I'm Director of Cambridge Crop Research the part of NIAB that houses our research and capabilities in arable genetics, pathology, biotechnology, data science and some of our statutory work for Defra.

I'm going to talk to you a little about the opportunities for prebreeding in pulses and more broadly in legumes.

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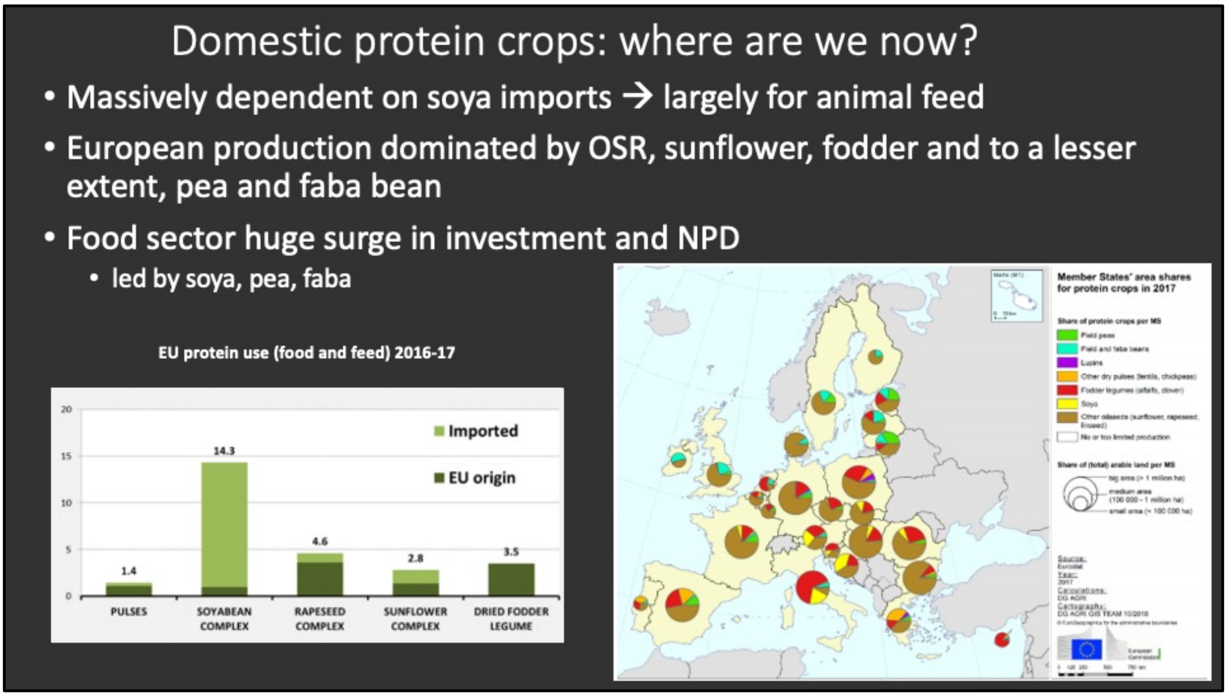

When considering pulse crops contribution to plant-based protein we must also look more widely to oilseeds, as many oilseeds have proteinaceous byproducts

Europe is dominated by soya imports, with only a small fraction of its plant protein needs being met by domestic production. In Europe we import around 32 million tonnes of soy each year in all of its different forms, about 1/10 of that coming to the UK.   Considering soy production in Europe alone we are around 1/10 self sufficient and production across the EU of all other protein and oil crops it is cumulatively less than soy imports.

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Self sufficiency in plant protein has often been highlighted by academic, government and industry sources; at the heart of the problem are several key challenges:
Firstly, the most versatile legume, soy is poorly adapted to most of Europe, but also other globally important protein crops, such as chickpea and lentils are not widely produced
Secondly, domestic sources of protein for animal feed, which drives the market are often not competitive with imported soy.
Of the legumes that we do have, weakness such as poor yield stability, problems with pest and disease resistance and a lack of sufficient margins, or in some cases (e.g. lupin) a guaranteed market all contribute to an overall lack of adoption and a lack of investment in genetics, when compared to wheat.

