CUPGRA

Cambridge University Potato Growers Research Association

32nd Annual Cambridge Potato Conference, 2021

Robinson College, Cambridge 14 & 15 December

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Exploring the future for potato production …innovation without constraint to research and development

David Baulcombe -Regius Professor of Botany Emeritus

Cambridge University

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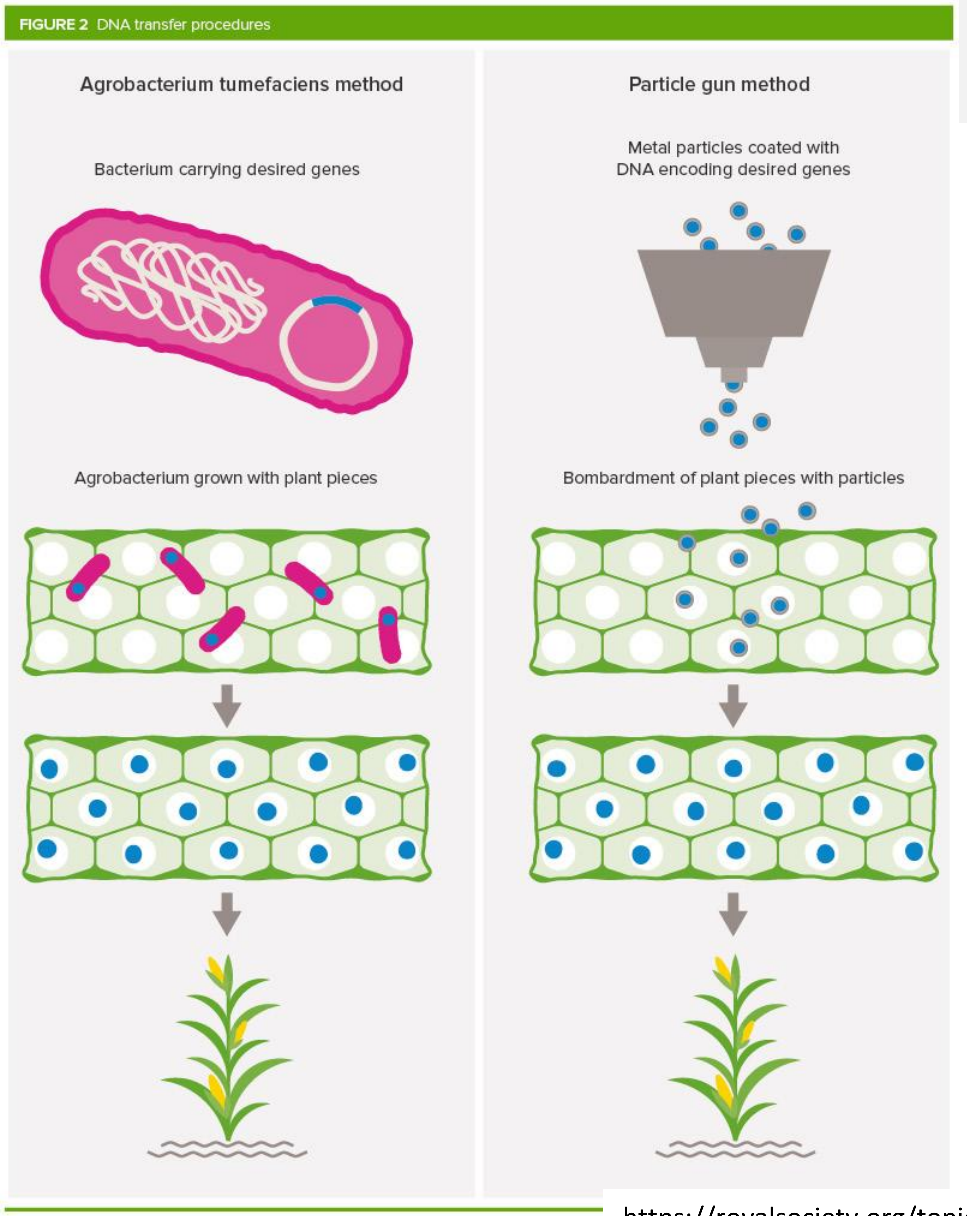
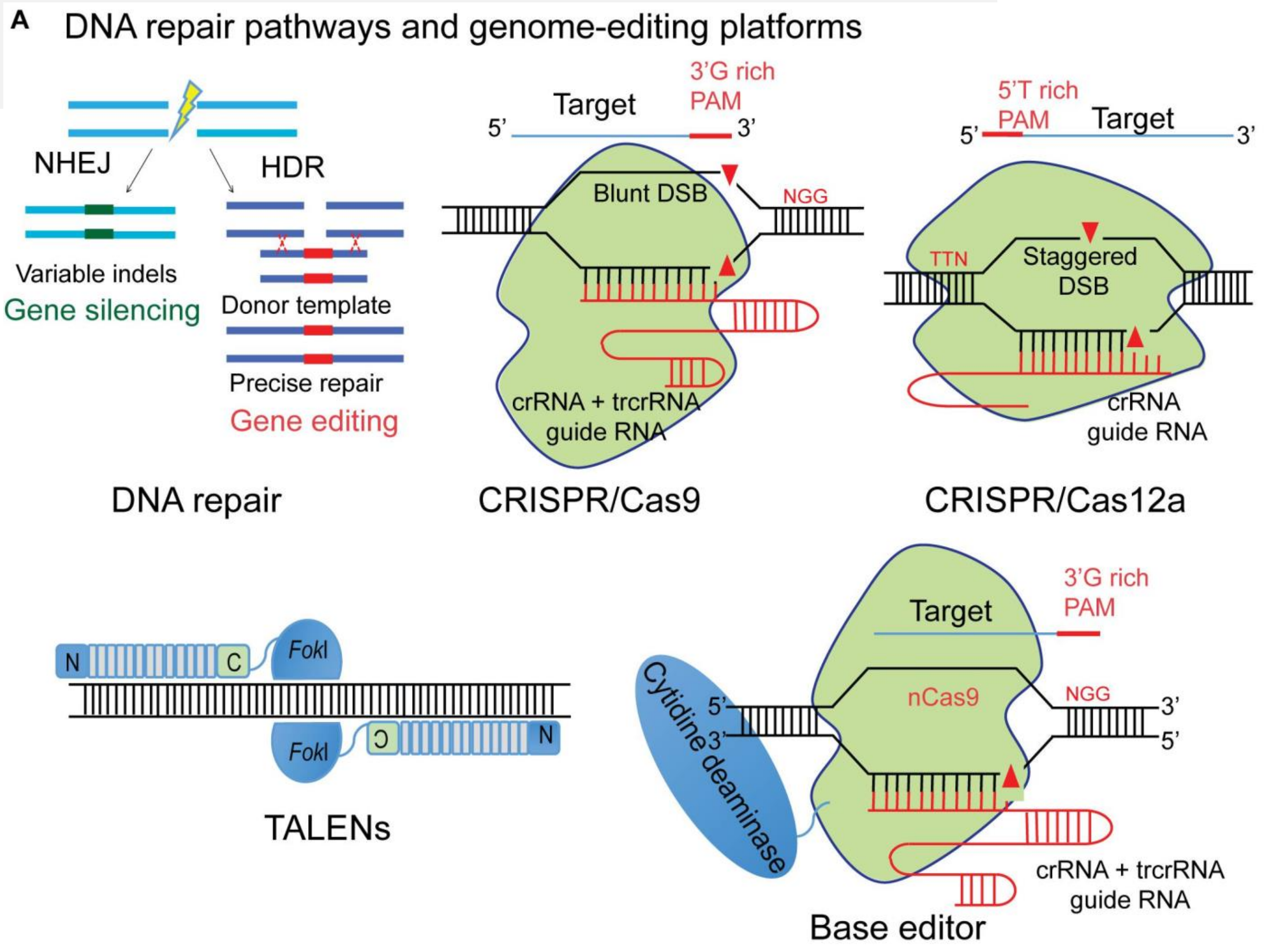
GM *vs* gene editing



