, resulting in near-Mendelian inheritance ratios

An. stephensi is both an established and emerging malaria vector. It is estimated to be responsible for ~12% of all transmission in India, mostly in urban settings, accounting for a total of ~106,000 clinical cases in 2014 (3, 16–18), and also may be responsible for recent epidemic outbreaks in Africa (19). Laboratory strains of *An.*


Todd
T
Greenland
Iceland
Finland
Sweden
Russia
Canada
Ukraine
Kazakhstan
Mongolia
North Pacific Ocean
North Atlantic Ocean
Japan
Iraq
Iran
Afghanistan
Pakistan
Algeria
Libya
Egypt
Saudi Arabia
India
Thailand
Mali
Niger
Sudan
Chad
Nigeria
Ethiopia
Kenya
DR Congo
Indonesia
Papua New Guinea
Brazil
Angola
Bolivia
Namibia
Madagascar
Indian Ocean
Chile
South Pacific Ocean
South Atlantic Ocean
Australia
South Africa
Argentina
New Zealand
Southern Ocean
Southern Ocean
RELATED MAPS
Google My Maps
ANTARCTICA
Map data ©2016 Terms 1,000 mi

Synthetic Biology
based on standard parts

Community Labs – Science is for EVERYONE

Home Updates 47 Backers 8,433 Comments 860 San Francisco, CA Technology

Funded! This project was successfully funded on June 7, 2013.

8,433
backers

$484,013
pledged of $65,000 goal

0
seconds to go

Project by
Antony Evans
San Francisco, CA

First created · **22 backed**

Antony Evans 1132 friends

glowingplant.com

See full bio | Contact me

Share 982 Tweet Embed

Create GLOWING PLANTS using synthetic biology and Genome Compiler's software - the first step in creating sustainable natural lighting

Pledge $5 or more

426 backers

You'll get a 2"x3" sticker showing the

DIY CRISPR Kits, Learn Modern Science By Doing

San Francisco, United States   Technology

Story | Updates 7 | Comments 4 | Backers 226 | Gallery 1

1.4k
Tweet
Embed
Link
Follow

If you had access to modern synthetic biology tools, what would you create?

#science #diy #biohacking

$60,884 USD
total funds raised

InDemand
Original campaign was 333% funded on December 8, 2015

$6 USD

Biohacker Stickers

Our cool Biohacker logo, Stickers that say "Create Something Beautiful" and "BioHack the Planet" for you to stick anywhere(we recommend most places except for faces of friends).

12 out of 500 claimed
Estimated delivery: March 2016
Ships Worldwide

GET THIS PERK

experiment   Discover   How It Works   Sign up or Register

Finding a Cure for Batten Disease

By Charlotte And Gwenyth Gray Foundation

Backed by Justin A Derow, Elvira Safiulina, Emily R Hulce, Kena Feaman, E L Dolan, Jennifer Berg, Stuart Fitts, Hannah Stroh, Kory Kawaguchi, David Smith, Jennifer L. Paskow, Carmen Martinez, Karen Stern, Jesse Shane C Erwin, Robert W Simmons, and 17963 other backers

$1,551,932

Pledged

155% Funded   **$2,000,000** Next Goal   **31** Days Left

Back This Project

All donations to the Charlotte and Gwenyth Gray Foundation are tax-deductible.

? How does this work?

The Charlotte and Gwenyth Gray Foundation | Medicine | Neuroscience | Tax Deductible

Gene Drives in the context of CBD

- AHTEG met September 2015
- SBSTTA meeting April 2016
- COP/MOP December 2016
- Other treaties (ENMOD)?

PLOS | ONE

RESEARCH ARTICLE

Large-Scale Range Collapse of Hawaiian Forest Birds under Climate Change and the Need 21st Century Conservation Options

Lucas B. Fortini[1,2]*, Adam E. Vorsino[3], Fred A. Amidon[3], Eben H. Paxton[1], James D. Jacobi[1]

1 U.S. Geological Survey, Pacific Island Ecosystems Research Center, Honolulu, Hawaii, United States of America, **2** Pacific Islands Climate Change Cooperative, Honolulu, Hawaii, United States of America, **3** U.S. Fish & Wildlife Service, Strategic Habitat Conservation Division, Pacific Islands Office, Honolulu, Hawaii, United States of America