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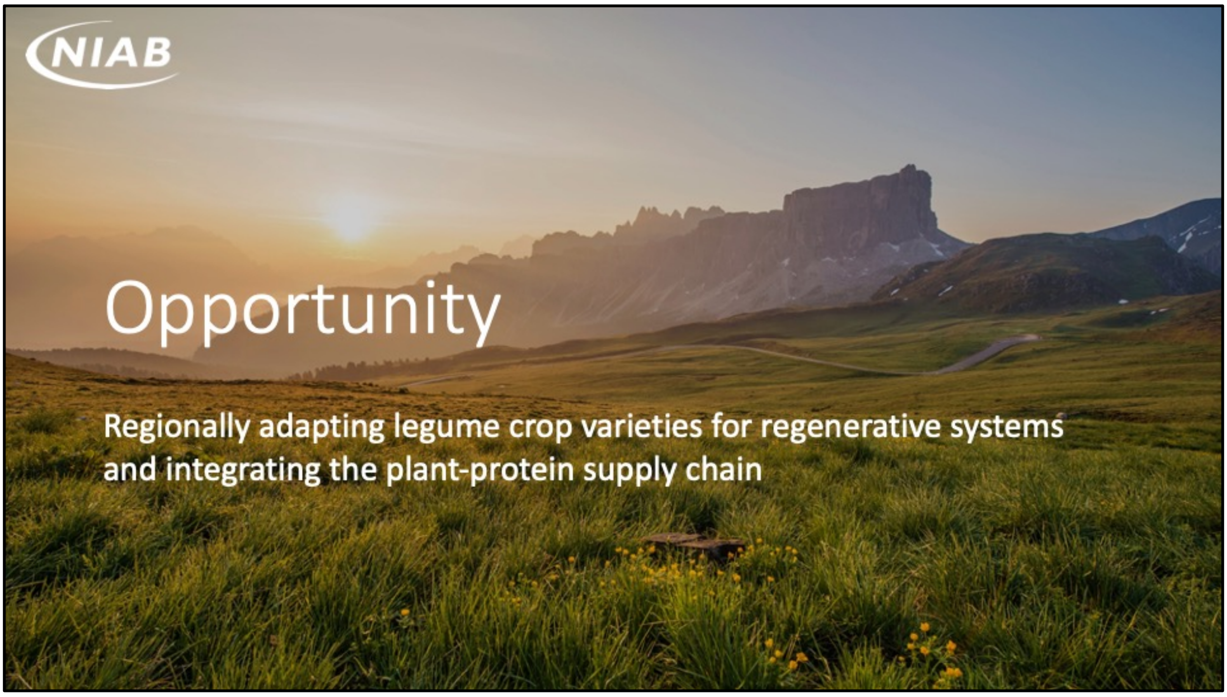

However, there is an enormous opportunity to both improve our existing crops and use our improved regulatory landscape to harness and bunch together new technologies to rapidly improve both field and end-use performance of legumes, in particular pulses.

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NIAB

Value and growth in plant-based meat products

	2020 Market Size	Growth Rate
GLOBAL PLANT-BASED MEAT MARKET	£9.2Bn[1]	16% CAGR[1]
EUROPEAN PLANT-BASED MEAT MARKET	£3.1Bn[2]	10% CAGR[3]
UK PLANT-BASED MEAT MARKET	£642Mn[4]	8% CAGR[4]

1. Statista 2021; 2. Smart Protein Project 2021; 3. ING 2020; 4. Smart Protein Project 2021

The commercial market for meat alternatives is experiencing an enormous growth, which if high performing varieties were available for domestic production should represent a strong commercial opportunity
The food ingredient market is expected to grow 5x in the next few years, whereas the animal feed market is expected to grow by 1/3 .

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However the total size of this market currently outstrips the food market by several orders of magnitude.

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In considering the need for viable protein crops for the UK and northern Europe more generally, it is important that the whole supply chain is considered and the wider environmental performance characteristics that the crop must fulfil. As we all know crops must be bred for efficiency, resilience against abiotic and biotic stresses and not just yield. Furthermore, when considering the destination of the crop, traits important for processing, flavour and the nutritional composition of the crop must be optimized. A more holistic understanding of both nutritional and antinutritional components and their effect upon the gut microbiome is going to be crucial in the future to ensure that diets remain healthy and nutritionally complete.