https://royalsociety.org/topics-policy/projects/gm-plants/what-is-gm-and-how-is-it-done/

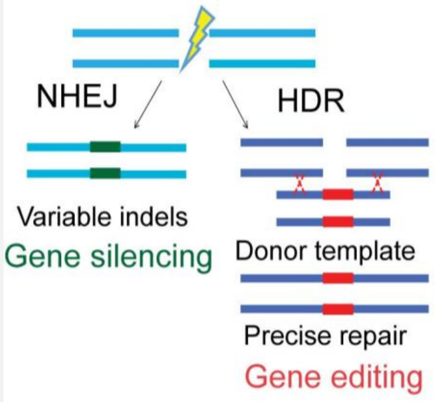


https://www.frontiersin.org/articles/10.3389/fpls.2018.01607/full

GM *vs* gene editing: potential applications

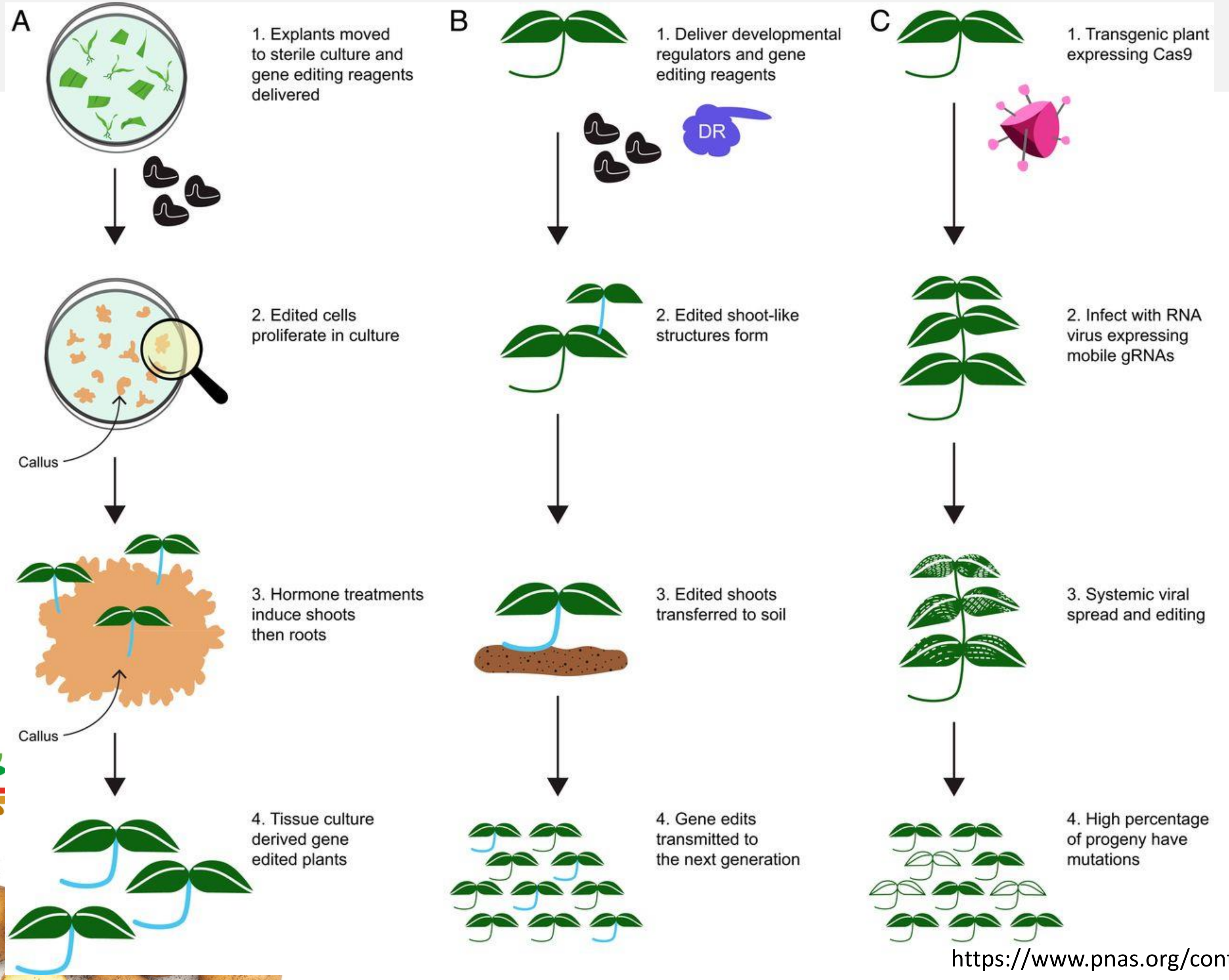
- Disease resistance including viruses and late blight
- Tuber starch quality
- Phosphate transport
- Herbicide tolerance
- Shoot morphogenesis
- Self incompatability (in diploids)
- Low acrylamide

- Regulatory approval
- Single gene traits
- Tissue culture and somaclonal variation
- Gene replacement not yet possible with GE



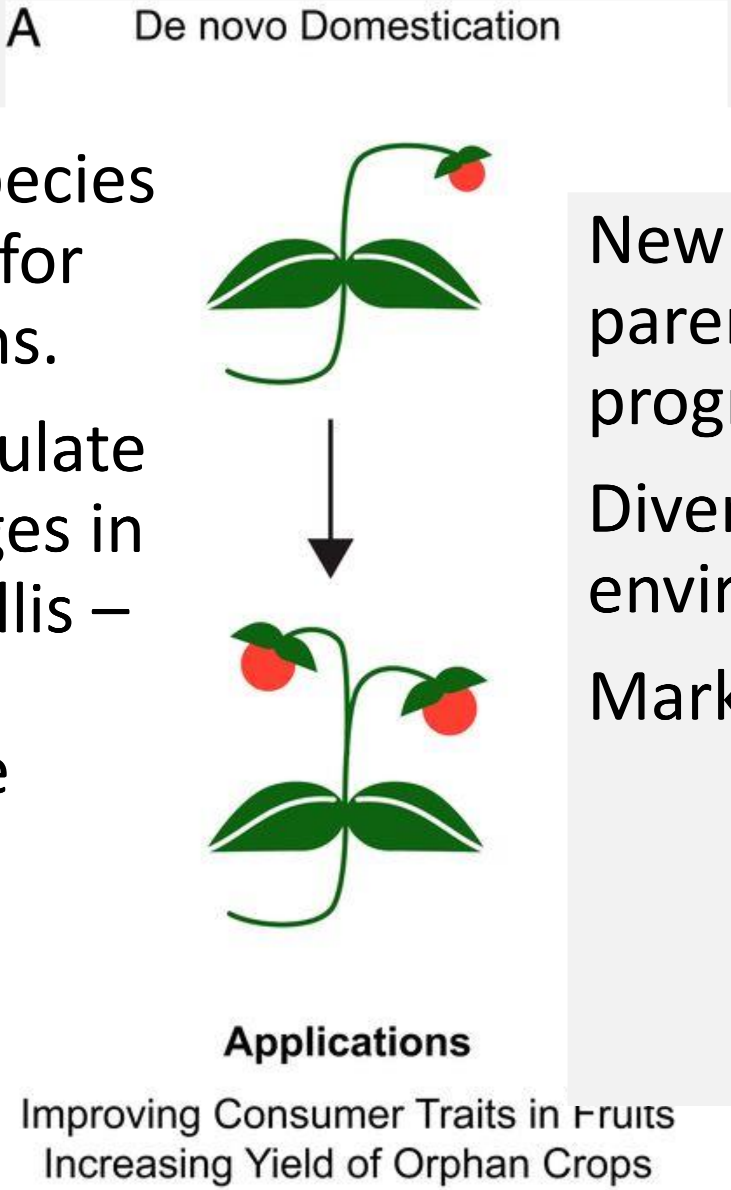
https://www.frontiersin.org/articles/10.3389/fpls.2018.01607/full

