# POTATO BREEDING IN A CHANGING WORLD

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scri
living technology

# POTATO BREEDING

Potato breeders aim to produce new cultivars better adapted than existing ones to the conditions in which they are going to be grown and stored and the ways in which they are going to be used.

# POTATO BREEDING

There are two ways to improve on existing cultivars:

1. Produce new cultivars using sexual hybridization.
2. Genetic modification of existing cultivars by transformation.

They are complementary because they have different outcomes. It is not a question of which is better or faster.

## My first example is Pentland Ace
## This cultivar has the *R3a* gene for blight resistance from the wild Mexican species *S. demissum*

*S. phureja* (2x) x *S. demissum* (6x) in 1937

↓

735 x Gladstone in 1939

↓

885(2) x Pepo in 1940

↓

997a44 x Craigs Defiance in 1942

↓

Pentland Ace (1951)

**The breeding of Pentland Ace was done very quickly, just three backcrosses to three European potato cultivars with selection for blight resistance and commercially acceptable tubers. Because potato is an outbreeding crop, the result was a new cultivar with a few hundred genes from *S. demissum*, not Gladstone with the *R3a* gene.**

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Pentland Ace (1951)

**Fifty years on, and Professor Visser and his colleagues have cloned the *R3a* gene and inserted it into the widely grown red cultivar Desiree.**

**The result is Desiree + *R3a*, not a completely new cultivar.**

***R3a* did not provide durable resistance to late blight, but many more resistance genes are now available from wild relatives of our potato and there is much debate about their use.**

# Genetically modified potatoes

- More controversial, but potentially of greater benefit, are targeted improvements by introducing genes not present in cultivated potatoes and their wild relatives to give desirable novel traits.
- Genes used to date have mainly been ones that code for proteins toxic to pests and pathogens, ones whose expression interferes with virus multiplication and ones that code for key enzymes in biochemical pathways in other organisms, often, but not always in other plant species.

# Genetically modified potatoes: examples

‘*Cry*’ proteins from *Bt*: Colorado beetle, potato tuber moth.

Cysteine proteinase inhibitors (cystatins): PCN

Replicase and coat protein genes: PLRV and PVY.

Lysozyme enzyme from chicken: *Erwinia* resistance.

Non-allergenic seed albumin gene from *Amaranthus hypochondriacus:* protein content and aa composition.

Fructosyltransferases from globe artichoke: inulins to improve carbohydrate composition.

Invertase inhibitor protein from tobacco: minimise conversion of sucrose to glucose and fructose and cold sweetening.

# Genetically modified potatoes: examples

The first GM cultivars to be commercialized were by Monsanto in North America from 1995 and were Russet Burbank, Atlantic, Snowden and Superior with a *Bt* gene for pest resistance from the bacterium *Bacillus thuringiensis.* Subsequently virus resistance was added.

But leading processing and fast-food outlet companies in North America were reluctant to purchase GM potatoes because of consumer concerns over GM potato products and Monsanto stopped marketing GM potatoes in 2001.