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Lars has talked about traits in much more detail, so I will just highlight for some of the key crops, what traits are important to generate products that are more competitive in the market and that could lead to import substitution opportunities. As you can see these are both a combination of agronomic and end user traits, each slightly different depending upon the crop under consideration.

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NIAB's role in this area is an important one, as we span the divide between discovery science and commercial implementation. We have been working for many years on pulse crops such as faba bean, but increasingly we are diversifying into other legume crops, particularly soy and building partnerships that will allow the acceleration in innovation required to address the protein crop challenge.

On this slide I highlight just some of our key strategic partners and programmes. We are working closely with John Innes Centre to build research platforms that span multiple pulse crops, building upon the excellent work that is taking part in PC-GIN.

Our alliance with the university of Cambridge, the Crop Science Centre led by Prof Giles Oldroyd, has brought in new researchers from the university of Cambridge, working on crop nutrition and symbiosis, new breeding technologies, photosynthesis and pest and disease research, increasing UK research activity in this area.

The UKRI-funded £18m investment in Strength in places, Growing Kent and Medway, led by NIAB from its East Malling site has the wider alternative proteins sector as a key pillar around which they are building end to end capability including a food processing laboratory at the university of Greenwich which will allow the evaluation of processing and nutritional traits

Finally the BBSRC funded Collaborative Training Partnership in Sustainable Agricultural innovation, led by industry and co-developed with NIAB and the Crop Science Centre aims to train 30 Phd Students. It has placed equal prority on protein crops and cereal crops. A key partner in this is PGRO, along with retailers and large breeding and agrochemical companies.

However, these partnerships all require additional investment, both public and private if they are to deliver the promise of improved crops.

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And we have a phenomenal opportunity to harness the skills within the institutes and universities in the UK to really accelerate the development of this market, through genetic innovation.

We have never had more tools and technologies at our disposal that in combination can so rapidly improve crops and bring varieties to market.

But they do require joined up thinking from public funders, private industry and us working collectively to deliver innovation to the market

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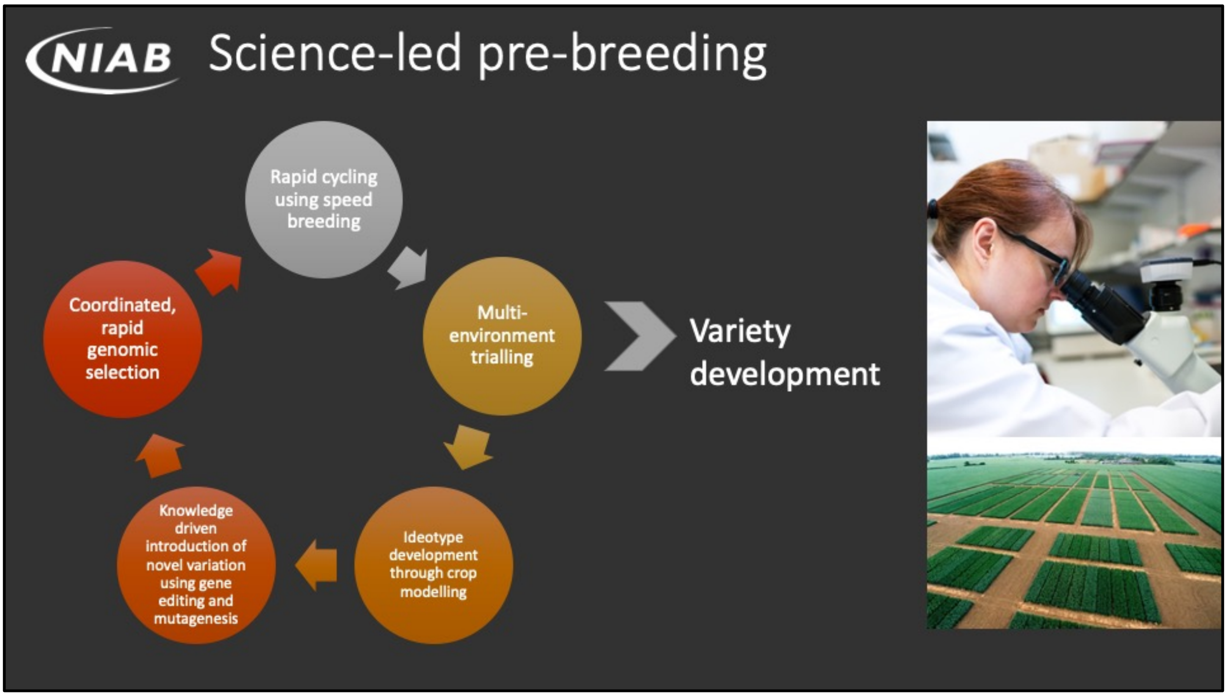

There are five interconnected key activities that together can be harnessed to develop 21st century pre-breeding programmes.