* lfortini@usgs.gov

CrossMark click for updates

Citation: Fortini LB, Vorsino AE, Amidon FA, Paxton EH, Jacobi JD (2015) Large-Scale Range Collapse of Hawaiian Forest Birds under Climate Change and the Need 21st Century Conservation Options. PLoS ONE 10(10): e0140389. doi:10.1371/journal.pone.0140389

Editor: Mariana M. P. B. Fuentes, Florida State University, UNITED STATES

Received: May 5, 2015

Accepted: September 24, 2015

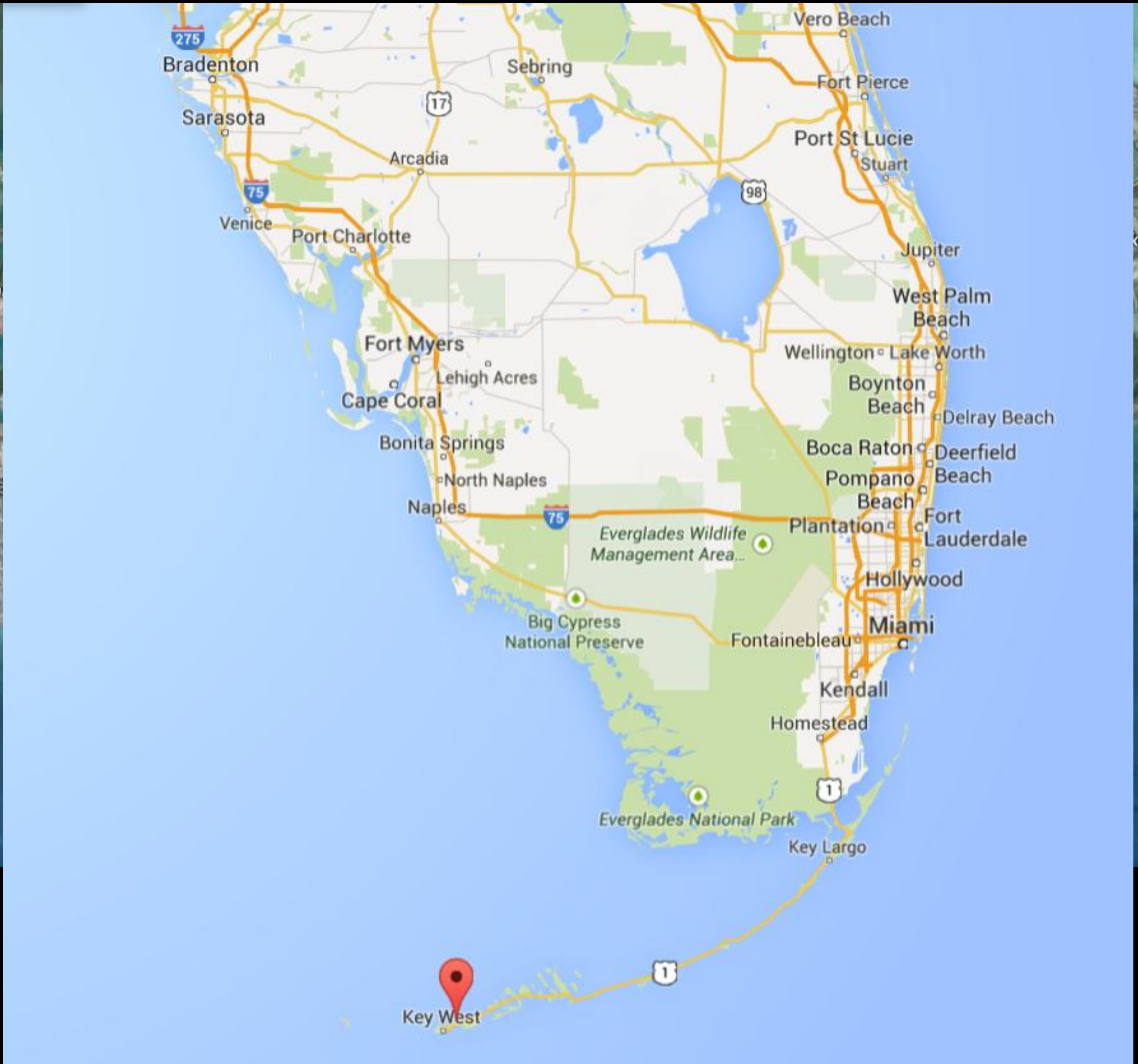
Published: October 28, 2015

Data Availability Statement: Species location, climate predictor datasets and related R scripts are available at www.sciencebase.gov, the data portal for U.S. Department of the Interior scientific efforts. Information resides at http://dx.doi.org/10.5066/