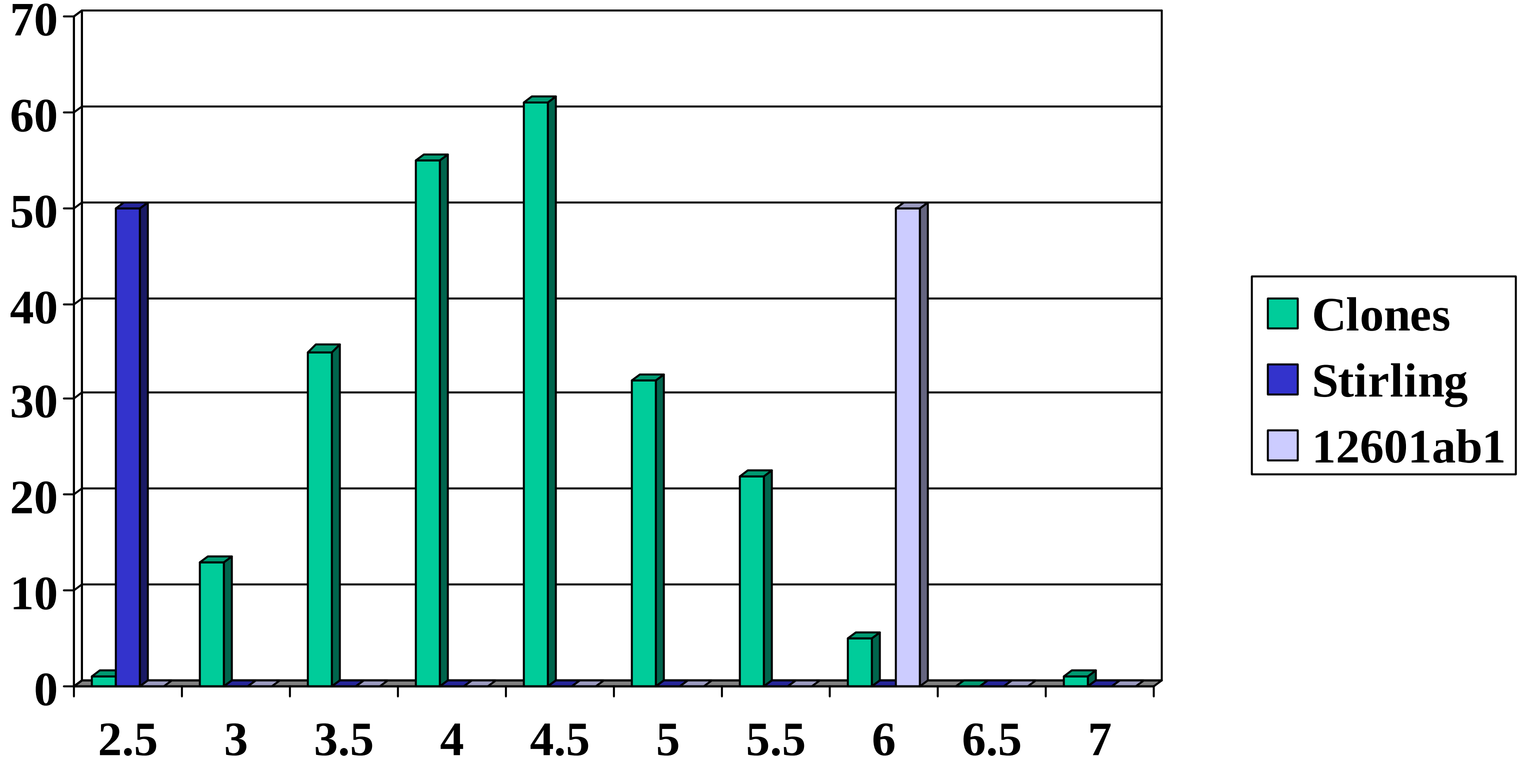
However, I think we need to assume that genetic modification will be an acceptable method of potato improvement in the future. In the meantime…

**All 72 cultivars bred at SPBS/SCRI since 1920 have come from pair crosses. With Pentland Ace we have considered backcrossing. Now I want to consider pair crosses between cultivars and clones that complement each other for desirable characteristics.