72nd Annual Meeting of the European Federation of Animal Science – Davos, Switzerland – 01/09/2021

Session 43 - Optimization of sheep and goats production systems: strategies for sustainable and resilient agroecosystems

Bench-testing future systems: combining genetics, nutrition and farm types to predict outcomes

Puillet L.

UMR MoSAR, Paris

INRAE

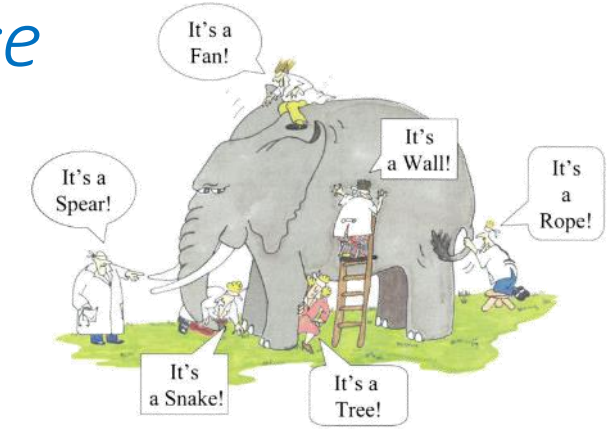
The full title of this talk, without limited character space

Bench-testing future sheep and goats production systems: using simulation models that combine genetics, nutrition and farm types to predict outcomes

The full title of this talk, without limited character space

Bench-testing future sheep and goats production systems: using simulation models that combine genetics, nutrition and farm types to predict outcomes

The full title of this talk, without limited character space



Bench-testing future sheep and goats production systems: using simulation models that **combine** genetics, nutrition and farm types to predict outcomes

ADAPT HERD

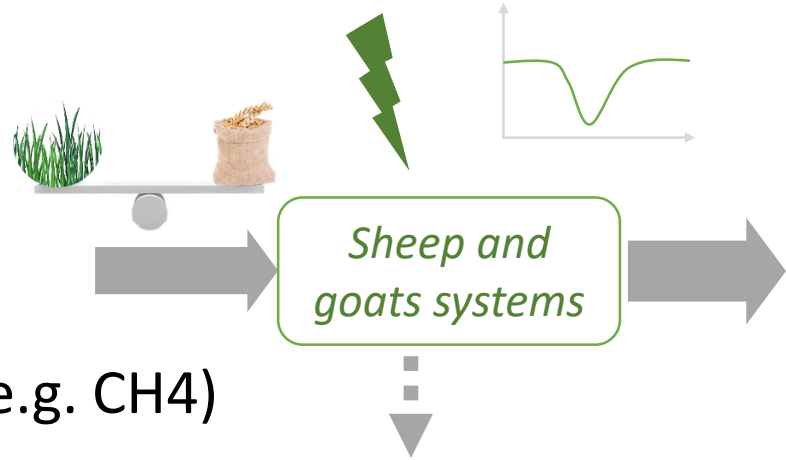
Smarter

Outline

- Context of the modelling approach
- How does it work?
  - Key features for integrating disciplines
- What is it for?
  - Potentialities for bench-testing
- Conclusion

