delivering bioscience solutions to global challenges

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Genome Editing and the Future of Farming

- 6th September 2016
- The Roslin Institute, Edinburgh, UK
- Free and open meeting

The meeting was convened to highlight how the latest advances in genetic technologies can be applied to improve crops and livestock

The meeting consisted of a series of talks and panel discussion sessions which examined the global scene and case studies from academia and industry. The opportunities and challenges in the field were discussed, especially the pressing global challenge of food security.

The event brought together people from academia, industry and regulatory bodies to discuss the emerging challenges, how best to inform future policy decisions and ensure that the potential socio-economic benefits of this research are realised.

Key Statistics

- 100-120 attendees
- Predominantly from the UK - speakers international
- 73 from academia
- 10 representatives from governmental bodies
- 28 from industry

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Session 1

Setting the global scene
Chair: Prof David Hume
The Roslin Institute

10:30 Reducing hunger and poverty by increasing agricultural productivity in a sustainable way

Prof Wayne Powell
Scotland's Rural College (SRUC)

11:00 Genome editing technology

Prof Bruce Whitelaw
The Roslin Institute

11:30 Opportunities to improve health, production and sustainability through applied gene editing

Dr Jonathan Lightner
Genus Plc

12:00 Lunch

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Session 2

Understanding the opportunities and challenges through case studies
Chair: Prof Helen Sang
The Roslin Institute

13:00 Genome editing in poultry: opportunities and impacts
Dr Tim Doran
Commonwealth Scientific and Industrial Research Organisation (CSIRO)

13:15 Genome editing to the rescue: sustainably feeding 10 billion human population
Dr Bhanu Telugu
University of Maryland

13:30 Improving milk for human consumption through genetic engineering technologies
Dr Goetz Laible
AgResearch

13:45 Mining tropical livestock diversity
Prof Steven Kemp
International Livestock Research Institute (ILRI)

14:00 Q&A

14:15 Coffee break

Tim Doran talked about GE in the avian industry particularly for vaccine production in eggs

Bhanu Telugu talked about GE for germline cells in pigs to accelerate the expansion of desirable traits

Goetz Laible talked about GE for improving cows milk to limit allergic reactions to it

Steven Kemp talked about GE as part of a set of approaches to improve livestock in developing countries

Session 3

Genome annotation issues and solutions (panel discussion)
Chair: Federica Di-Palma
The Earlham Institute

14:30

Challenges of genome editing with insufficient genome references

Dr Wes Warren
McDonnell Genome Institute, Washington University

FAANG - making animal genomes informative

Prof Alan Archibald
The Roslin Institute

The genetic architecture of economically important traits provides major challenges for the implementation of gene editing in livestock

Prof Dirk-Jan De Koning
Swedish University of Agricultural Sciences

Potential of promotion of alleles by genome editing to improve quantitative traits in livestock breeding programs

Prof John Hickey
The Roslin Institute

The last two sessions were panel discussions where the chair encouraged the delegates ask questions and participate in the discussion among panellists

The first focussed on the advances in genome science

- Genome editing for genetic improvement does not just require accurate genome sequences, it relies on the identification of the locations of genes and regulatory elements in a genome, as well as knowledge about their function

To make sure that that these genome editing technologies reach their full potential the consensus from the session was that funding large collaborative projects is vital

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Session 4

Risk assessments, implementation strategies and engagement (panel discussion)
Chair: Prof James Smith
The University of Edinburgh

EFSA's role in the risk assessment of genetically modified organisms
Dr Elisabeth Waigmann
Genetically Modified Organisms, EFSA

Genome editing in context
Dr Laura Bellingan
Royal Society of Biology

15:30

Gene editing: breeding or GMO
Dr Alison Van Eenennaam
UC Davis

Genome editing: the promise and the politics
Prof Huw Jones
IBERS

Final session focussed on the regulation and public dialogue around genome editing

Various issues were raised but it was clear that there is a disconnect between the technology and the policy frameworks that regulate it in different countries

- For example at present, it is unclear whether genome edited animals will be regulated as GMOs

The consensus was that concerns about regulation are already stalling the investment, development and application the technology

The discussion also covered the importance of public acceptance of the technology

- There was agreement from the panel that now is a key time for researchers to get involved and contribute to framing the public debate

Conclusion?

Bruce Whitelaw closed the meeting

- Reinforced the message that genome editing is a game changing technology

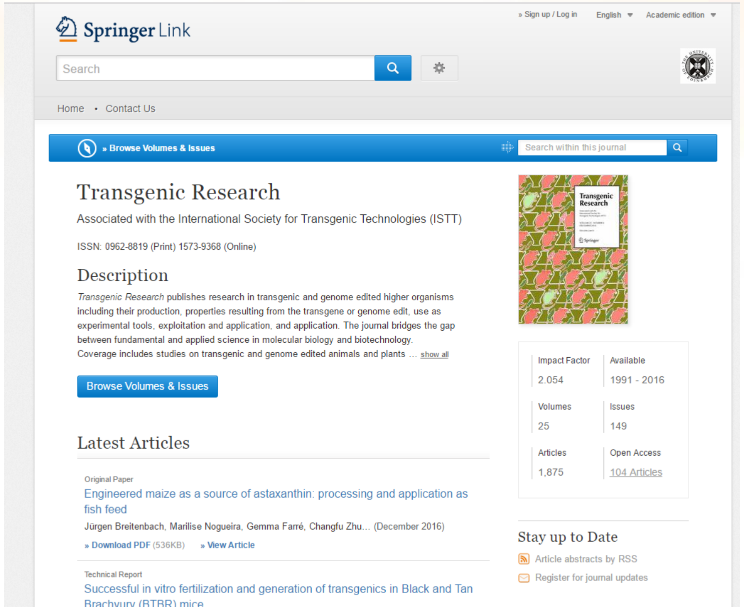
The 3 S's Society, Systems (both regulatory and funding), and Science need to work together to ensure that the technology can be developed and applied to achieve the sustainable productivity gains that global agriculture requires

A networking dinner for the speakers which was supported by CTLGH, The Centre for Livestock Genetics and Health.