**

# The cross between processing clone 12601ab1 and table cultivar Stirling is typical.

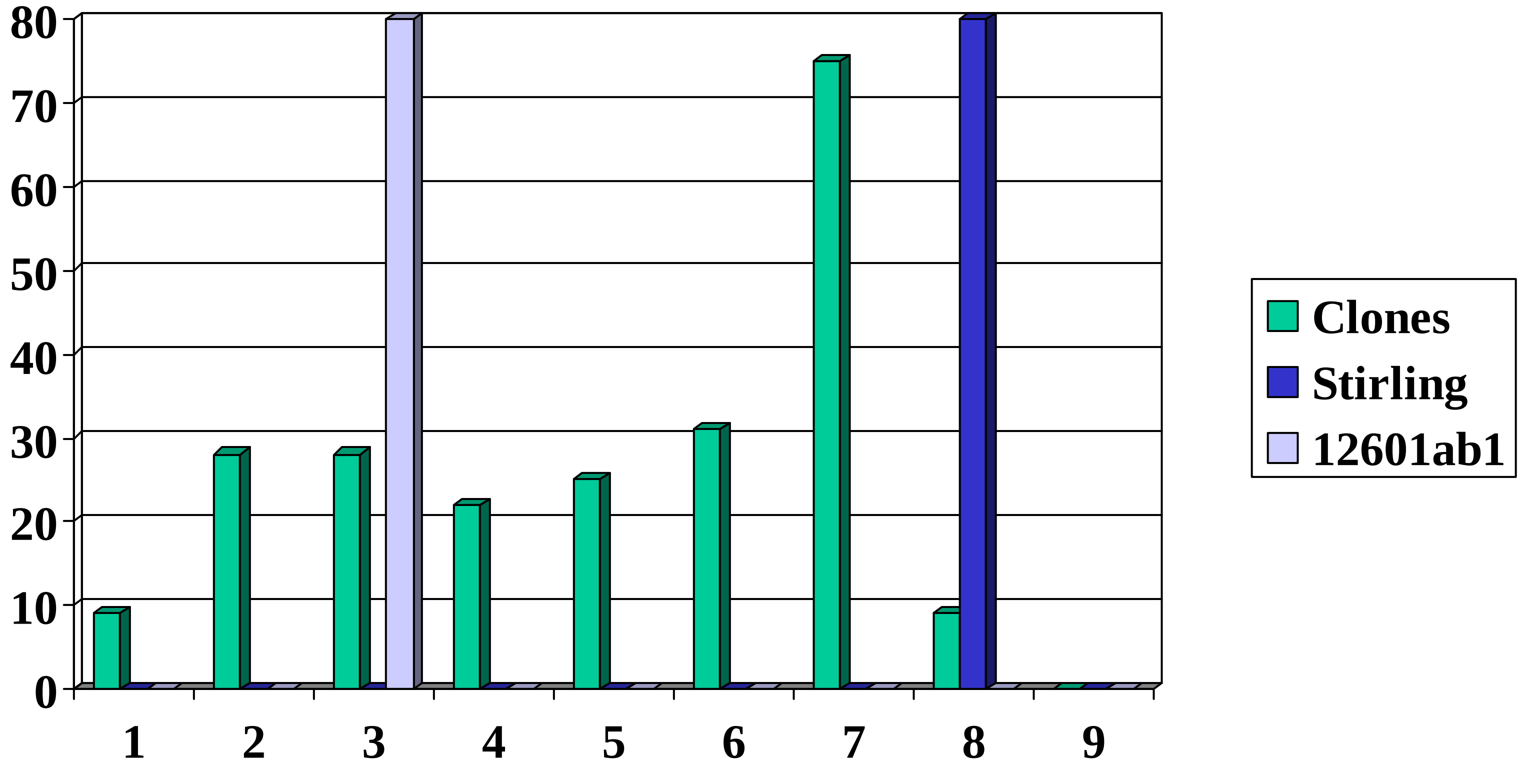
**We know a lot about it. 225 progeny clones assessed in ware trials in 1999, 2000 and 2001.**
**Fry colour assessed after storage for 3 to 4 months at 4°C.**
**Resistance to blight and potato cyst nematodes were also assessed.**