Context

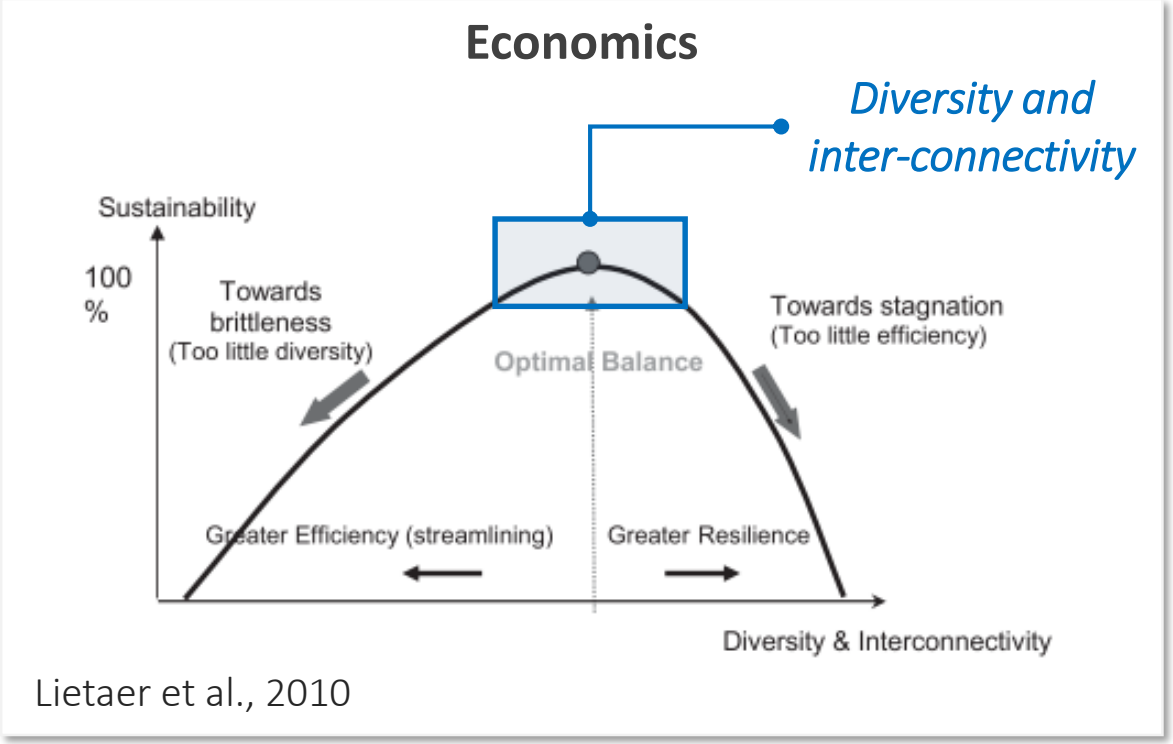
- What are the “future sheep and goats systems”?
  - Efficient $(E)_{FEED}$
    - Making the best use of limited natural resource
    - Limiting feed-food competition, environmental impacts (e.g. CH4)
    - Providing sufficient income (limiting feeding costs)
  - Resilient (R)
    - Coping with perturbations, tolerate disturbances
    - Extreme climate events, pathogens, price hazard, resources variability



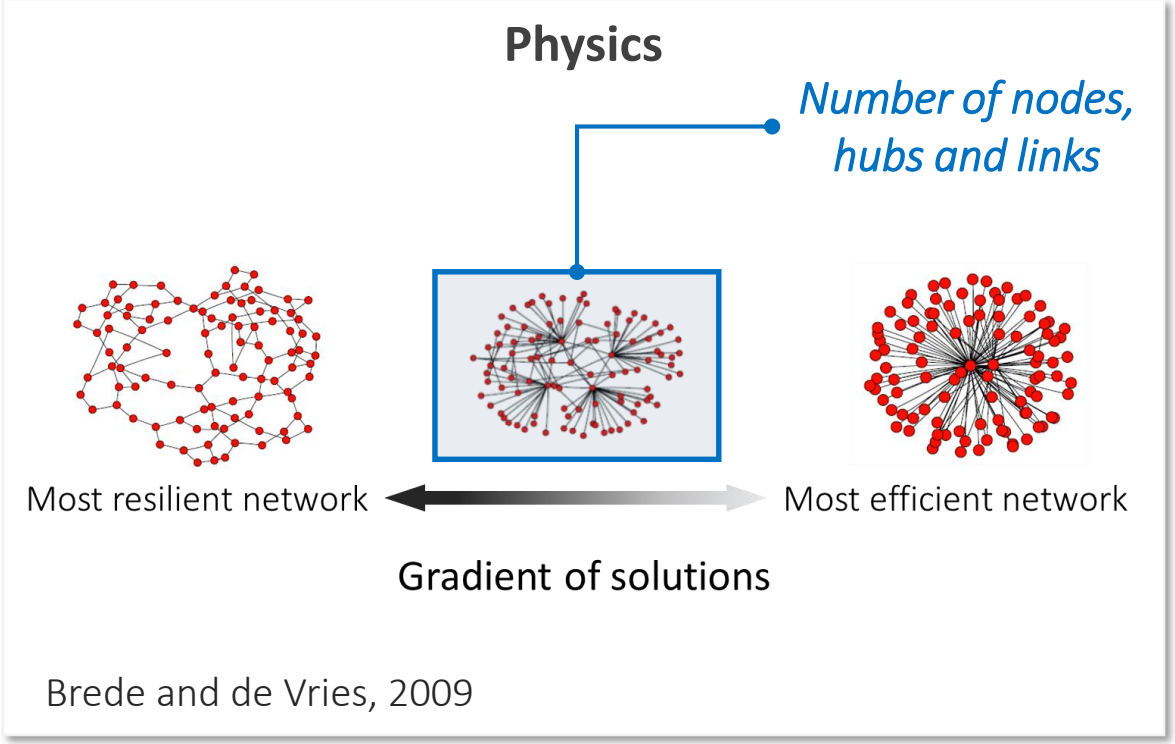
For a broader view,
☞ Meuwissen et al., 2019