The feedback from participants was good with 100% of forms received giving it a positive overall evaluation.

Meeting outputs

- Meeting report submitted to the journal of Transgenic Research
- Articles from speakers hosted on NIB Journal site



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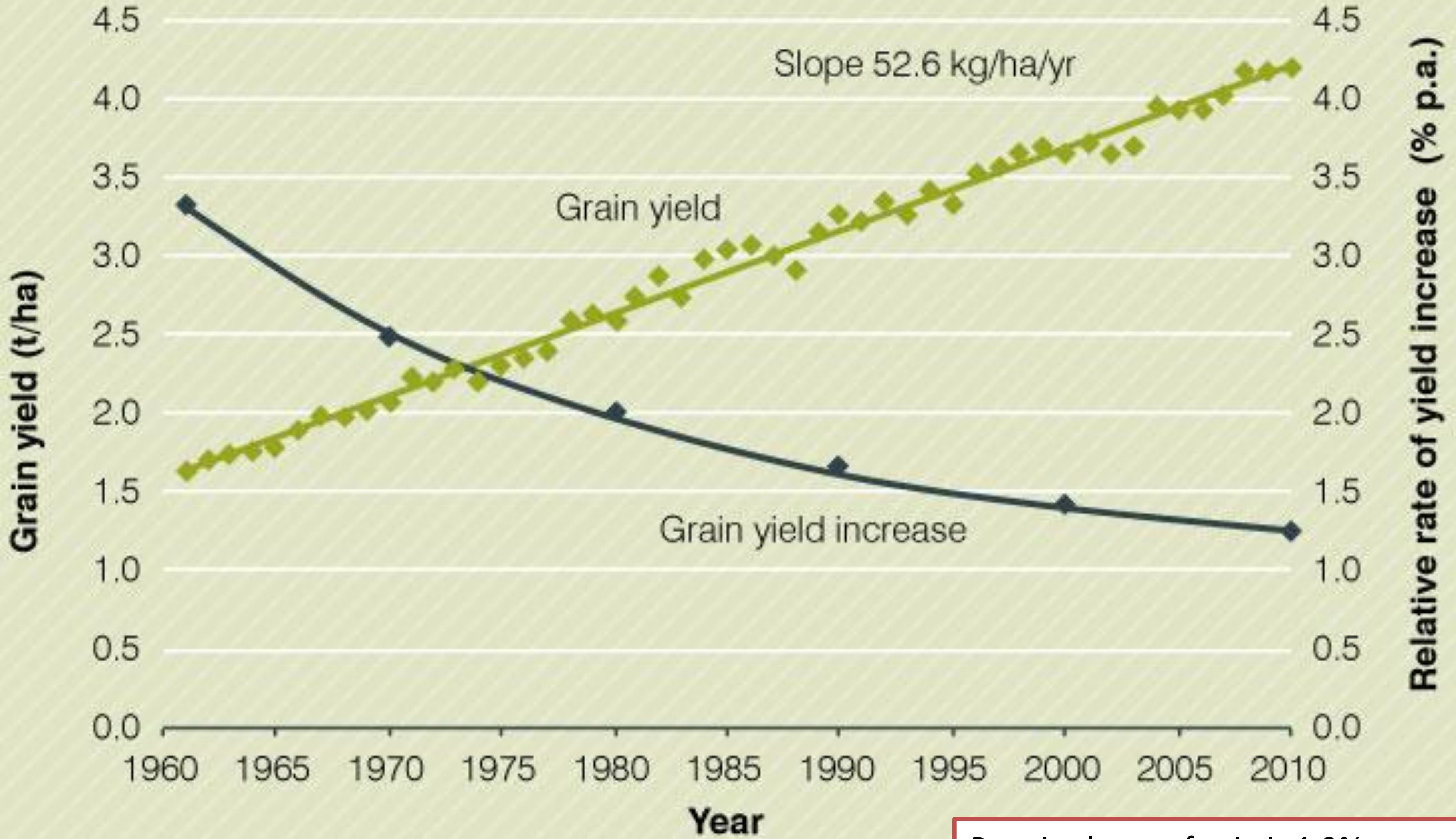
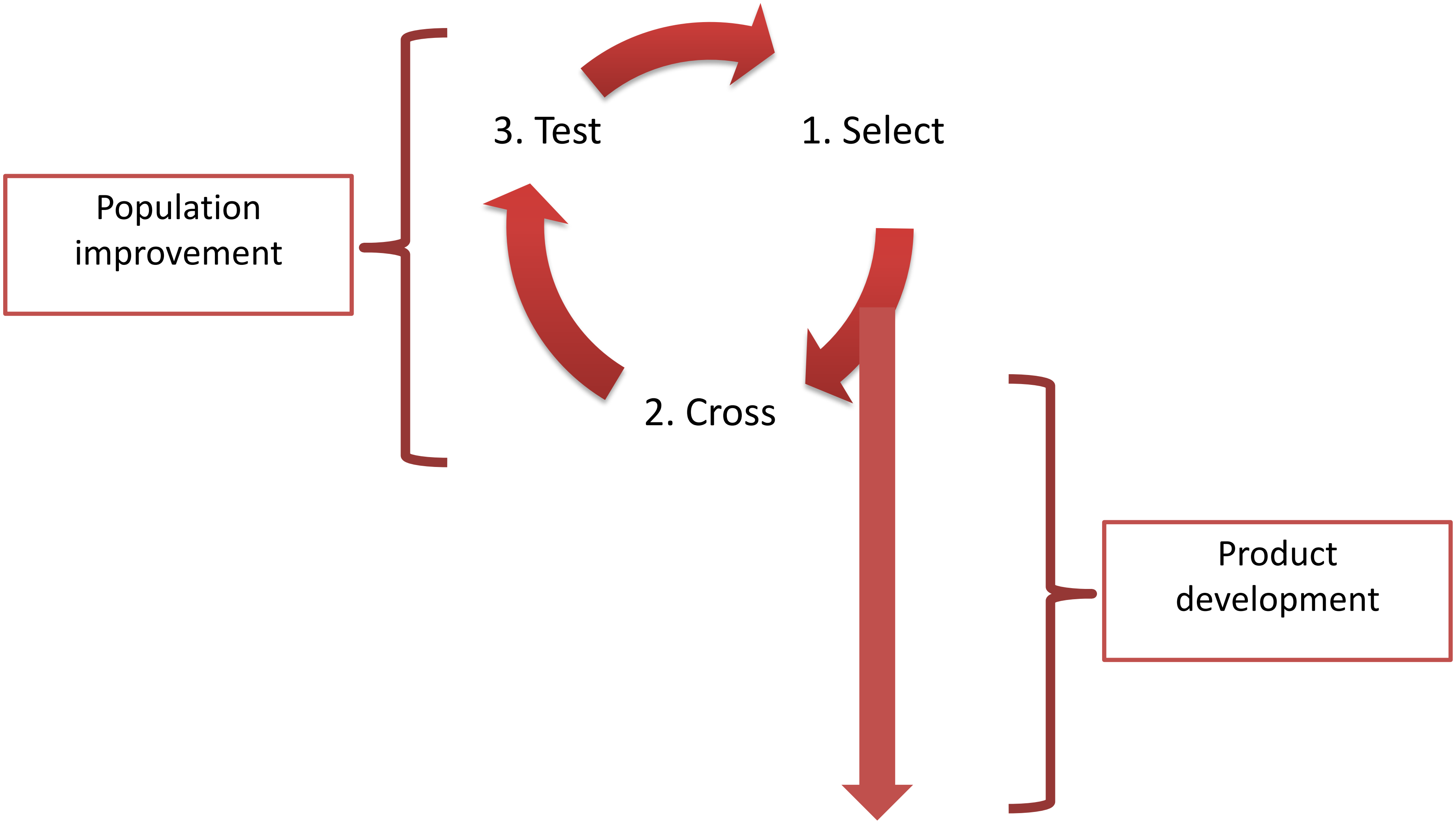
Global yield of wheat, rice and maize and the relative annual yield gain from 1960 to 2013