# 12601ab1 x Stirling



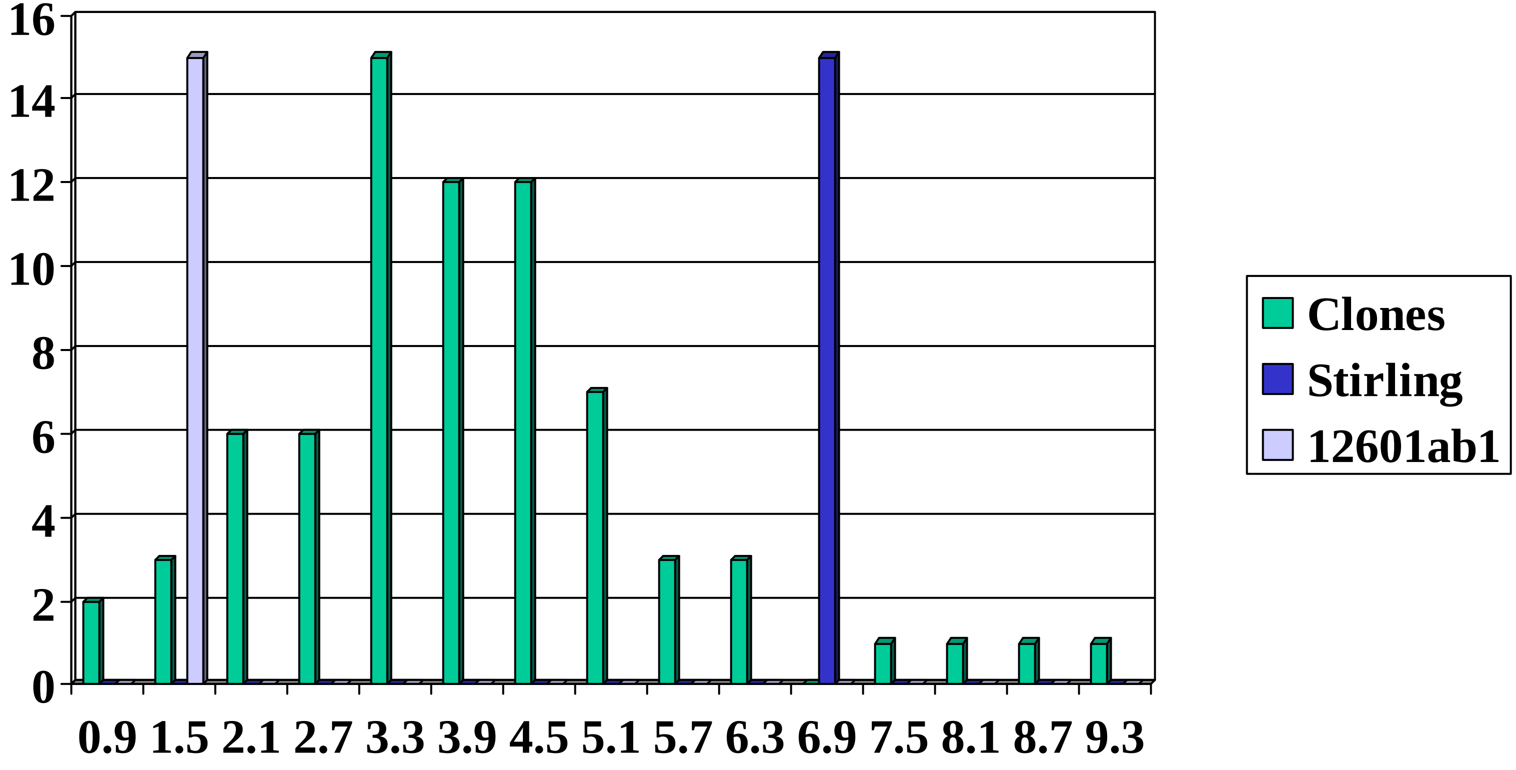

**Fry colour (4°C) on a 1 (dark) to 9 (pale) scale.**
**Normal distribution with 79% of variation genetical.**
**Highly heritable trait but no genes of large effect.**
**A low frequency of clones as good as the better parent.**

# Field assessment of foliage blight resistance in 1998




**Continuous but not normal distribution of blight scores (1 susceptible, 9 resistant).**
**88% of variation genetical. So highly heritable trait.**
**Segregation of gene of large effect did explain 37% of variation.**

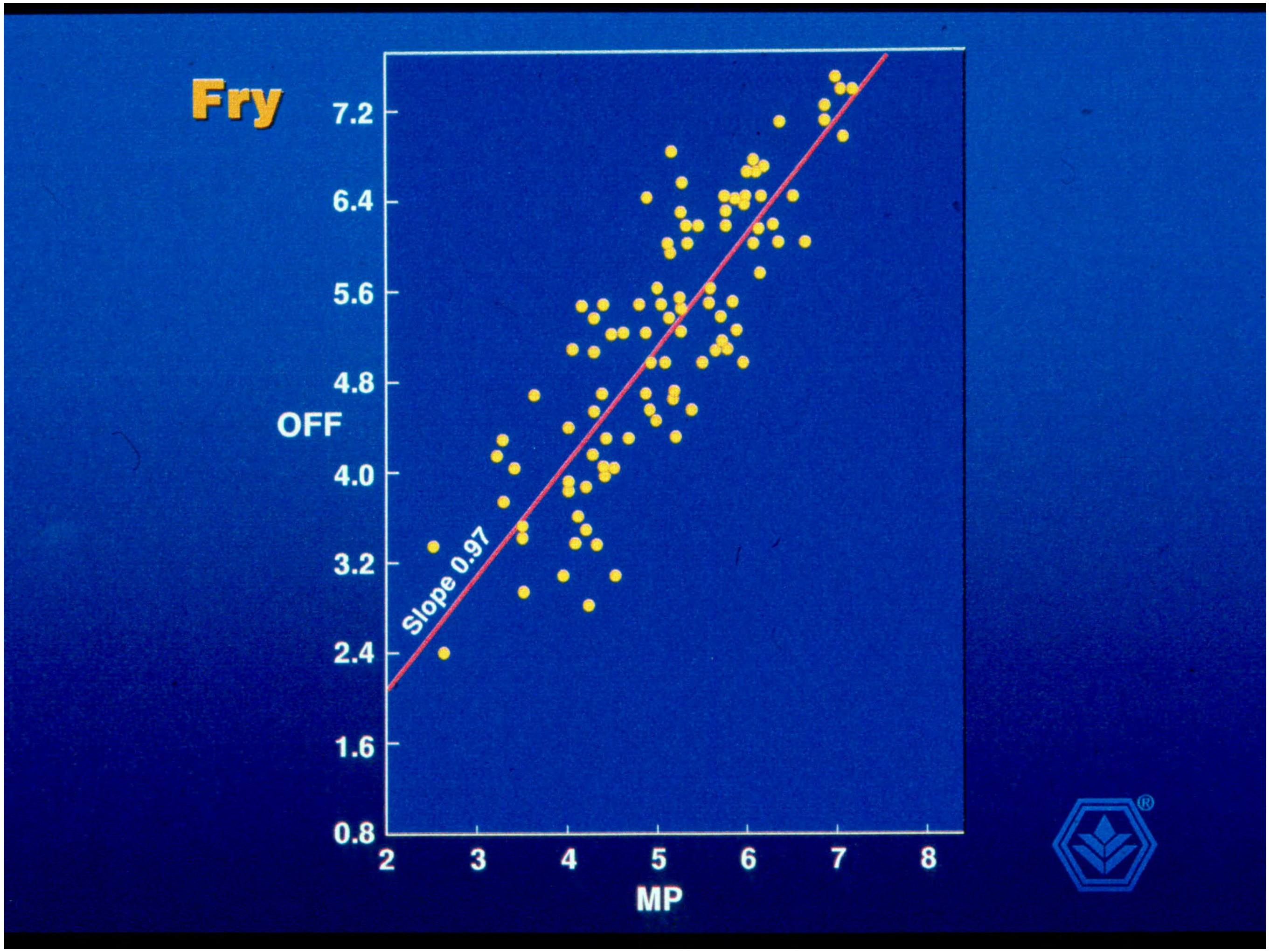
# Assessment of resistance to the white potato cyst nematode