I am briefly going to talk about each of these in turn to illustrate how in combination these can lead to much more rapid breeding improvements that we have ever seen before.

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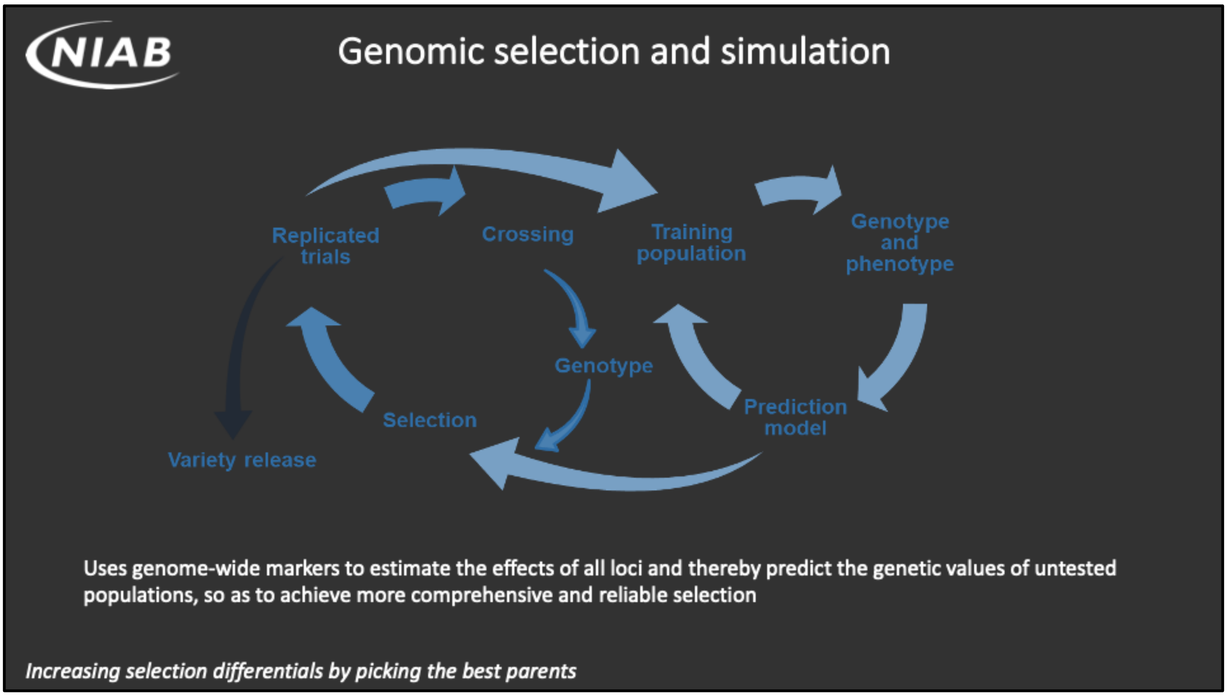

They are the use of genomic prediction, which allows estimates of plant performance prior to planning is already improving the selection of new varieties

This complements well, with other new approaches in plant breeding.

Through the integration of genomic selection with crop modelling we can rapidly spin the wheels of breeding improvement drawing on and combining the genetic variation in populations faster and more accurately than ever before.

This is only affordable now due to the step change in DNA sequencing technology and the rapidly dropping price of genome sequencing.