Required rate of gain is 1.3% p.a.

An idealized breeding scheme



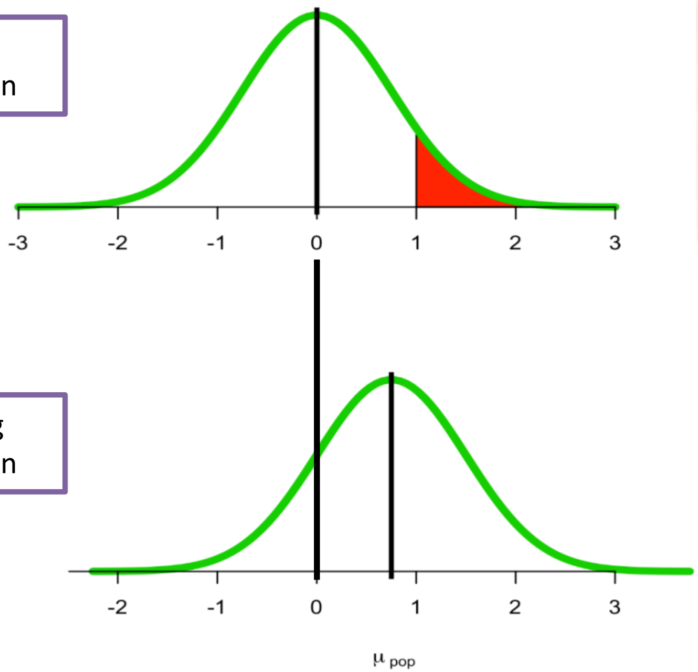
Slide adapted from Ian Mackay

Response to Selection

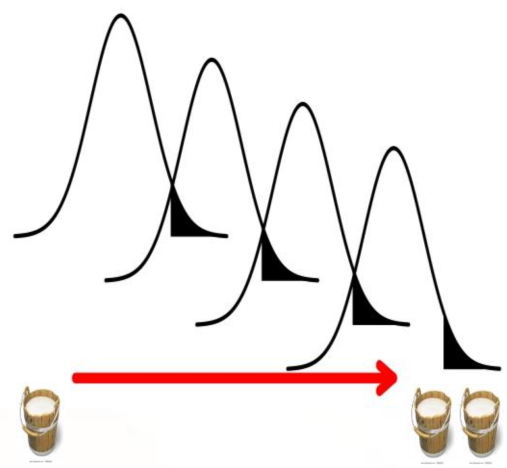
Difference between the mean of 2 generations