**Approximate normal distribution of scores (square root of number of females so low is resistant).**
**94% of variation genetical. Highly heritable trait.**
**Segregation of a gene of large effect did explain 34% of variation.**

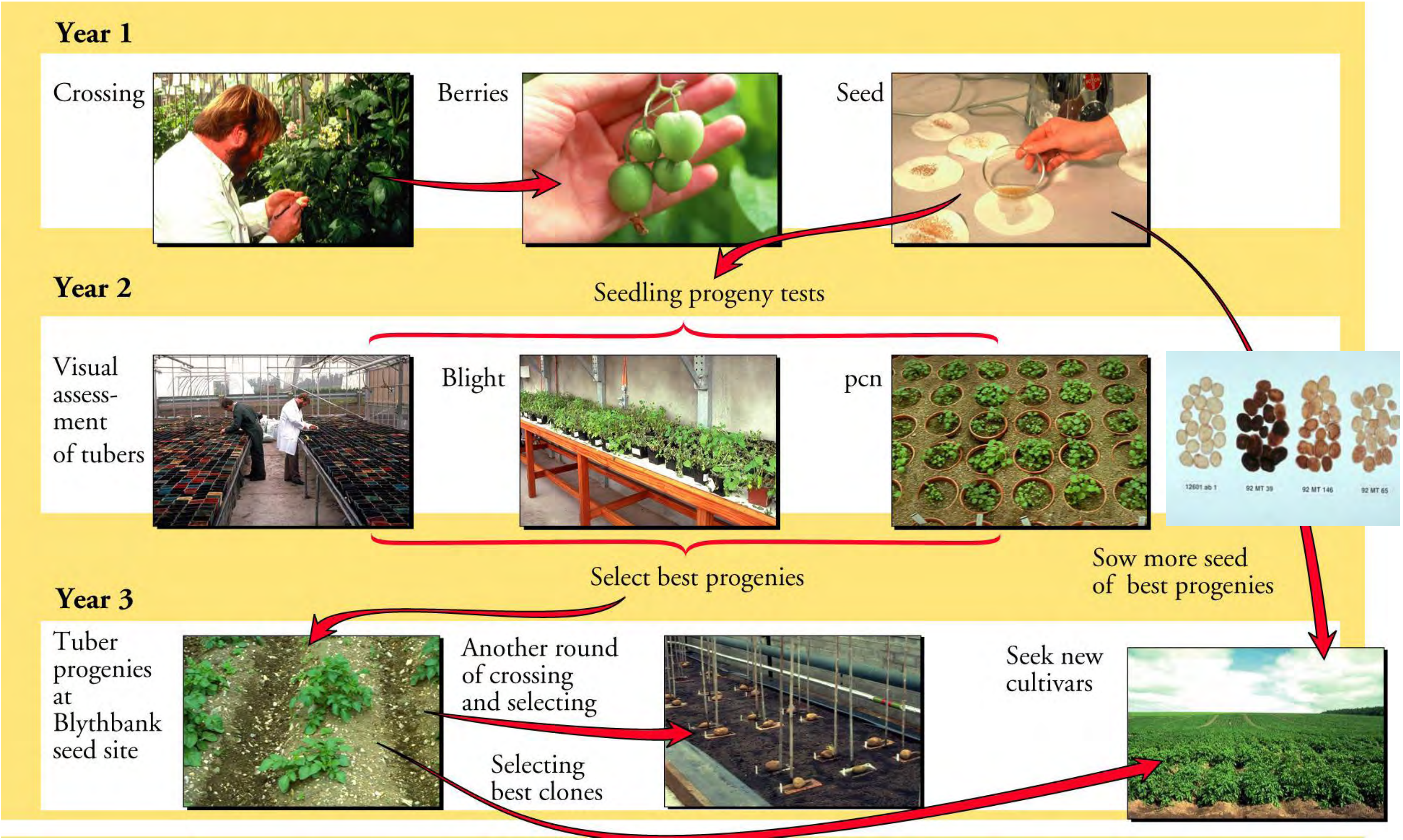
# The cross between processing clone 12601ab1 and table cultivar Stirling is typical.