Context

- What are the challenges?
  - Finding an optimal balance between R and E
  - Addressing a diversity of environmental conditions (current and future)



Lietaer et al., 2010



Brede and de Vries, 2009

Context

- Solutions
  - Breeding resilient and efficient genotypes
  - Adaptive capacities of sheep and goats
  - Herd management
  - Crop and forage management
  - Health management
  - …
- But disciplinary silos
  - How these solutions can be combined?
  - Compatibility ?

Objective

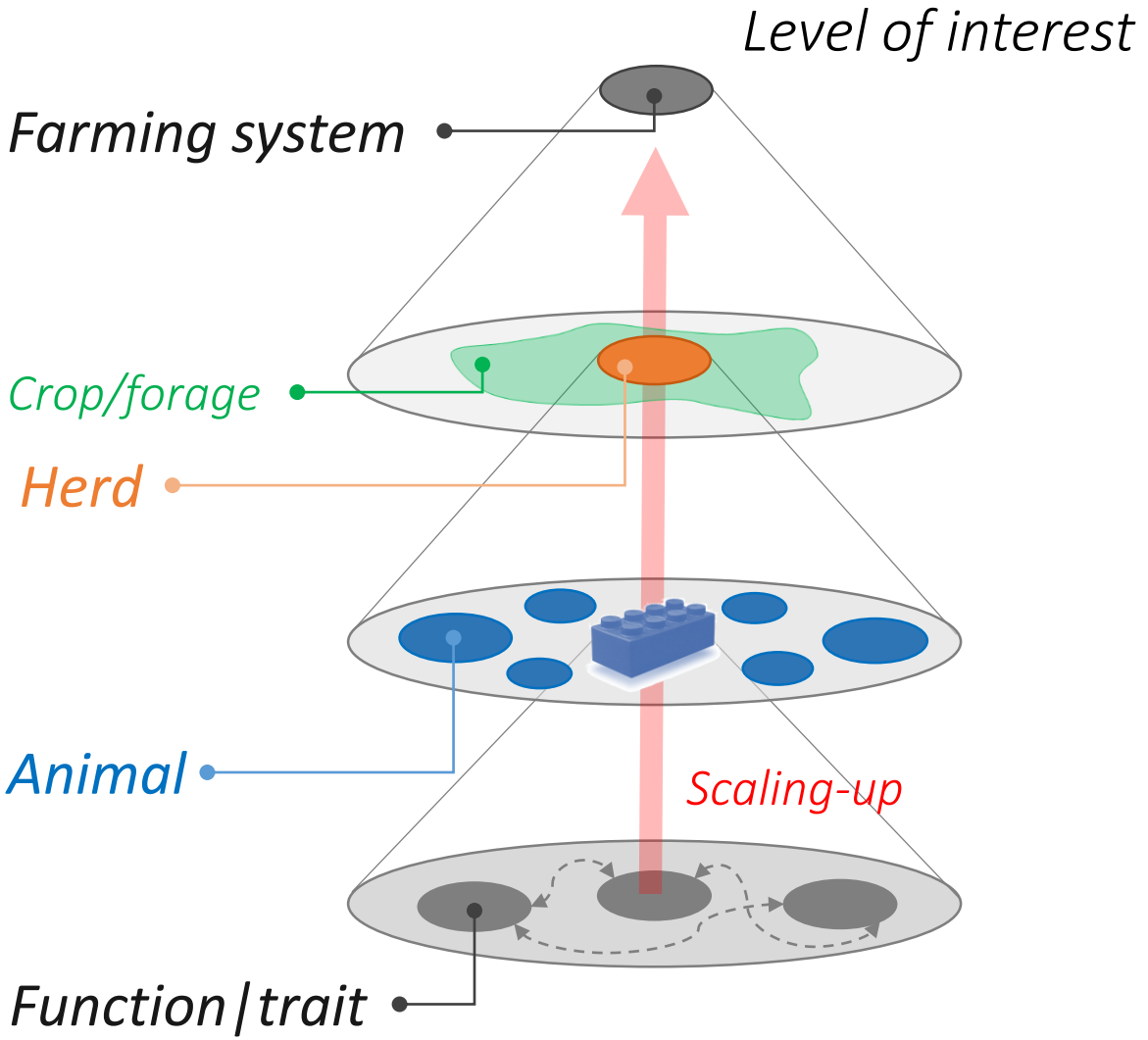
- Illustrate how modelling approach is a way to:
  - Integrate determinants of R | E
  - Combine different disciplines
    - Here, nutrition, genetics and farming systems
  - Explore different contexts, scenarios
    - Bench-testing locally-tailored solutions