Parental Generation

Offspring Generation



Gain over many generations



Genomic selection is the current gold stand method for estimating breeding values

The breeders equation

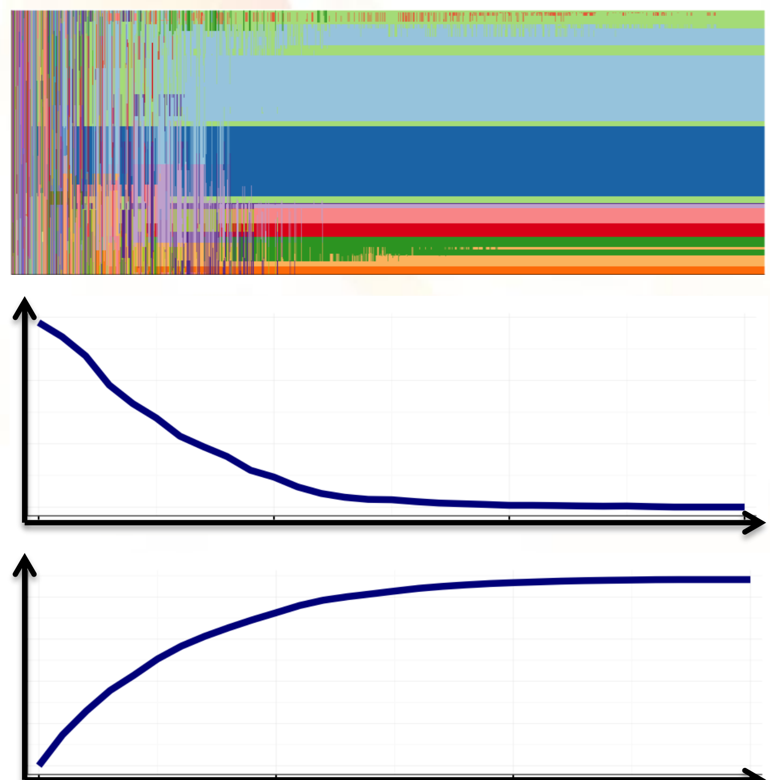
$$\text{Response} = \frac{\text{Accuracy} \times \text{Selection intensity} \times \text{Diversity}}{\text{Time}}$$

Time in generations

Diversity
(as haplotypes)

Diversity
(as $\sum 2pq\alpha^2$)

Genetic
gain
(Response)



Time in generations

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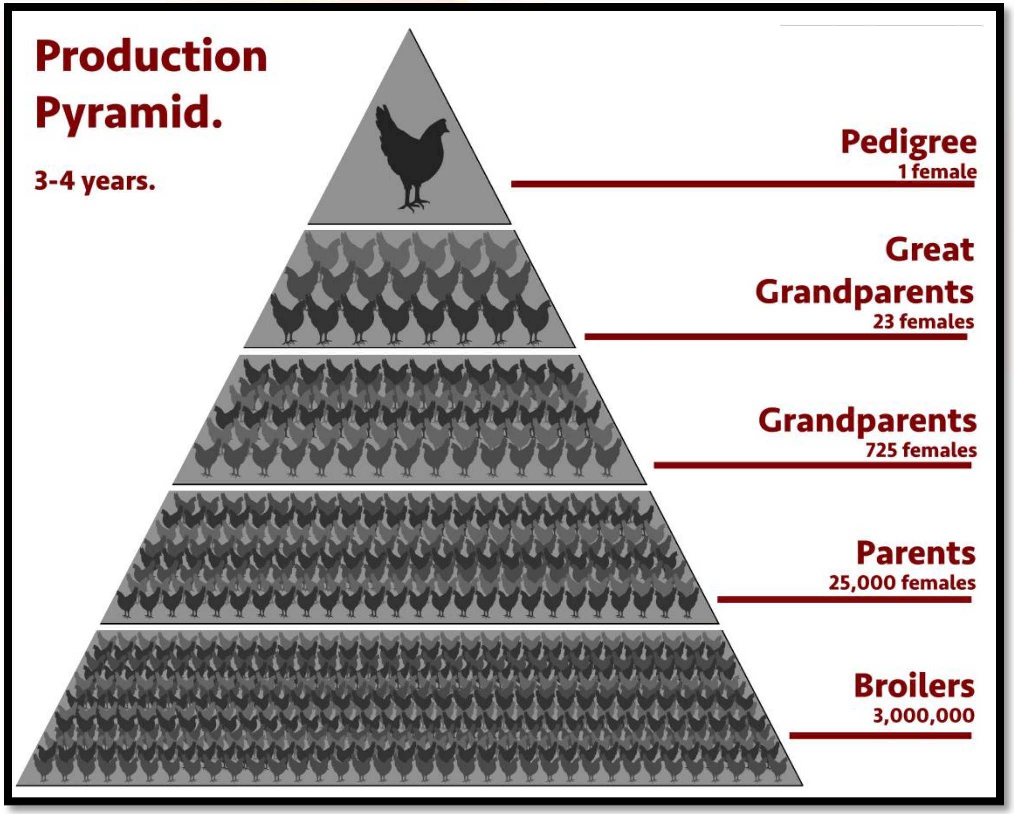
Global dissemination of genetic gain

Breeding supply chains are organized into layers:

– Nucleus	100’s to 1000’s of parents
– Multiplier	100,000’s of individuals
– Production	Millions of individuals



3-4 years

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What has been achieved?