**Despite finding a few genes of large effect, the conclusion is that the frequency of clones combining all of the desirable characteristics of the two parents is going to be extremely low.**




**To increase our chances of success we need to cross, for example, a clone with good fry colour with another one with good fry colour, rather than one with poor fry colour. And that means increasing the frequency of desirable genes in our breeding programmes.**

# One way developed at SCRI is population improvement using progeny testing




**Have completed 5 cycles in 18 years (also practised clonal selection in one cycle) and made good progress: so that is the rate of improvement that can be achieved.**

## It is certainly faster than the 10 generations and 73 years that separate The Alness (our first cultivar) from Vales Everest

1932 *Solanum demissum* × The Alness

↓

1934 429a8

↓

1936 571(18) × Shamrock

↓

1939 699(49) × 692a52 1104a3

↓ ↓

1945 882(5) × 1104c2 Craigs Defiance × 1306a2

↓ ↓

1953 Roslin Chania × Roslin Sasumua

↓

1959 Pentland Crown × Pentland Dell

↓

1972 H1H3(75) × Pentland Ivory

H1H3(140) × Pentland Ivory

↓ ↓

1976 10915ab10 × 10950ab2

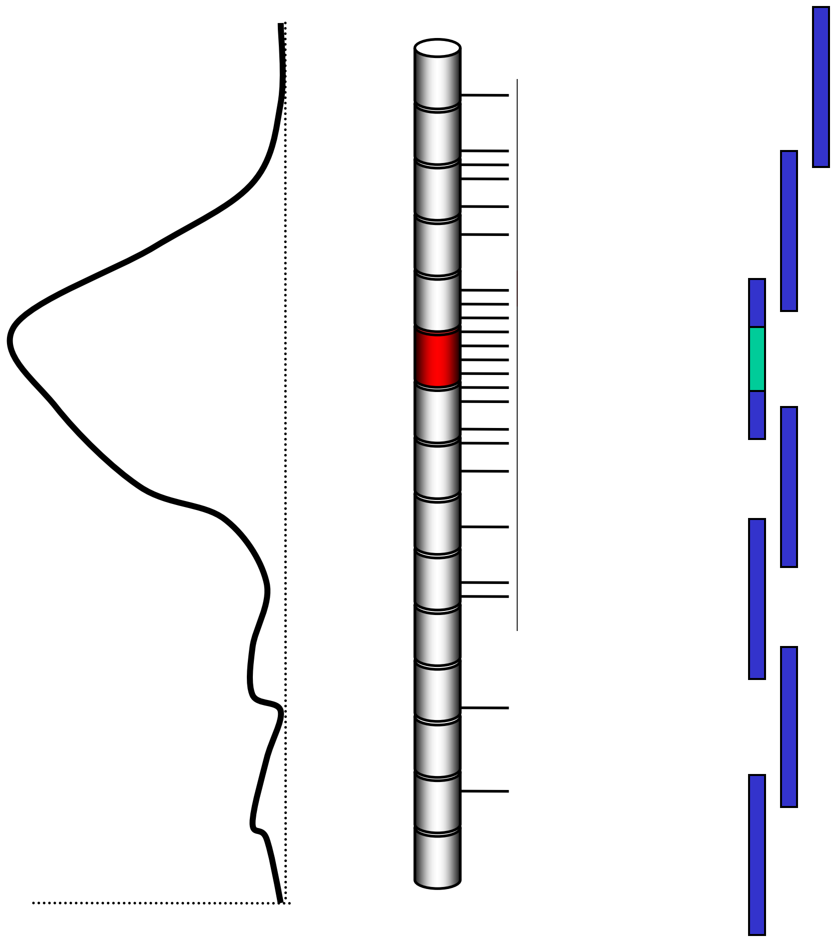
↓

1988 Cara × 12674ab1

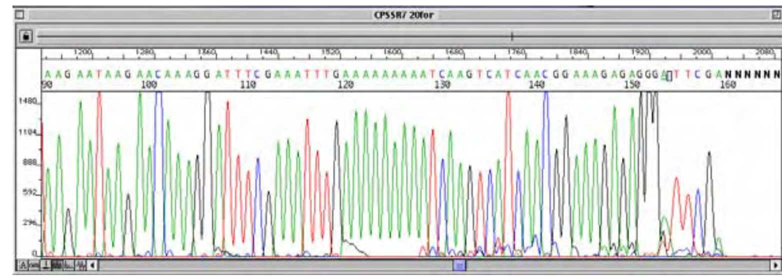
↓

2005 Vales Everest