Constraints- making gene editing fit for purpose



https://www.pnas.org/content/118/22/e2004846117/tab-figures-data

GM/GE – grand challenge traits – de novo domestication



Domestication of wild species often involved selection for just one or two mutations.

Gene editing can recapitulate the domestication changes in orphan species eg Physallis – ground cherry, S. pimpinellifolium and rice

New crop species and new parents in breeding programmes

Diversity – good for environment, disease control

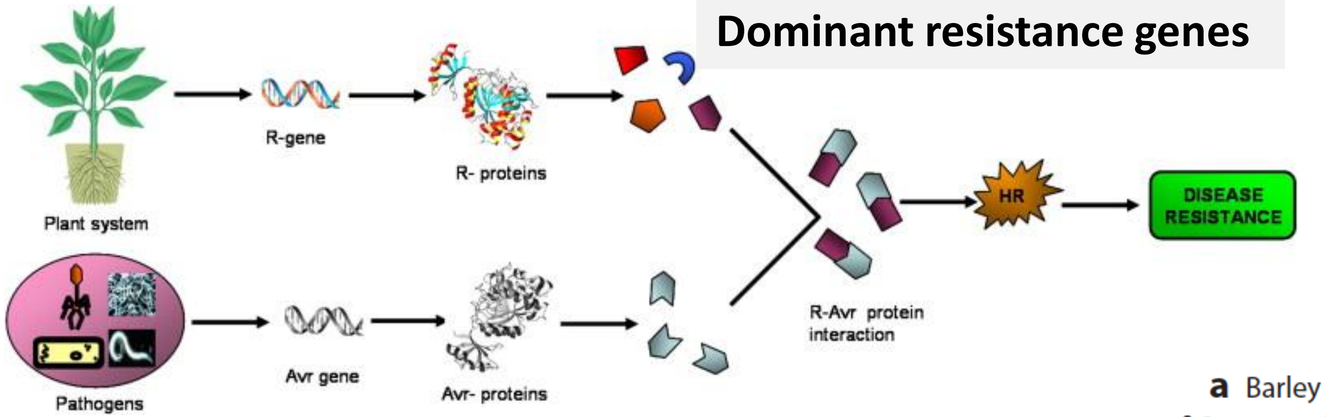
Market opportunities …….

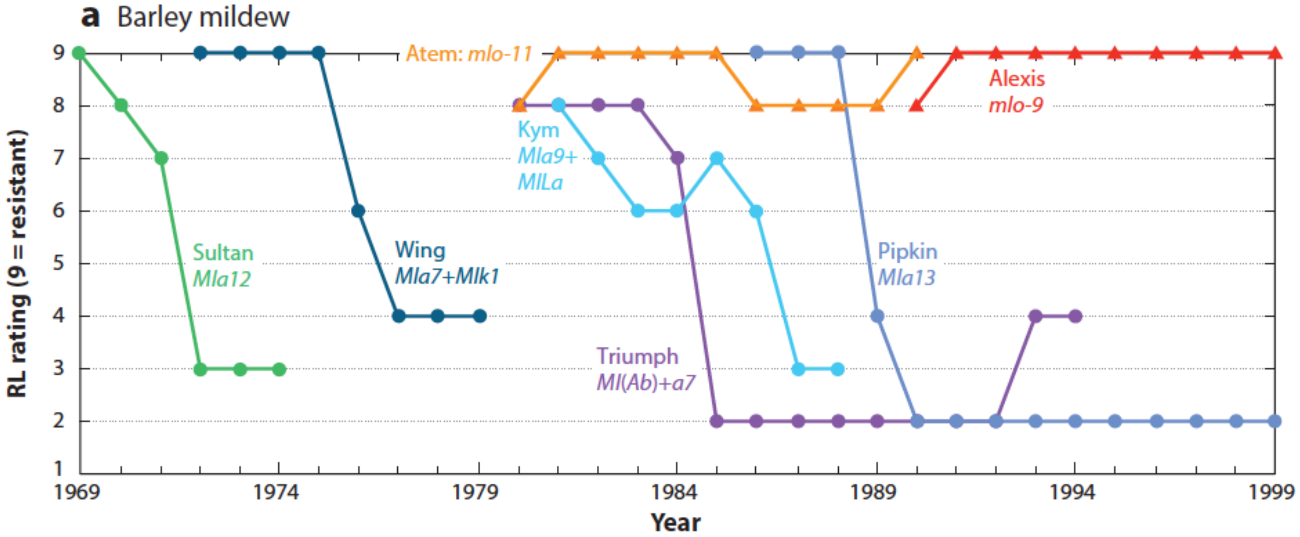
https://www.tasteatlas.com/most-popular-potatoes-in-south-america