USDA genetic evaluation of US Holsteins is the GS poster child!!!

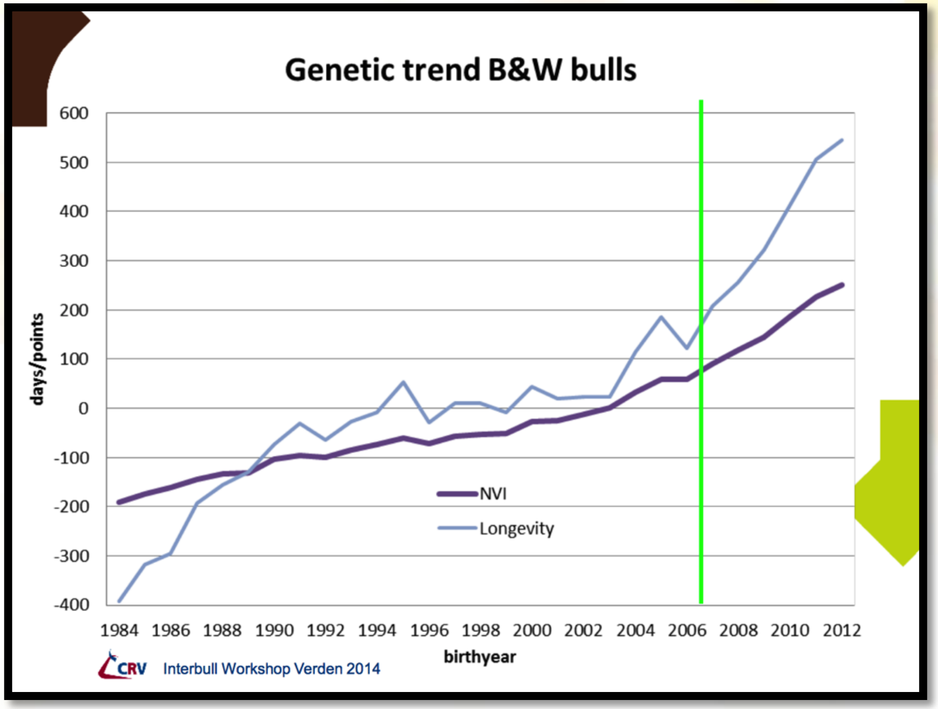
Method	Accuracy
Pedigree	0.51
Genomic	0.86

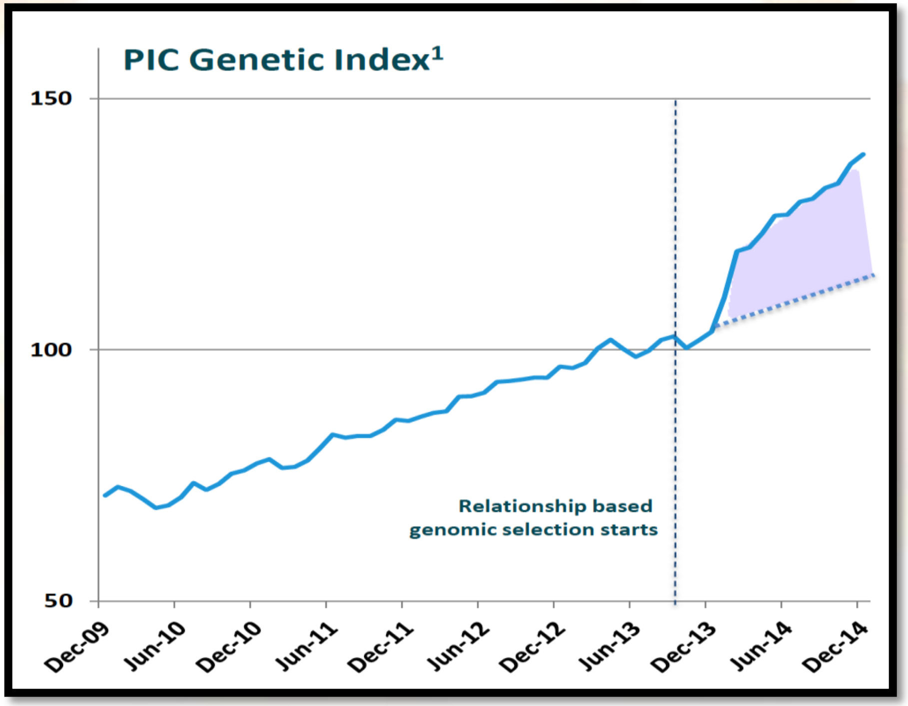
Courtesy of G. Wiggans

This can be achieved for ~$15 investment per candidate

Realized genetic gains from genomic selection

Slides courtesy of Gerben de Jong (CRV) and William Herring (PIC)