# What does potato genomics and the other ‘omics’ have to offer?

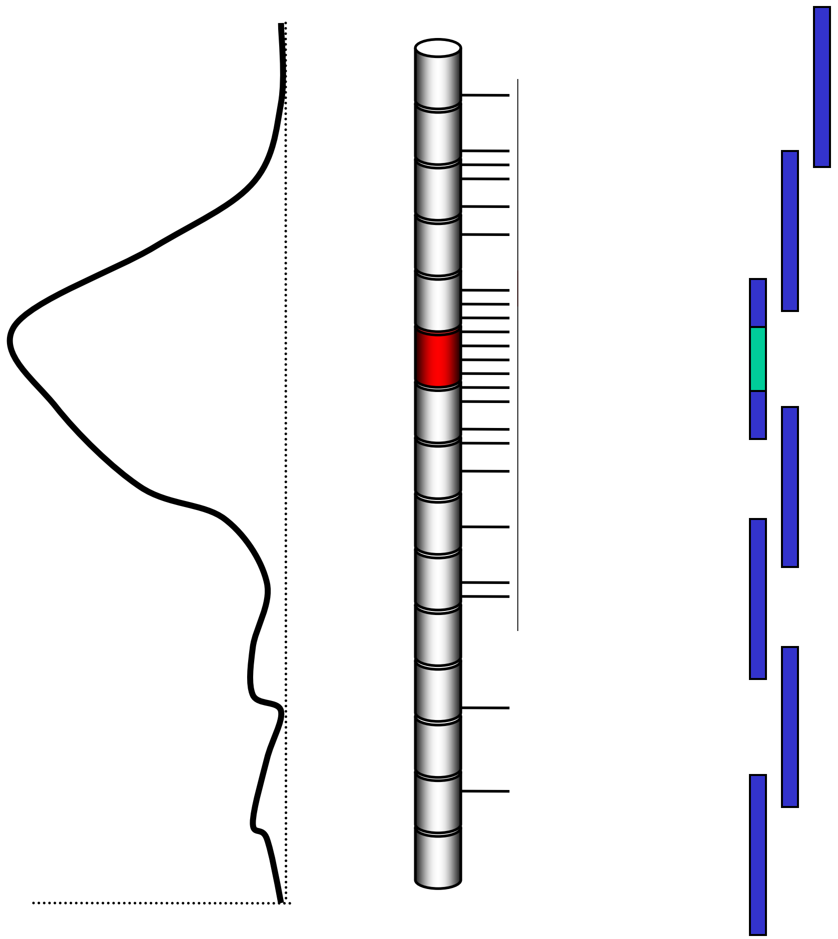


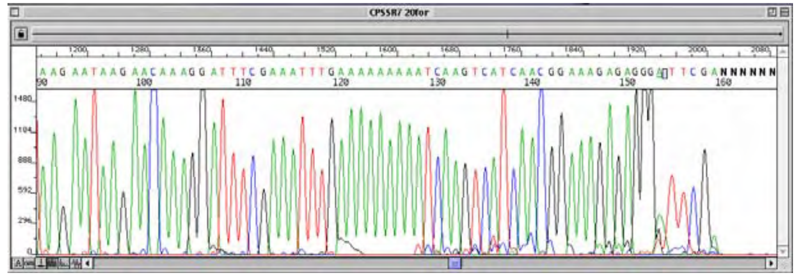
**Trait data Genetic Map Physical Map**



**Gene sequence, which will soon be the whole potato genome.**

# What do potato genomics and the other ‘omics’ have to offer?





Trait data    Genetic Map    Physical Map

**I don’t think that they will speed up potato breeding.**

**I do think that they will speed up gene discovery and ensure the presence of discovered genes in new cultivars.**

**So by gene discovery I mean finding the genes required for the genetic improvement of potatoes.**

**And those genes may come from a number of sources (GM approaches giving more possibilities):**

**The wild and cultivated potatoes of Latin America held in genebanks such as the Commonwealth Potato Collection at SCRI.**

**Long-day-adapted populations of Andigena potatoes (Neotuberosum) such as the one at SCRI.**

**Long-day-adapted populations of Phureja potatoes such as the one at SCRI.**

# Gene Discovery

One recent example
of gene discovery is again
from Professor Visser:

namely confirmation that
the Y locus ‘for yellow
flesh’, which was mapped
to chromosome 3 in 1988,
codes for β-carotene hydroxylase.

A number of research groups,
including those at SCRI,
are now having success with
gene discovery for more complex
traits such as flavour and texture.