- Share ideas and concepts
  - No equations, numbers, detailed results …
  - Recent developments (on-going projects)

Outline

- Context of the modelling approach
- How does it work?
  - Key features for integrating disciplines
- What is it for?
  - Potentialities for bench-testing
- Conclusion

#1 How does it work?
Overview



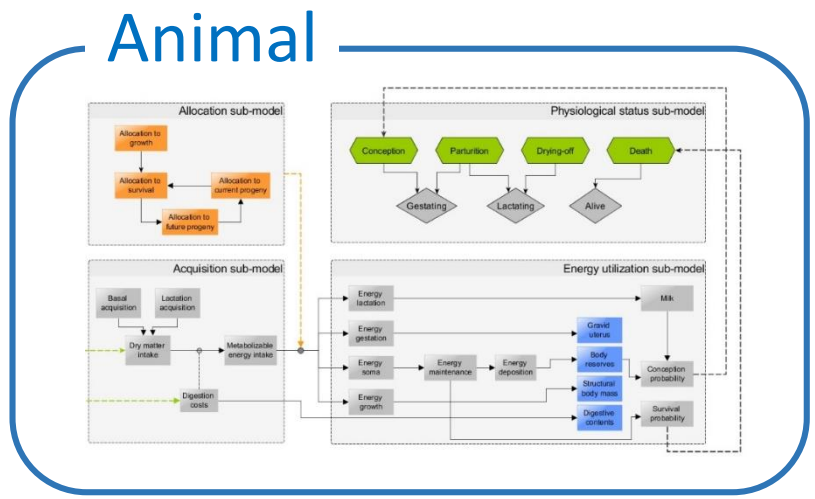
#1 How does it work?

Animal building-block

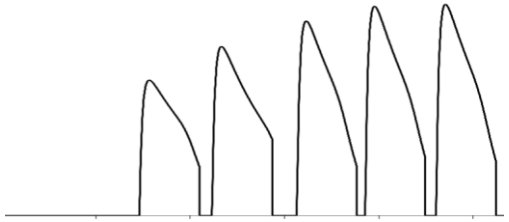
- Simulating the lifetime trajectory of a (dairy) female
  - Daily dynamics of traits: DMI, BW, milk, reserves
  - Nutritional principles to convert energy from the environment into traits

Dry matter offer (kg/d)

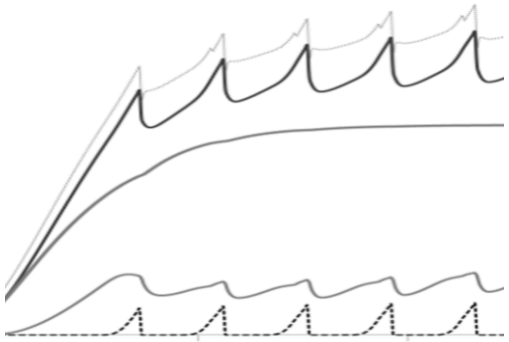
Energy content (ME/kg DM)