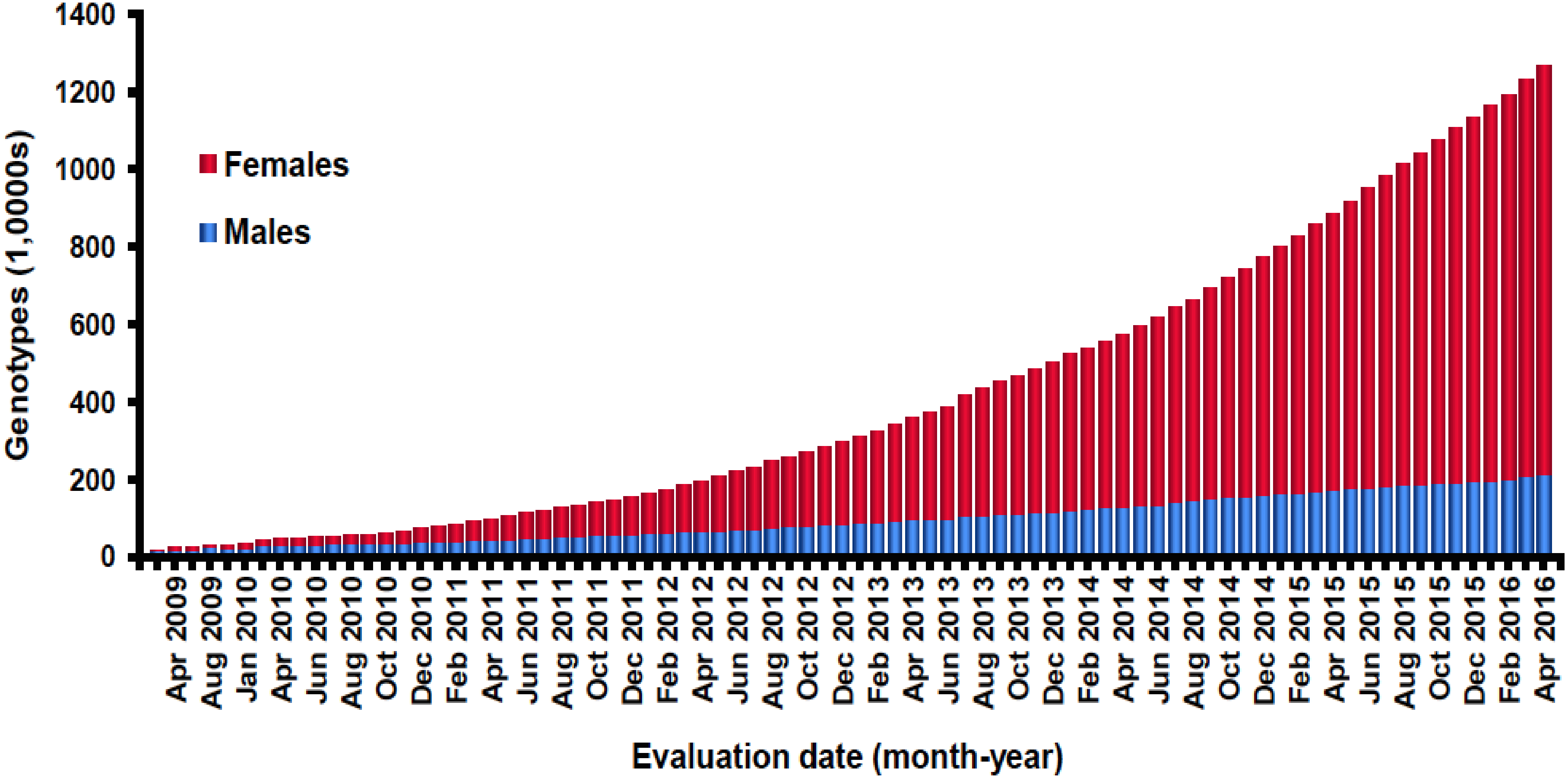


Gain 21 points/year (2000 to 2007)
Gain 34 points/year (2008 to 2012)
60% increase

$$\text{Response} = \frac{\text{Accuracy} \times \text{Selection intensity} \times \text{Diversity}}{\text{Time}}$$

Growth in genotyped animals in USDA evaluation

Courtesy of George Wiggans



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Genome editing

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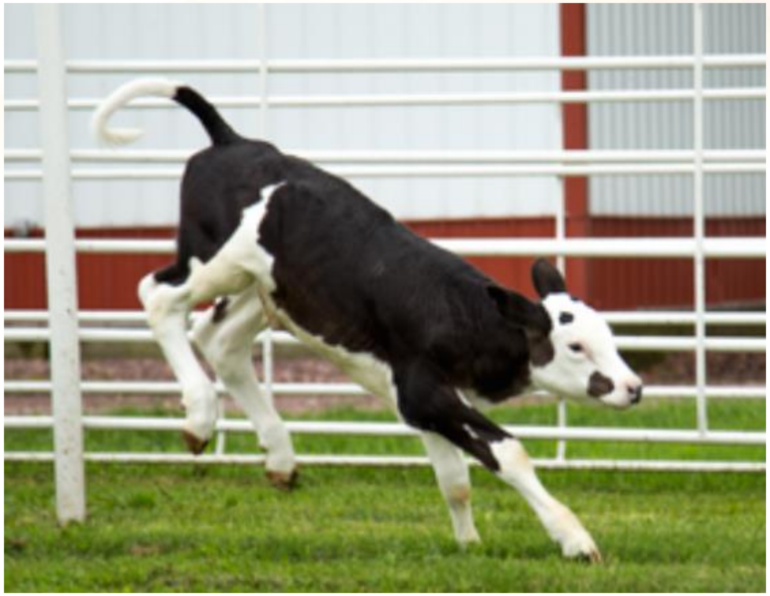
GE is the process of precise editing genome