The genomics capabilities at JIC and NIAB, have been developed over many years and work in the designing future wheat collaboration has shown how GS can be used in practice by breeders to harness new genetic variation arising from prebreeding programmes

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Speed breeding, to rapidly cycle through generations in the glasshouse rather than the field is a key technology

Using speed breeding approaches we can get closer to end products in a timescale that is acceptable to both public and private sector investors and to the scale of the challenge that is in front of us

The Crop Science Centre and The John Innes Centre both have state of the art speed breeding capabilities and we are currently working up protocols for speed breeding in faba, soy and other pulse crops

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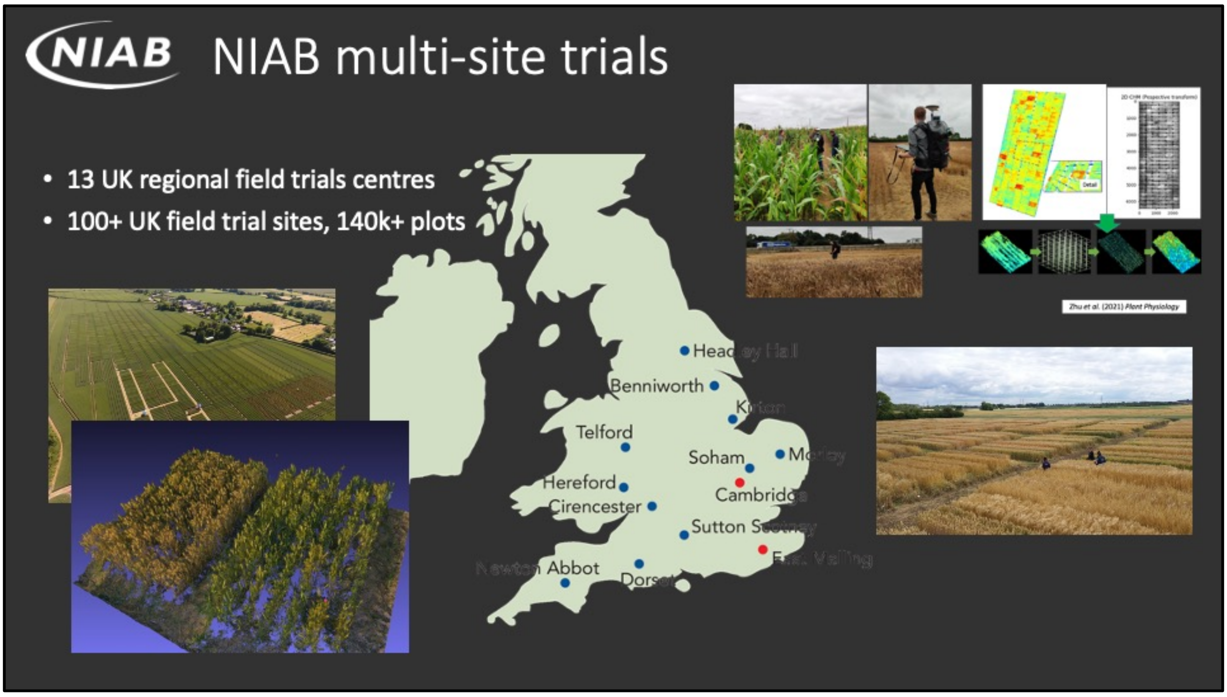

Multi environment trialling, harnessing genomic data and high throughput in field phenotyping is absolutely crucial to successful genomic prediction and NIAB has one of the largest trials networks in the country, which so far has not been used in anger for genomic-assisted breeding.

Prof Ji Zhou has developed some amazing capabilities to measure plant traits automatically in the field, integrating internet of things sensor devices, satellite, drone and smartphone data to provide estimates of plant performance throughout the whole growing season.