https://www.pnas.org/content/118/22/e2004846117/tab-figures-data

GM/GE – grand challenge traits – disease protection

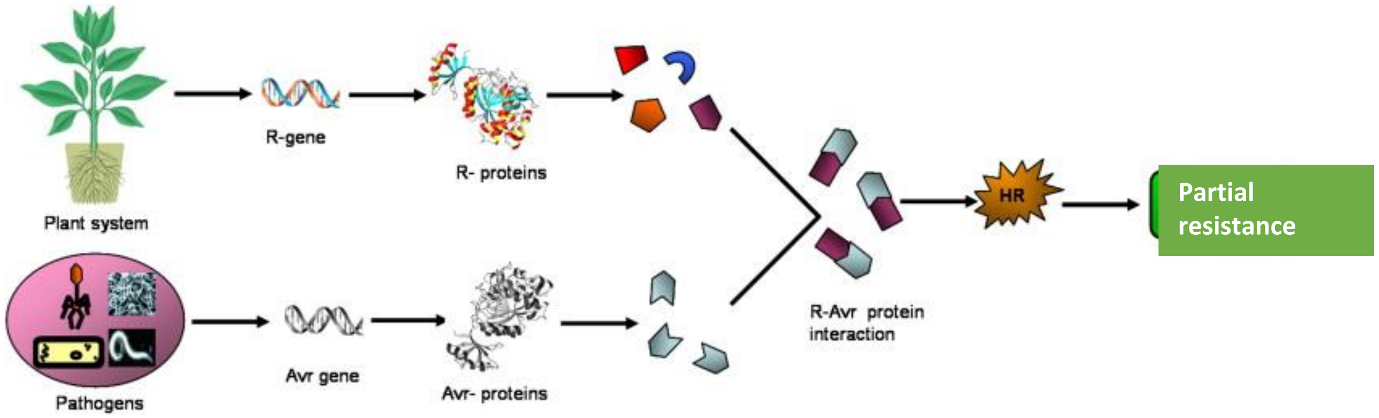
Dominant resistance genes

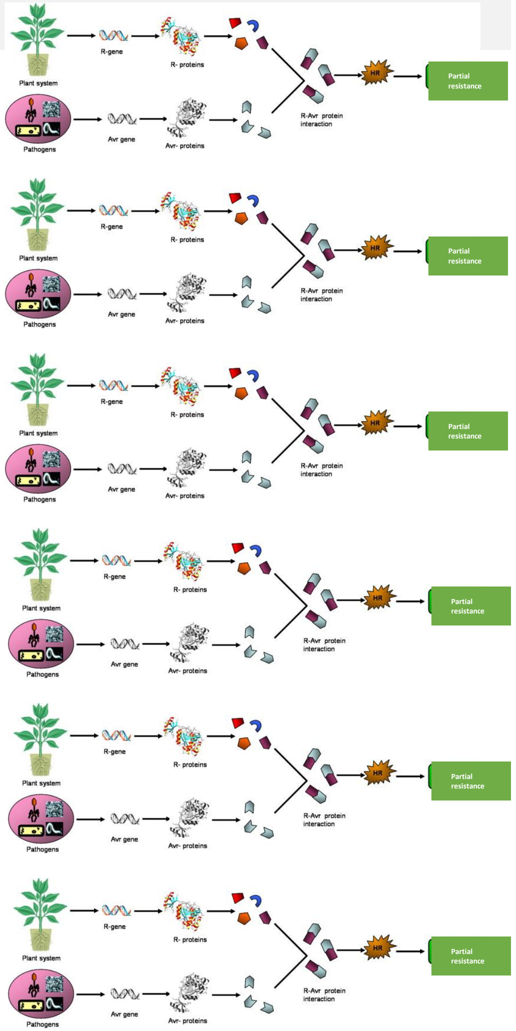




From: Brown JKM. 2015. Durable Resistance of Crops to Disease: A Darwinian Perspective. *Annu Rev Phytopathol* **53**: 513-539.