Milk production



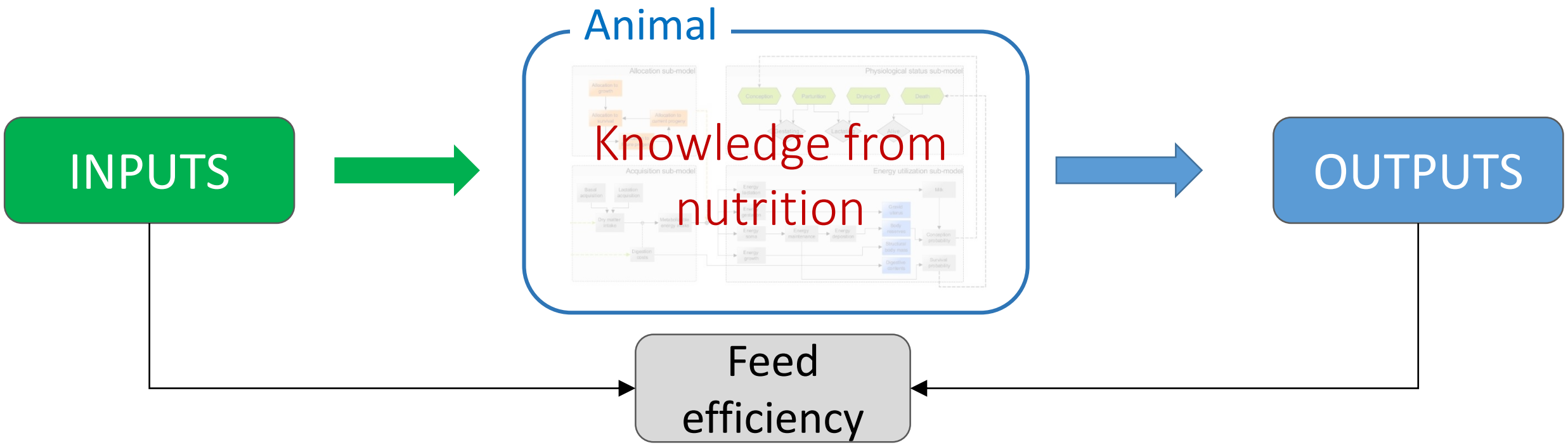
Body mass component



#1 How does it work?

Animal building-block

- Simulating the lifetime trajectory of a (dairy) female
  - Daily dynamics of traits: DMI, BW, milk, reserves
  - Nutritional principles to convert energy from the environment into traits



#1 How does it work?

Animal building-block

- From static conversion to lifetime dynamic processes
  - Trajectory of acquisition
    - Intake capacity = *f*(age, φ status)
    - Beyond availability in the environment, intake limitation by animal capacity
  - Trajectory of allocation between functions
    - Energy partitioning = *f*(age, φ status)
    - Strategy reflecting long-term regulations that coordinate physiological changes
    - Shift in priorities according to reproduction / survival
  - Key role of body reserves
    - Expression of trade-offs
    - Feedback on probability of conception and survival

#1 How does it work?

Animal building-block

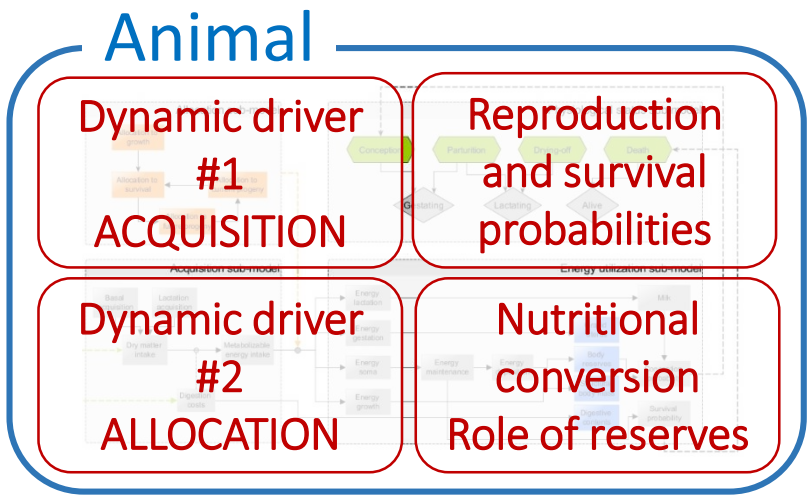
Genetic-scaling parameters, used to simulate ≠ animals

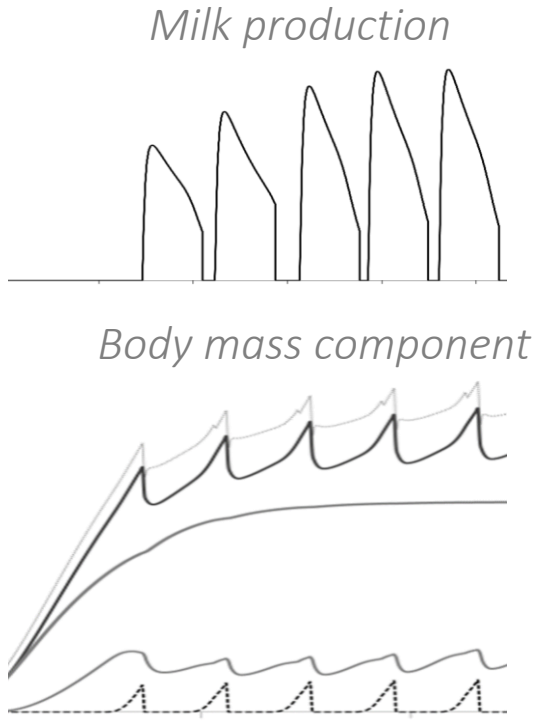
User-defined parameters for acquisition | allocation