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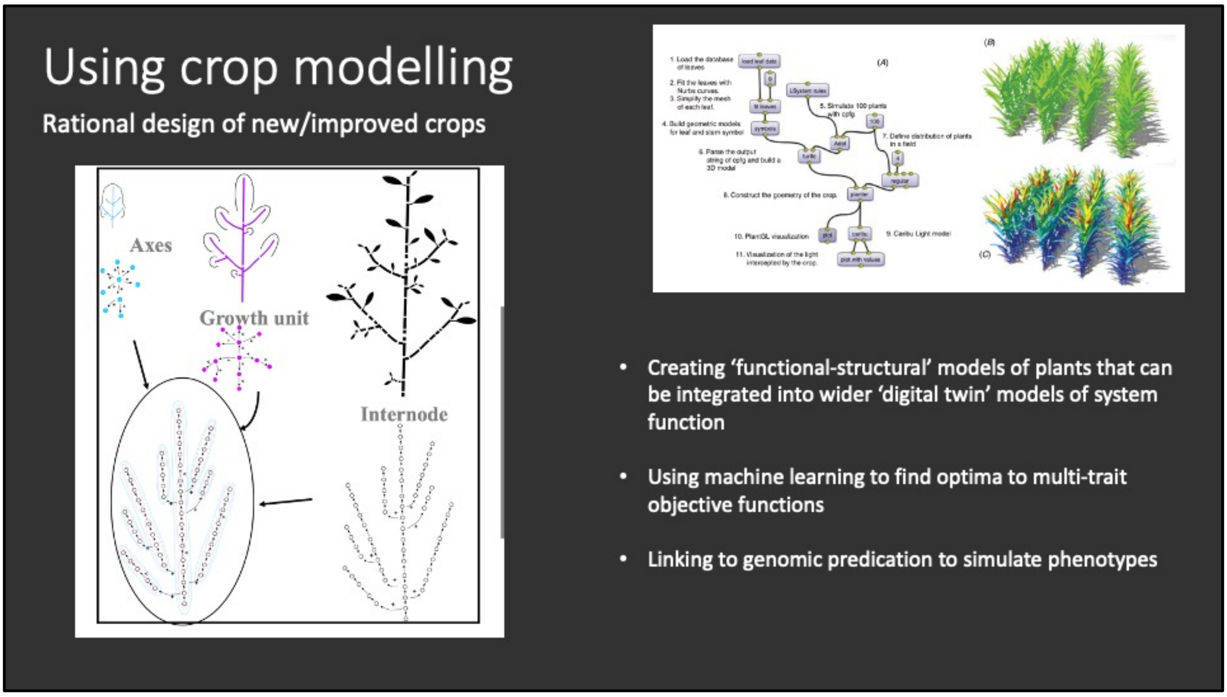

The use of crop modelling to rapidly identify traits for selection and to simulate breeding programmes computationally is a rapidly developing area for NIAB and currently we are expanding our modelling capabilities. We are using a particular kind of crop model that accurately represents the architecture of the plant, allowing realistic simulations of growth in fluctuating environments to be carried out. Coupling crop models to machine learning methods allows the rational design of crop ideotypes and architectures that perform in different farming systems.

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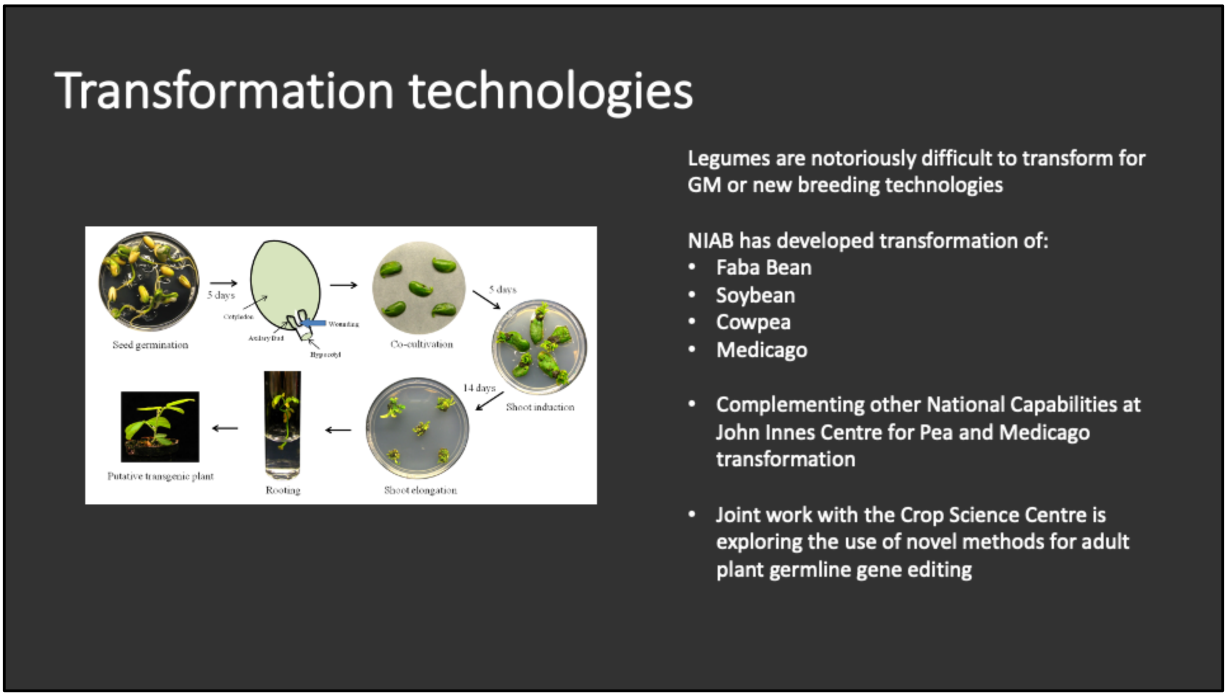