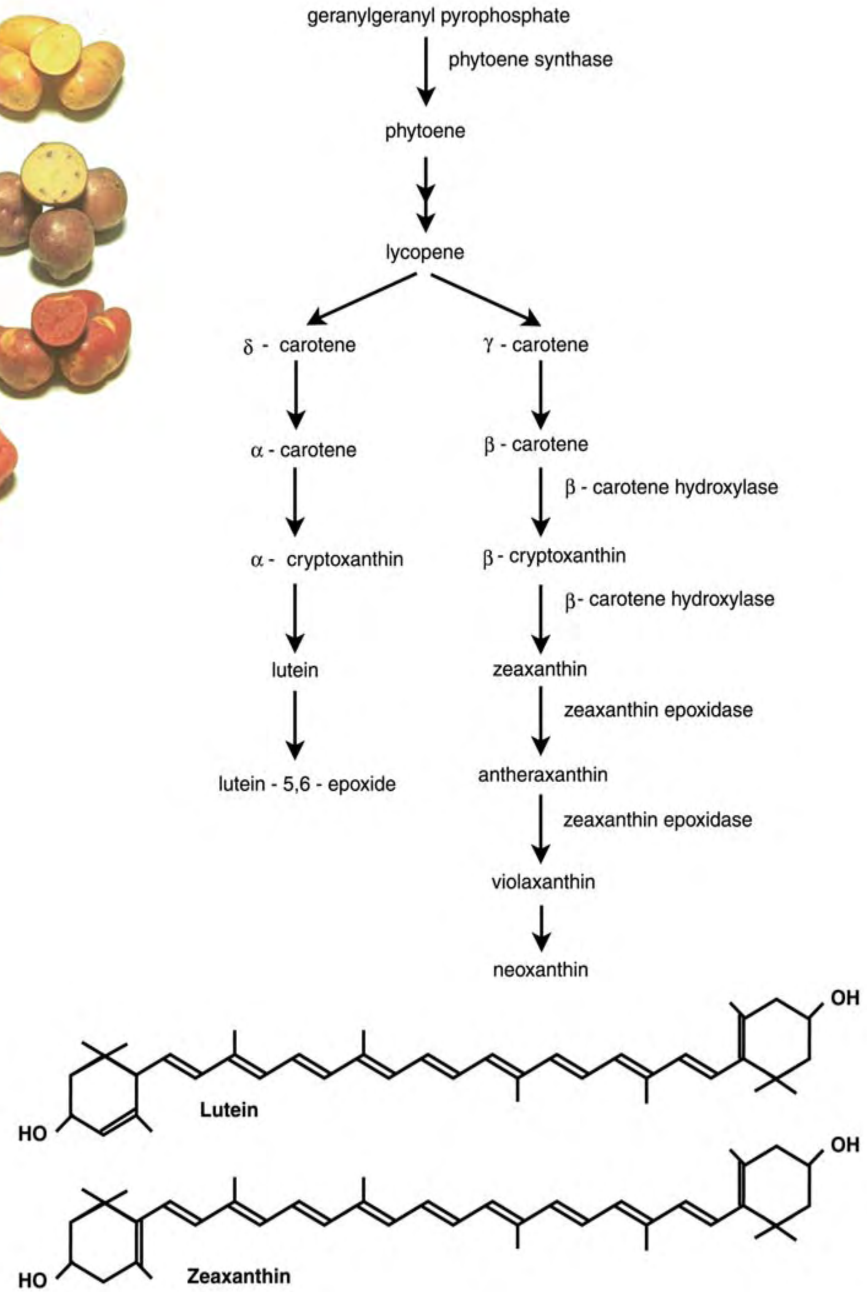



**Figure 2.** Carotenoid biosynthesis

# New cultivars are required in Great Britain

- Increased potato usage in an economically and environmentally sustainable way.
- Economic benefits: more yield of saleable product at less cost of production, whether for processing or table use.
- Environmental benefits: reduced use of pesticides (PCN), fungicides (late blight) and sprout suppressants; and increased water and fertiliser (P, N) use efficiency.
- Consumer benefits: convenience foods, improved nutritional and health benefits (lower glycaemic index, lower potential acrylamide production), improved flavour and novel products.

# New objectives are increased water and fertiliser (N, P) use efficiency as these are environmental and hence political issues

- **Most potato growing is in nitrate vulnerable zones**
- **Potatoes need large inputs of phosphate (P) fertiliser and irrigation to maintain crop yields and quality**
- **Potatoes occupy 2.5% of arable land, but consume 8% of P-fertiliser applied in UK & P enrichment of surface water is a problem**
- **Half of the irrigation water applied in England goes on potatoes**
- **And with climate change, we expect competition for water resources between agricultural, industrial and domestic users.**

**Can these traits be found in cultivated species?**

**Or do we need to go to wild species ?**

**When considering the need for new cultivars in Asia (China and India), Africa and South America, I think it is worth remembering that in Britain, as in other European countries and North America, we now produce a high yielding potato crop (fresh yields average 45 t/ha compared with the world average of 17 t/ha) of good quality of which half is processed.**

# Key developments that have led to this situation in Europe and North America can be summarized as follows:

- Modern chemical fertilizer industry by 1900s
- Cultivar registration and seed certification since 1920s
- Industrial production of crisps (chips) since 1920s and French fries since 1950s
- Modern herbicides, insecticides and fungicides since 1950s
- Mechanization and larger fields since 1960s
- Controlled environment stores since 1960s
- Extensive irrigation since 1980s
- Cultivars adapted to changing growing conditions, storage and end uses

**How many of these are realistic, and desirable, for developing countries?**

# Whatever the answer

Potato breeders will continue to produce new cultivars better adapted than existing ones to the conditions in which they are going to be grown and stored and the ways in which they are going to be used, but the timescale is certainly going to be more than the next 10 years.