Genetic improvement of productivity and health in Honeybees

– scope and developments in Australia

Prof. Rob Banks

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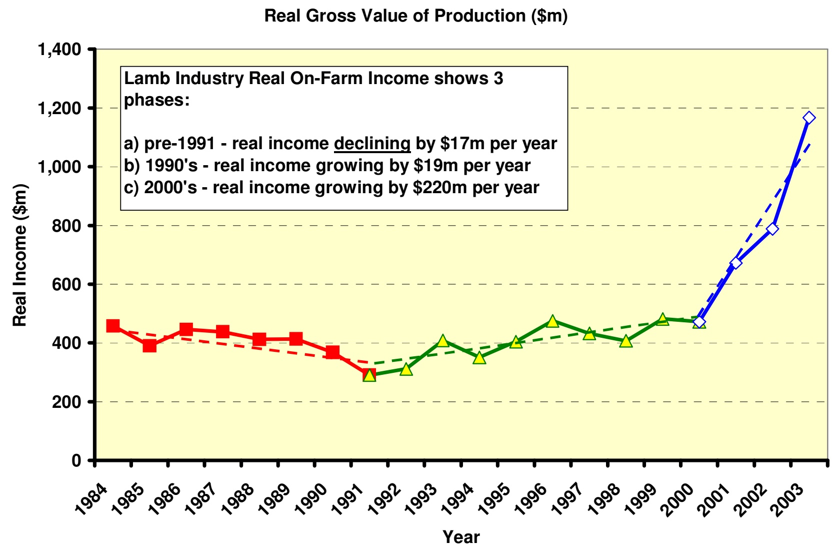
Key Points:

1. What is genetic improvement, and why is it important?
2. What is needed to achieve it?
3. What's in place?
4. Scope for genomics
5. Challenges

Genetic improvement makes a difference – Lamb in Australia:



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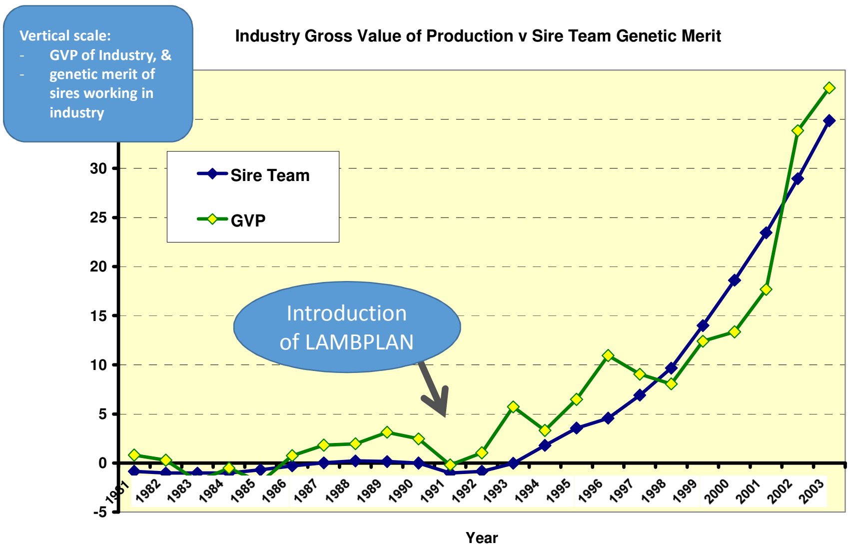

What is genetic improvement, and why is it important?

- Genetic differences among queens generate differences in hive performance:
  - In honey production
  - In health and hygiene traits
  - In temperament
- Using the queens with the best genes each generation means better and better genes over time
- Without genetic improvement
  - Completely dependent on rising price of honey to be viable
  - Completely exposed to disease risk