GM/GE – grand challenge traits – a Darwinian approach to disease protection



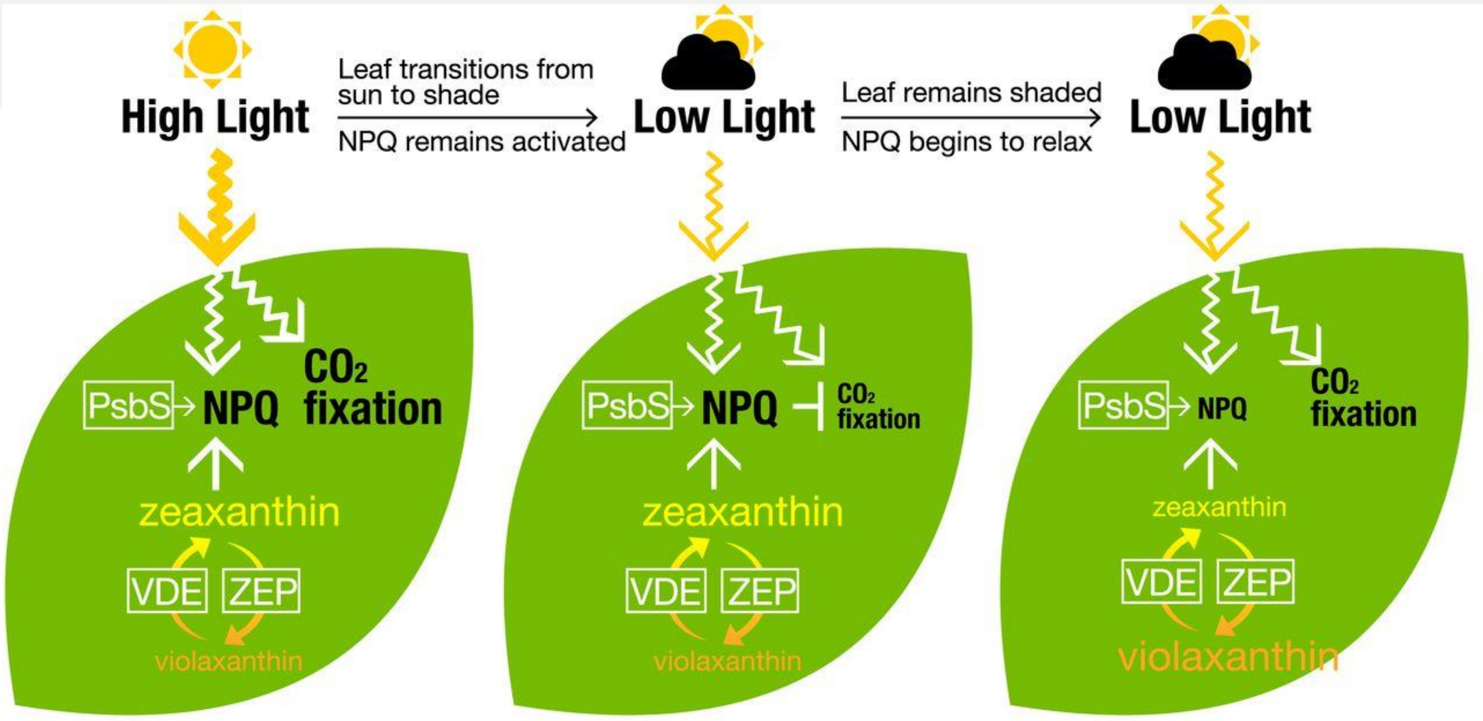


Small increases in number or expression level of multiple R genes could give broader spectrum and more durable resistance than breeding or GM/GE of few major genes

GM/GE – grand challenge traits – enhanced photosynthesis

nonphotochemical quenching of chlorophyll fluorescence (NPQ) limits photosynthetic efficiency in transition to low light

Speeding up NPQ relaxation gives greatly enhanced photosynthesis and huge increase in biomass that could be converted into enhanced tuber yield in potato



ZEP speeds up NPQ relaxation
VDE balances ZEP activity during NPQ induction
PsbS adjusts NPQ level to maintain WT amplitude