Abstract

Hawaiian forest birds serve as an ideal group to explore the extent of climate change impacts on at-risk species. Avian malaria constrains many remaining Hawaiian forest bird species to high elevations where temperatures are too cool for malaria's life cycle and its principal mosquito vector. The impact of climate change on Hawaiian forest birds has been a recent focus of Hawaiian conservation biology, and has centered on the links between climate and avian malaria. To elucidate the differential impacts of projected climate shifts on species with known varying niches, disease resistance and tolerance, we use a comprehensive database of species sightings, regional climate projections and ensemble distribution models to project distribution shifts for all Hawaiian forest bird species. We illustrate that, under a likely scenario of continued disease-driven distribution limitation, all 10 species with highly reliable models (mostly narrow-ranged, single-island endemics) are expected to lose >50% of their range by 2100. Of those, three are expected to lose all range and three others are expected to lose >90% of their range. Projected range loss was smaller for several of the more widespread species; however improved data and models are necessary to refine future projections. Like other at-risk species, Hawaiian forest birds have specific habitat requirements that limit the possibility of range expansion for most species, as projected expansion is frequently in areas where forest habitat is presently not available (such as recent lava flows). Given the large projected range losses for all species, protecting high elevation forest alone is not an adequate long-term strategy for many species under climate change. We describe the types of additional conservation actions practitioners will likely need to consider, while providing results to help with such considerations.

Dengue (Zika) Control



Oxitec Solution for Dengue (Zika)?

- Until 2009, no reports of Dengue since 1934
  - 2009 – 22 people; 2010 – 66 cases in Florida
  - 136 cases in Hawaii (as of Dec 4th)
- Aedes aegypti
  - Feed mostly on humans
  - Only females bite
- Key Haven Florida – 444 houses
- Petition – 149,000 signatures
- 1600 emails to mosquito control district

New poll on CRISPR (human)

- Which of the following statements best describes your feelings about this new technique for changing an organism's DNA?
  - Total Positive Development – 20%
  - Total Mixed both a positive and a negative development – 62%
  - Total Negative Development – 18%

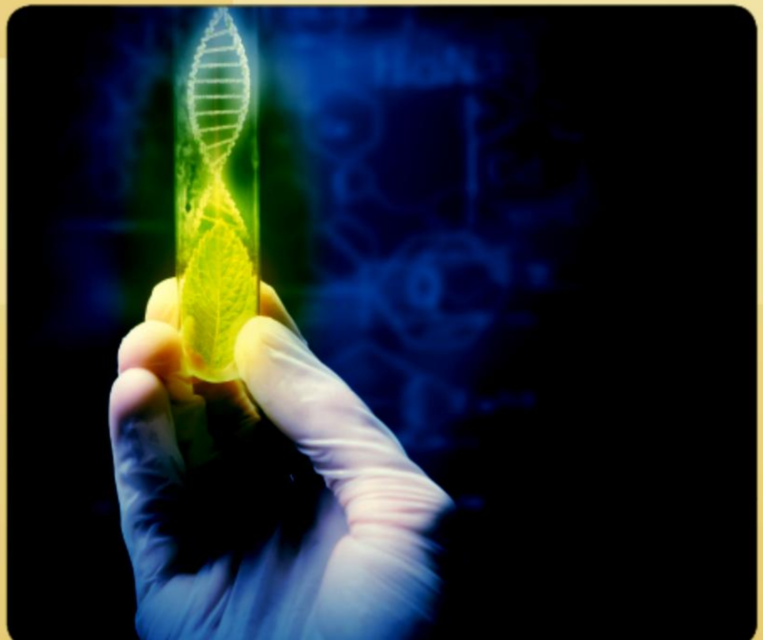
Moratorium?

- Please indicate below to what degree you favor or oppose temporarily stopping research using these techniques on humans until ethical guidelines and safety controls are in place.
  - **Total Favor – 45%**
  - **Total Oppose – 12%**
  - **Total Favor with Leaners – 72%**
  - **Total Oppose with Leaners – 28%**

THE DNA OF THE U.S. REGULATORY SYSTEM:

ARE WE GETTING IT RIGHT FOR SYNTHETIC BIOLOGY?