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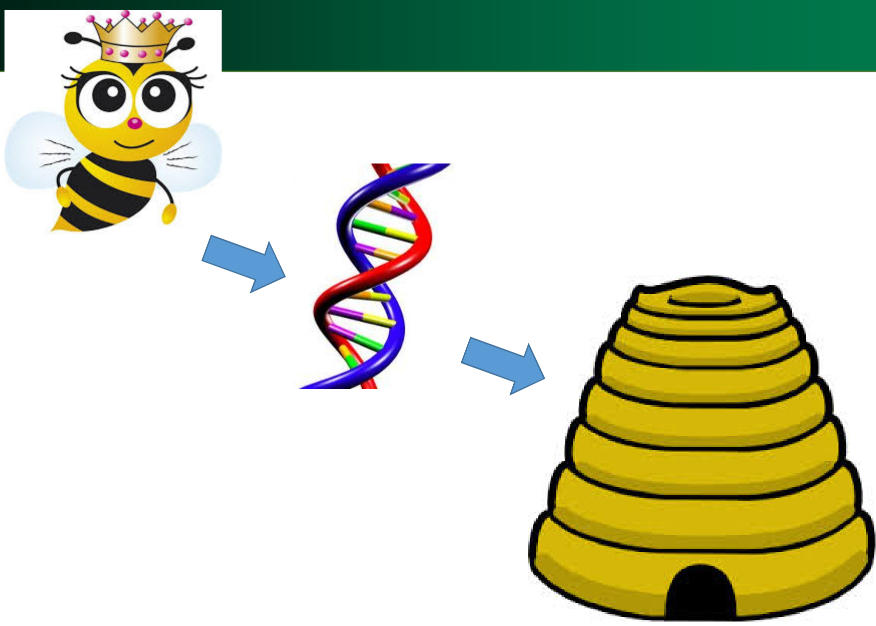

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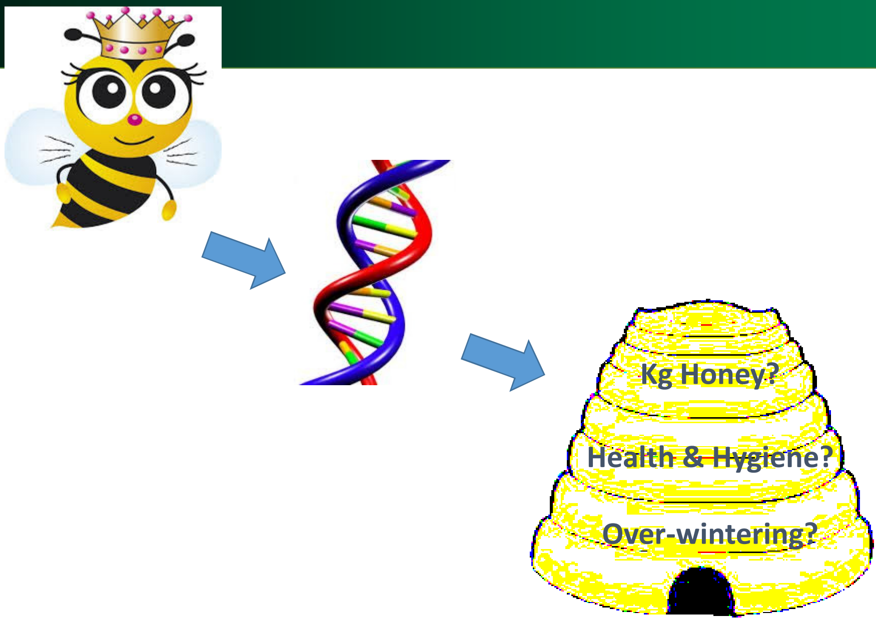
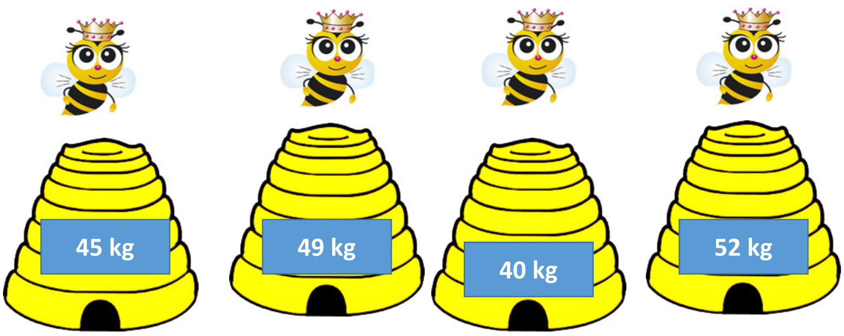


Which Queen has the best genes?