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GM/GE

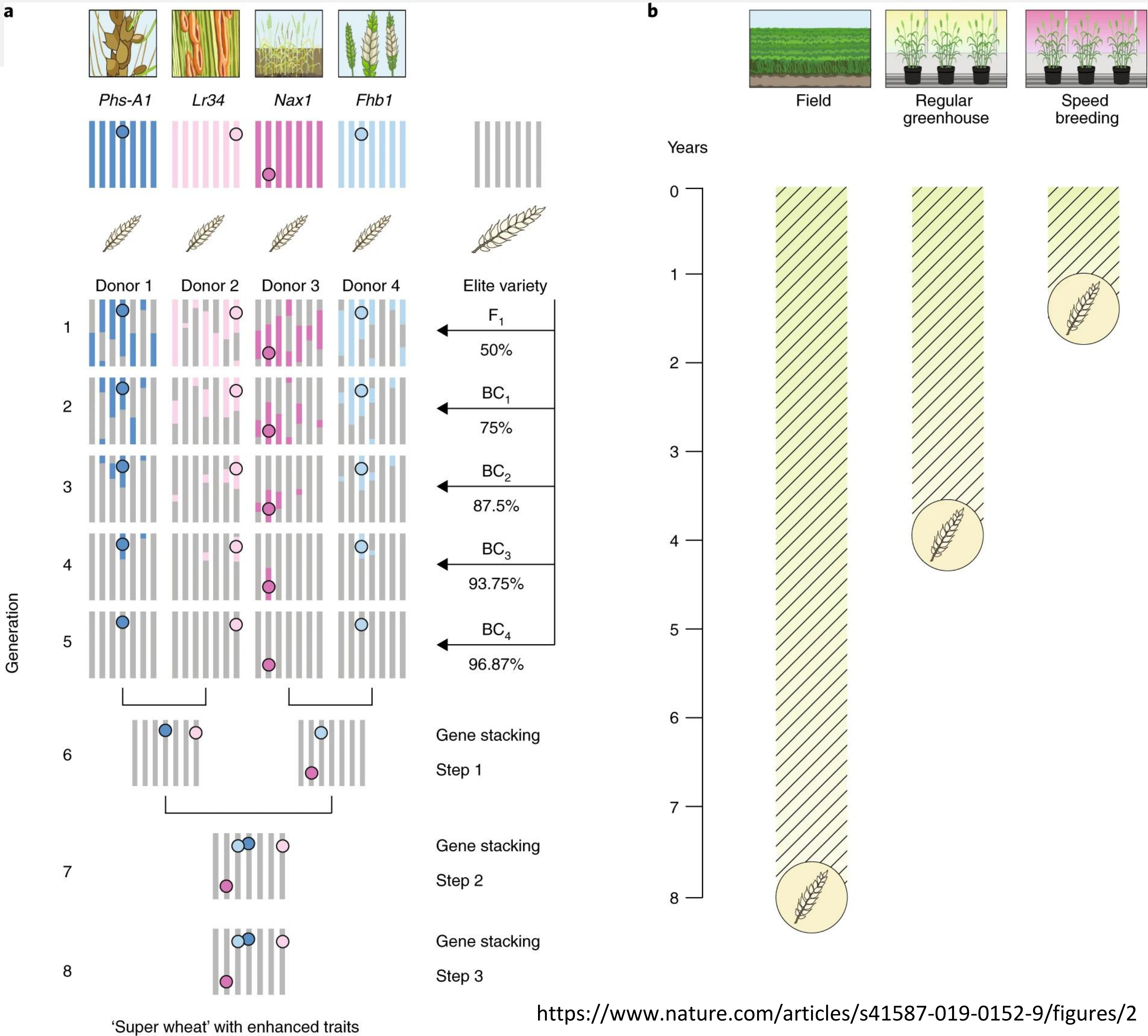
- Time/effort involved (even with improved technologies) – only few examples of single gene traits where there is benefit of these new breeding technologies over conventional approaches in most instances

- Big opportunities however with grand challenge traits (new crops, better photosynthesis, disease resistance + water and nutrient use efficiency

Accelerated agronomy – a lesson from (speed) breeding

Selection for traits based on marker presence rather than analysis of trait.

Removes lengthy testing of yield, stress tolerance etc

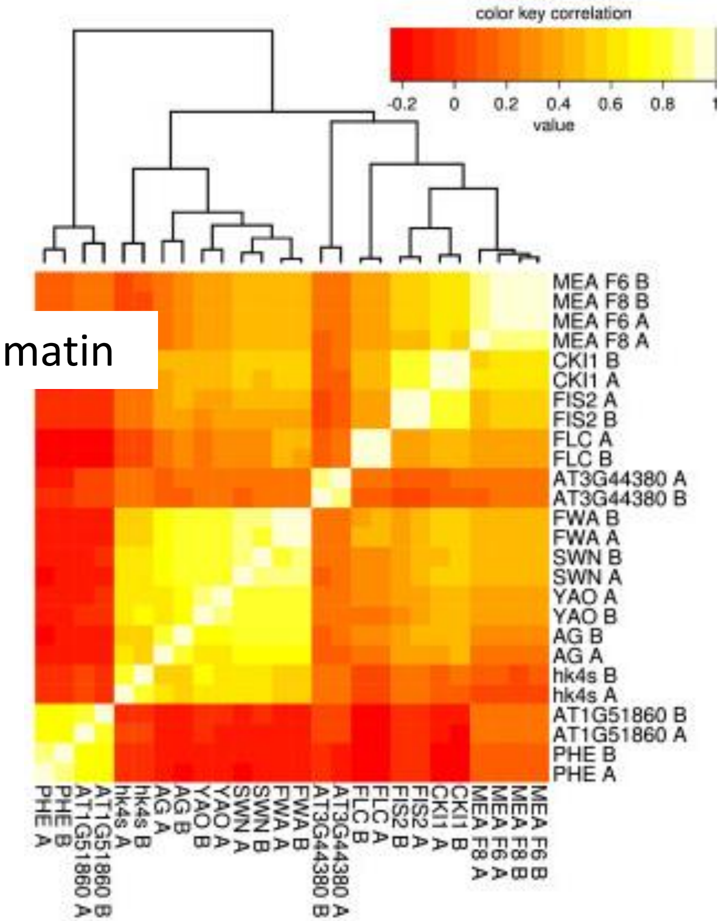


https://www.nature.com/articles/s41587-019-0152-9/figures/2

Gene expression and chromatin organisation patterns in young plant may be predictive of adult plant phenotype

The technology used for genome sequencing has been adapted to give genome-wide information about gene expression and chromatin organisation