THE DNA OF THE U.S. REGULATORY SYSTEM: ARE WE GETTING IT RIGHT FOR SYNTHETIC BIOLOGY?



October 2015

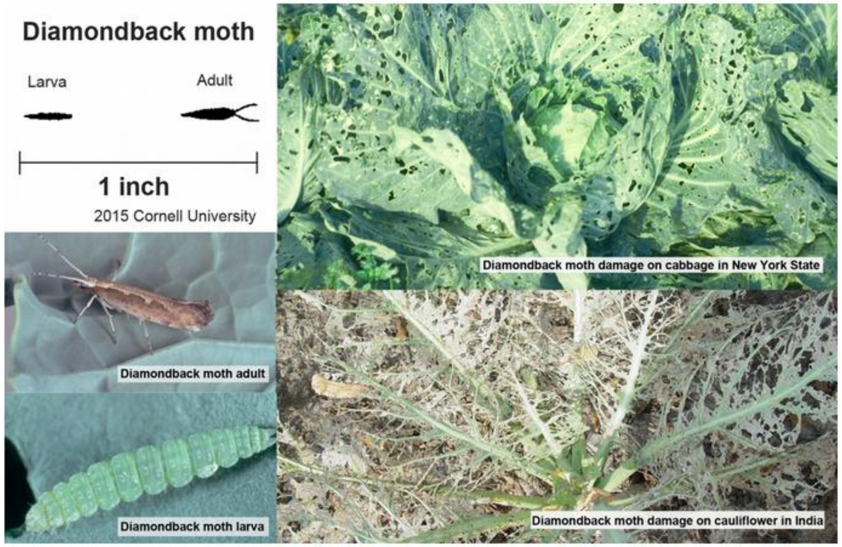
Synthetic BIOLOGY PROJECT

Wilson Center

BIOTECHNOLOGY, ENVIRONMENT, PEST MANAGEMENT

DIAMONDBACK MOTH PROJECT AT CORNELL UNIVERSITY IN 2015

JUNE 17, 2015 AMS5@CORNELL.EDU



What is a Diamondback Moth?

The diamondback moth (DBM) (*Plutella xylostella*) is the world's worst insect pest of brassica crops (cabbages, canola, broccoli,

Are our risk assessment frameworks keeping pace?

- Oxitec mosquito is at FDA/Oxitec moth is at USDA
- How will current risk assessments deal with CRISPR kits?
- Malaria/song birds…where does this fall?
- Time frame of assessment versus immediate threats to conservation and biodiversity?
- How do we deal with biology moving (moving risk)?
  - Local to State to National to International?

New plans are possible?

- Past models will take us only so far…may need new ones; ones which include the public (indigenous knowledge) in risk assessments
- Risk assessment needs to incorporate ecological time scales, both in terms of assessing risk but also risk of inaction (in relation to CBD issues)
- U.N. could establish an ecological risk research station (ELA type reservation)?
- Establish a coordinated research strategy that co-funds ecological risk research (too avoid duplication and recognizing limited research funds)
- Recognize that traditional governance mechanisms may not reach all the actors participating in the field

vig·i·lan·te

/, vijəˈlan(t)ē /

noun: vigilante; plural noun: vigilantes

a member of a self-appointed group of citizens who undertake law enforcement in their community without legal authority, typically because the legal agencies are thought to be inadequate.

ENVIRONMENTAL LAW • INSTITUTE®

2016 Invasive Species Webinar Series

Gene Editing: A Next Generation Tool for Invasive Species Management?

Thursday, February 18, 2016 • 2:00pm – 4:00pm ET

Q & A Session

Questions for the panelists? Submit via the "Questions" box or raise your hand by clicking on the hand icon.

Please visit the event page (http://tinyurl.com/eligeneediting) for background materials and resources.

ENVIRONMENTAL LAW • INSTITUTE®

2016 Invasive Species Webinar Series

Gene Editing: A Next Generation Tool for Invasive Species Management?

Thursday, February 18, 2016 • 2:00pm – 4:00pm ET

Thank you for joining!

Please visit the event page (http://tinyurl.com/eligeneediting) for background materials and resources.