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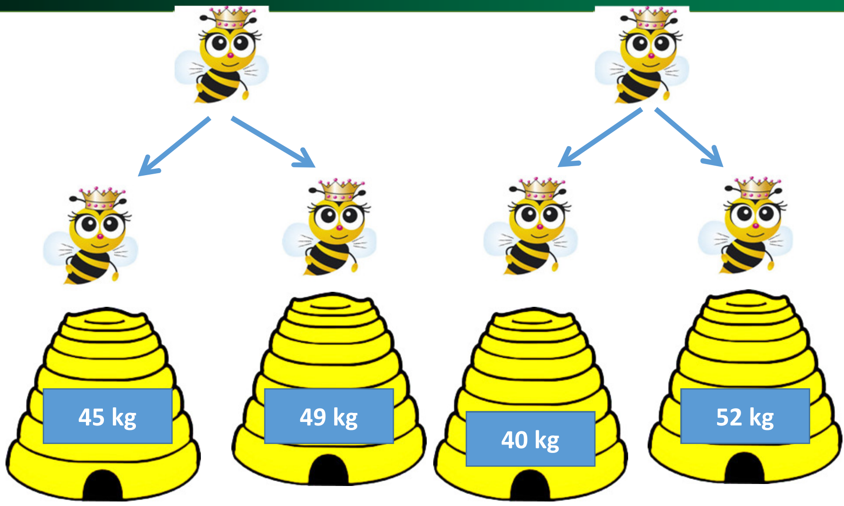

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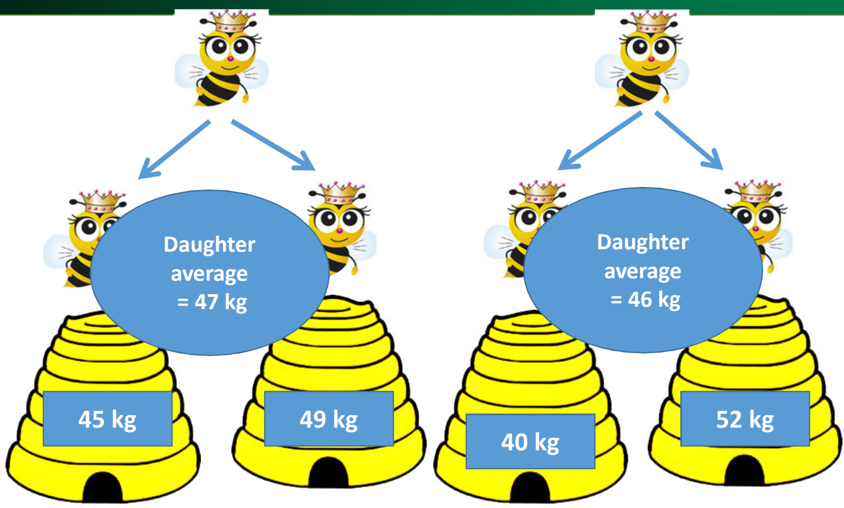

What is needed:

- Defined breeding goal:
  - What traits are important?
  - How important is each one?
- **Recording:**
  - **Need data (consistently recorded) for each important trait**
  - **Need pedigree information (can be via genotype)**
- Genetic (genomic) evaluation
  - Analysis to estimate genetic merit for recorded traits
- Selection:
  - Can use tools to jointly manage selection and inbreeding
- Size of population
  - Number of parents in recorded population is ideally 500-1,000 or more
  - This implies total recorded needs to be 5,000 or more (in bees, that means 5,000 recorded and pedigreed queens/hives per year)

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R&D (AgriFutures-funded):

- Stage 1:
  - Outline principles
  - Analyse available data (Horners', Queen Bee assessment program) – BLUP method
  - Benefit-cost estimation
- Stage 2:
  - Extend analysis to larger data set(s)
  - Genotype queens if available
  - Include genotypes in the BLUP evaluation
  - Develop recommendations for industry-wide application

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R&D Progress 1:

- Dataset provided by the Horner family (Mudgee):
  - Only very small dataset for first analysis
- 4 categorical traits (ie scored 1-5) over 6 years – 3 cycles of breeding and production
  - CB: chalk brood, no variation observed
  - W: general rating of the “value” or work of the hive
  - Be: bee size
  - Br: brood viability
- Approximately 200 hives recorded within 1 family line for each trait

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Results: genetic parameters

Trait	Heritability
W – hive work rating	20%
Be – bee size	38%
Br – brood viability	40%

For all 3 traits, these values mean that the Horner’s could use their scores as a basis of selection, to improve the merit of their bees for these traits.