Chromatin



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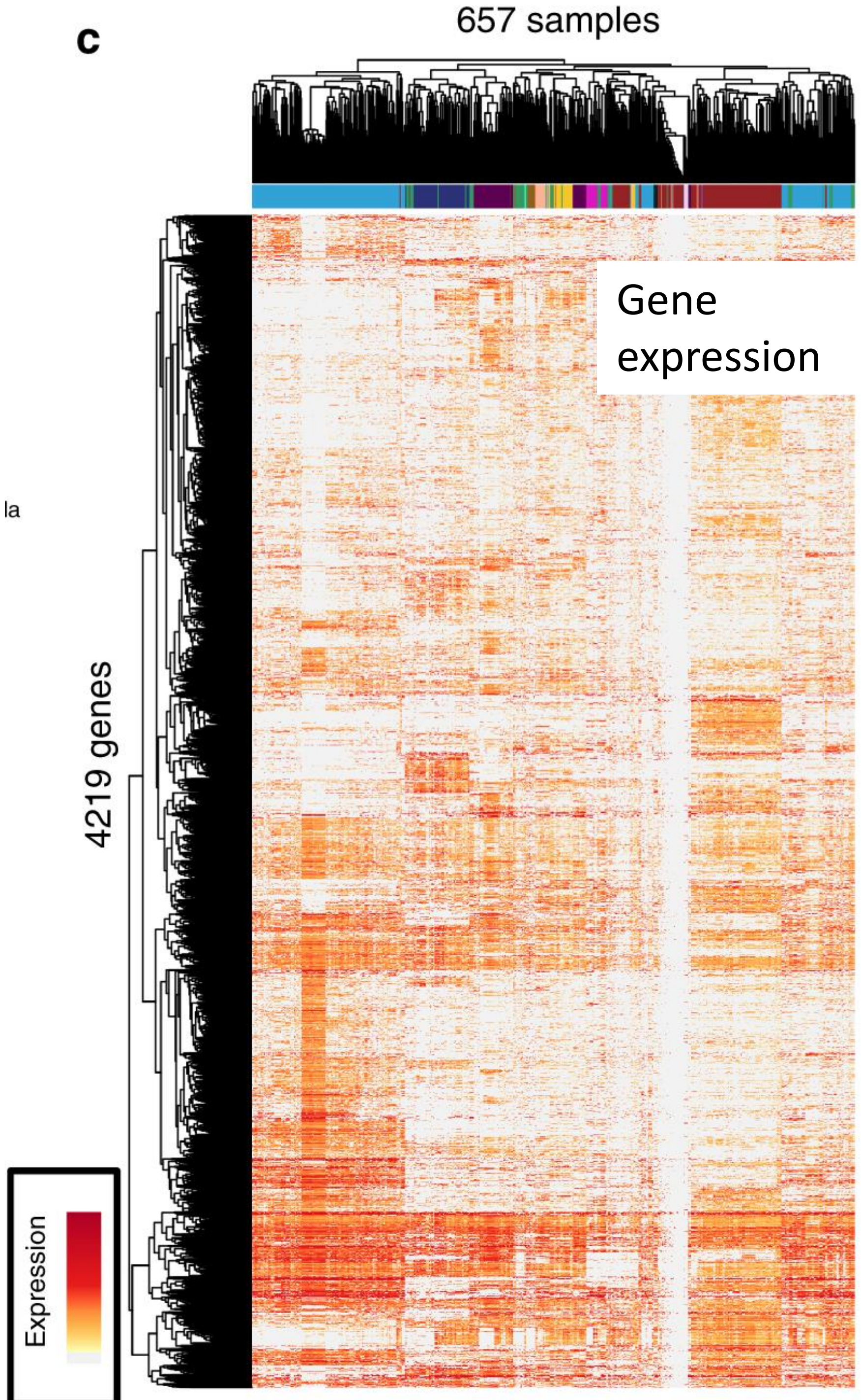
Gene expression



https://www.nature.com/articles/s41467-018-07436-y

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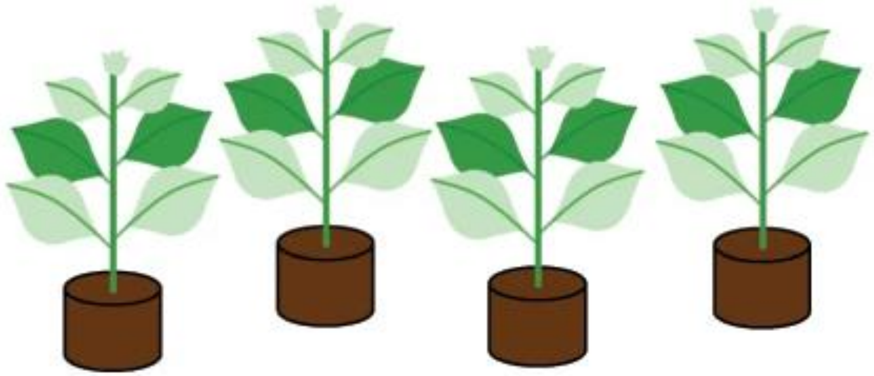
Speed agronomy or predictive GxExM



Grow genotypes with known field performance characteristics under standard conditions in growth chamber

Profile gene expression, chromatin organization, metabolomics etc

Grow replicate plants under different conditions and monitor E, M and phenotypic performance

AI and machine learning to correlate gene expression, chromatin organization, metabolomics profiles with E, M and performance

Refine with iterative cycles using different collections of plants under different conditions to derive predictive GxExM.

Towards the superspud…..

- Constraints so far are funding, regulation, technology and imagination