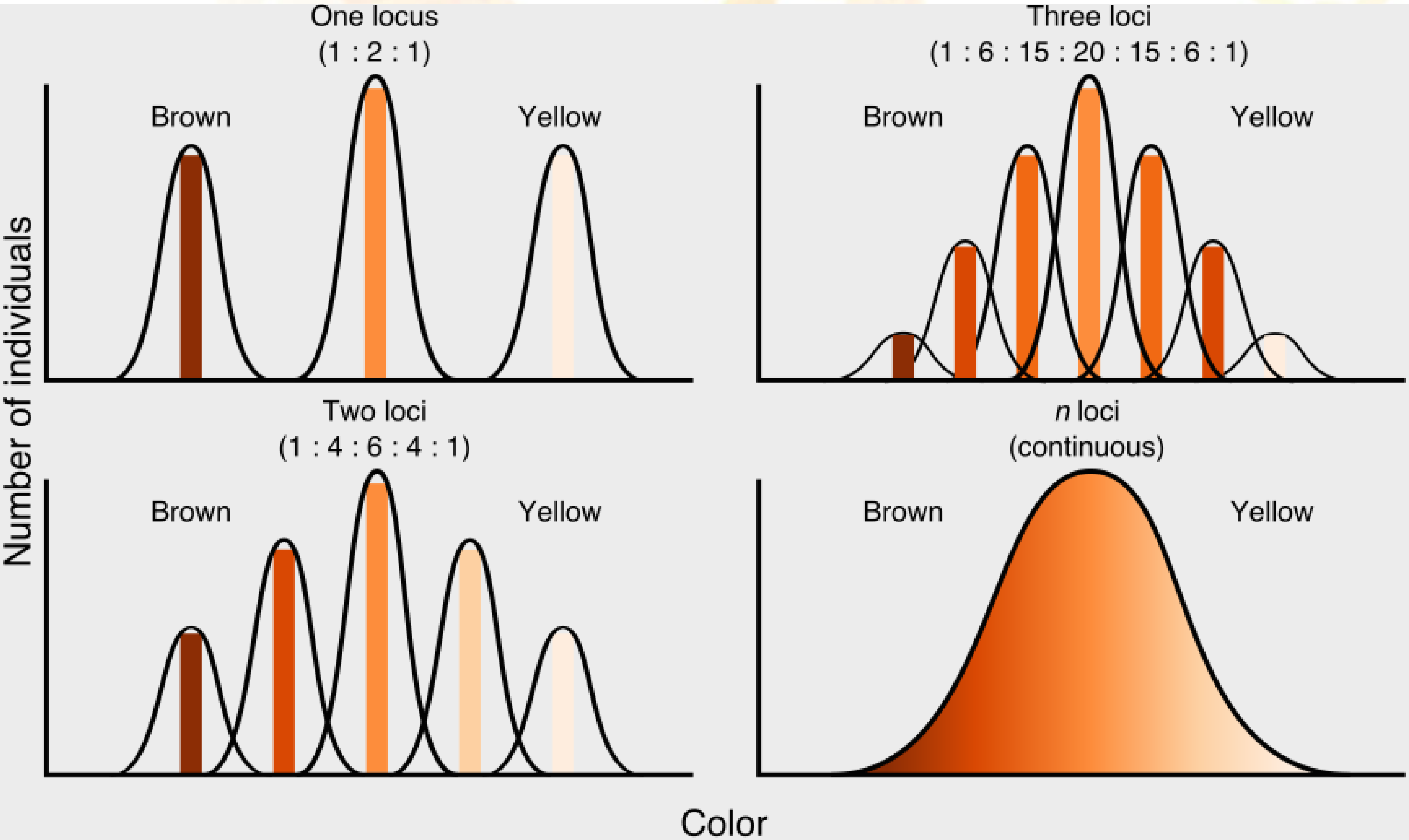
Nucleotides can be

- added
- deleted
- replaced

Examples!



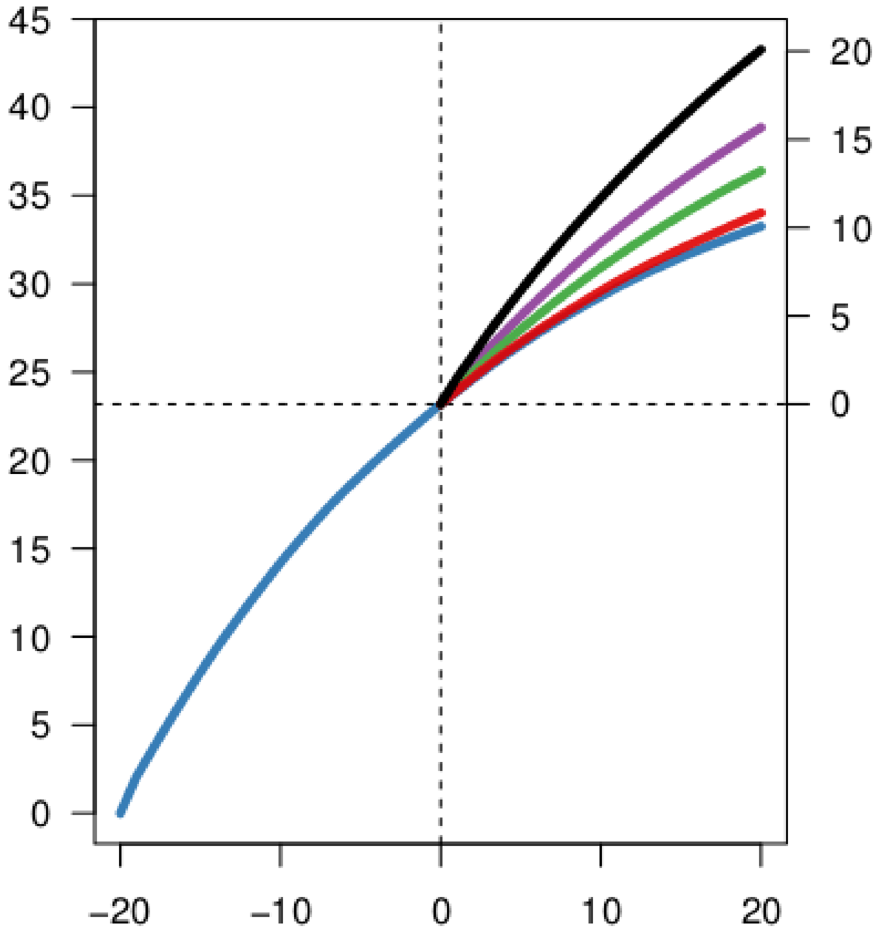
Hypothetical genetic architecture for coat color in cattle