Transformation and gene editing technologies are integral to any modern breeding programme.

We have been working for many years to improve the methods of crop transformation in legumes and have recently transformed soybean for the first time.

We are working to develop still better methods of gene editing which will form part of any pre-breeding effort.

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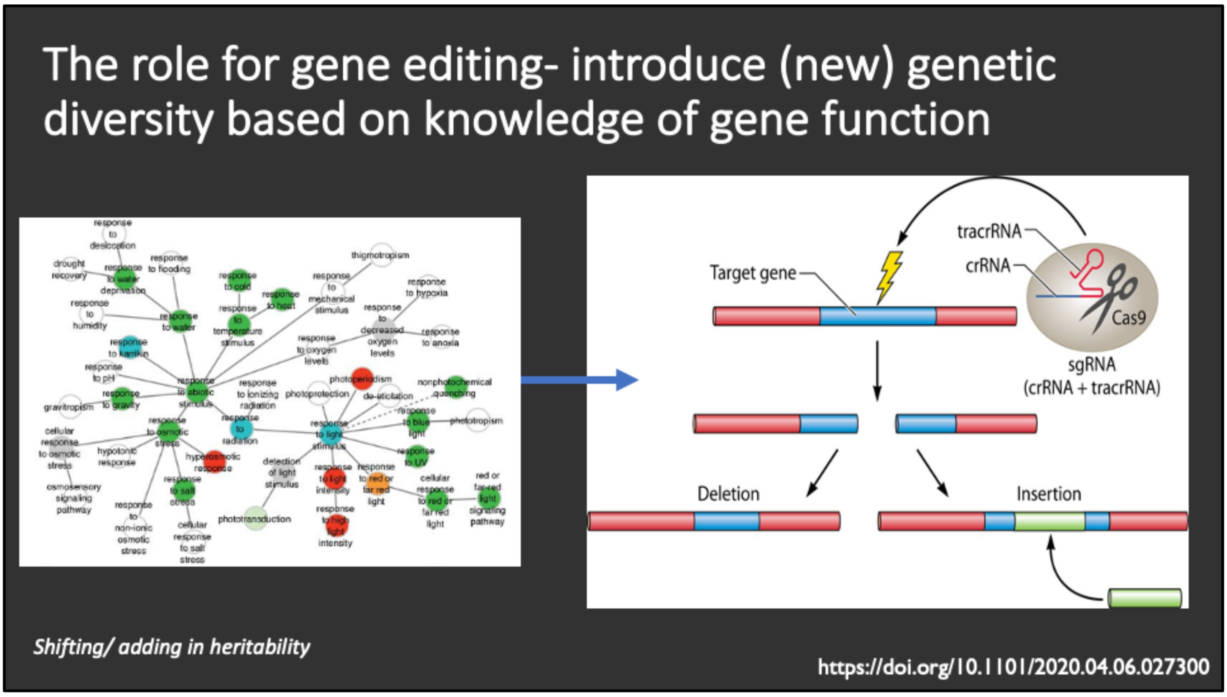

The key to successful gene editing is knowing which genes to edit!

The use of structured knowledge and machine learning to provide new breeding targets that new breeding technologies such as gene editing is now a real possibility.

Building on the last thirty years of discovery science we can use our knowledge of biological function of genes to introduce new mutations in key genes in order to provide new genetic variation which would likely be at very low frequency in natural populations to further enhance genetic gain per unit of time.

This is a subject of active research at NIAB and we've hired new experts in computer science to drive this research and development forward.

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With that I'll close and thank the colleagues that I've listed on this slide, who all contribute to NIAB's capability in legume pre-breeding.