Estimates of genetic merit can be calculated using the heritability – and these estimates of genetic merit (EBVs) will make selection more effective

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Results: Example EBVs

queen	EBV for W	EBV for Be	EBV for Br
C1	0.01	0.19	-0.37
C1a	0.27	1.46	1.20
C1b	0.33	-0.05	-0.06
C2c	0.41	0.41	0.44

C1 is genetically below average for Brood Viability (Br)
C1a is genetically above average for Bee size (Be) and Brood Viability
C2C is genetically above average for Work Rating (W)

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R&D Progress 2:

- Dataset provided by the Lindsay Bourke
  - Australian Queen Breeding Program
- A number of lines providing queens in each of several years
- Data analysed so far – weight of honey per season per hive (kg), from 134 recorded hives across 3 production seasons

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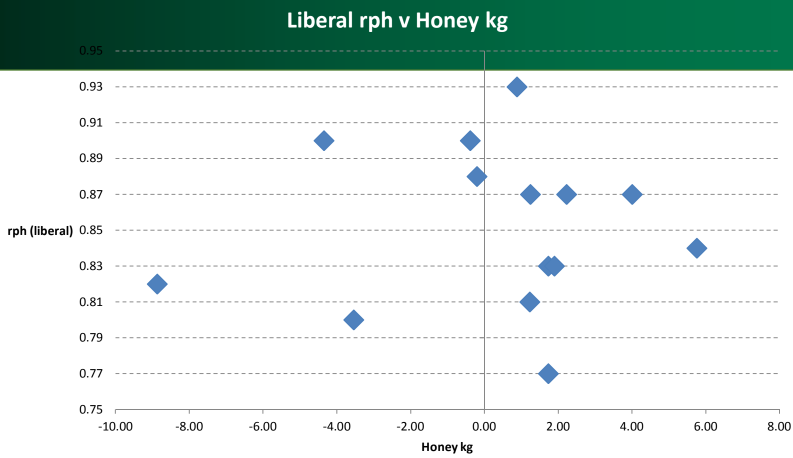

Data from "Hygienic Behaviour in the AQBBP, June 2015 Update"
Beescientifics
Correlation between rph score and honey production ~ 0

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R&D Progress 3:

- New data from Horners:
  - complete production season including individual hive weight of honey
  - Data on approx. 600 hives, including pedigree
- Genotyping program planned
- Evaluating genomics
  - Ability to select earlier
  - Turn over generations faster
  - **BUT** very data dependent ie **LOTS** of recording

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Challenges and opportunities:

- Traits:
  - Honey production, hygiene traits, pollination traits, temperament
  - All heritable – can be improved simultaneously

- Opportunities:
  - Selection to improve all important traits
  - Value in industry-research continuous partnership
  - Value in wide-scale phenotyping in large breeding programs
  - International collaboration – data sharing (phenotypes and genotypes)

- Challenges:
  - Number of recorded queens
  - Number of viable (size) breeding programs
  - Recording of Varroa (and other diseases) incidence

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New R&D collaborating with industry:

Partner co-investment from Australia - would enable
a) Increased scale of core (more queens, wider sample of Oz gene pool)
b) Satellite site recording
c) Additional traits recorded

Domestic R&D Collaboration:
a) Understanding the genetic basis of traits
b) Additional health traits
c) Assistance with genotyping?

Core:
- Recorded breeding program c 200 queens at Tocal, including genomic methods

Outreach (community engagement):
a) Teaching and training
b) Recording in smaller programs
c) Flow of genetic material if scale is large enough

International R&D collaboration:
a) Knowledge sharing (traits and recording methods, funding/partnership models)
b) Data sharing – genotypes enabling estimation of genetic relationships between populations
c) Potential exchange of genetic material for recording

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Expected outcomes:

- Increased scale of recording ie number of pedigreed hives recorded per year
- Potentially more traits recorded, including for honey production, pollination traits and health
- Wider engagement with industry (pollinators, honey) would increase resilience via human capacity, and potentially increase even further the recorded population (this is the absolute core goal)
- Subject to quarantine, ability to test Australian material overseas, and overseas material here, even if only via exchange of genotypes, would be advantageous:
  - Would include scoping methods to select for Varroa resistance using both domestic and exotic genetics
  - Would include drawing on elite genetic material from overseas, for potential infusion into Australian genetic improvement program

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Challenges:

- Size of program:
  - At least 500-1,000 recorded hives per year needed
- Time-scale:
  - Think of this as 5+5, +5, …
  - Genetics is a continuous improvement, not a once-off
- Coordination:
  - Sectors working together is essential to ensure right focus of selection, and address market failure (returns re-invested in genetic improvement)

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Vision:

- Continuous genetic improvement is:
  - Practical
  - Valuable – extra $250m each year is possible
  - Relatively straightforward if resources are allocated and coordinated
  - Essential to meet cost-price squeeze
  - Essential to ensure resilience to shocks

- Home-grown solution infusing best knowledge world-wide

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