Genetic gain

Editing all 25 selected bulls

Genetic Gain (since generation -20)



Genetic Gain (since generation 0)

Generations

20 edits
10 edits
5 edits
1 edit
No editing

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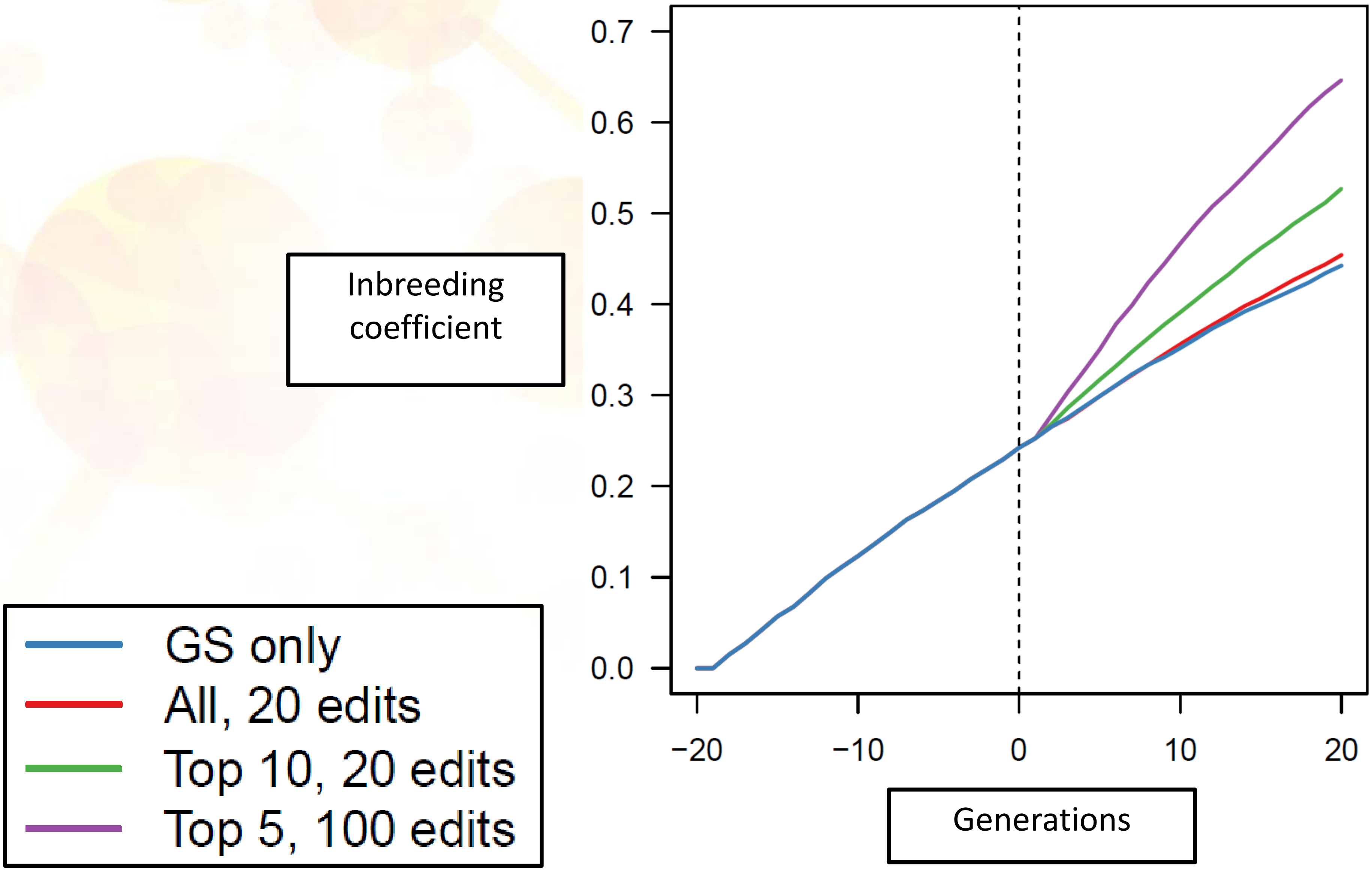
Inbreeding



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Final remarks

- Genome editing could work for quantitative traits
- Likely next steps
  - Short term = focus on disease traits
  - Medium term = fix up recessive deleterious mutations
  - Long term = PAGE for quantitative traits