Phenotypes (e.g. milk production, longevity) emerge from simulation

Dry matter offer (kg/d)

Energy content (ME/kg DM)





#1 How does it work?

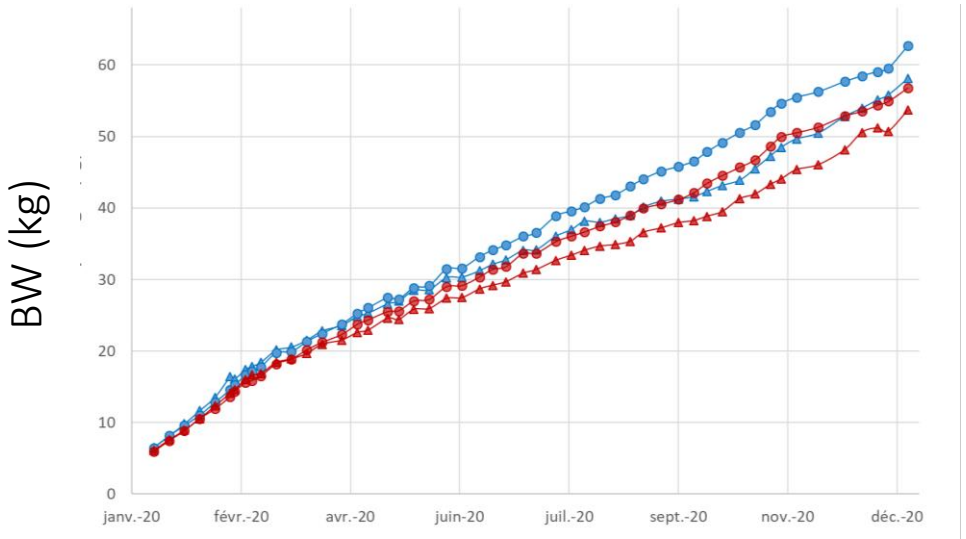
Animal building-block

- Deepen our understanding of resilience
  - 2 aspects of adaptive capacities
    - Partly determined by genetic background (allocation strategy)
    - Built during early-life development and potentially impaired by the environment
  - Adult adaptive capacities $\rightarrow$ Interplay between early-life and genotype
  - Experimental design
    - Divergent genetic lines for longevity (INRAE GenPHYSE, Toulouse)
    - Contrasted diets during growing period
    - Responses to short-term nutritional challenges

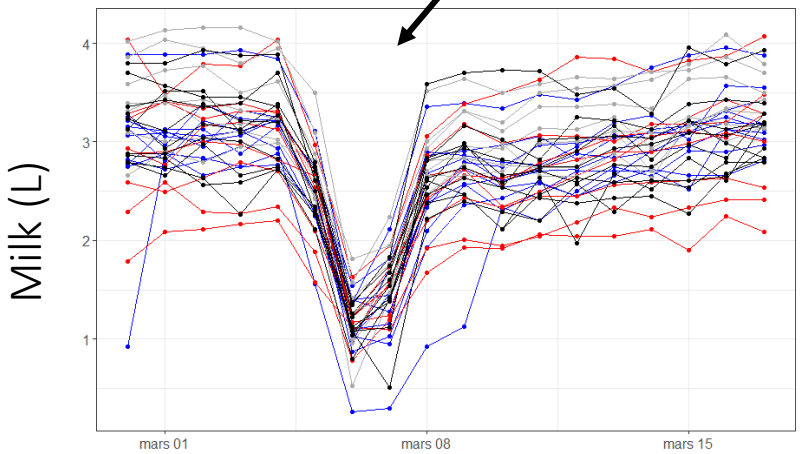
#1 How does it work?
Animal building-block

Longevity -
Longevity +
Longevity -
Longevity +

Benefits of integrating modelling and experimental approaches



2 days on straw in early lactation



First lactation

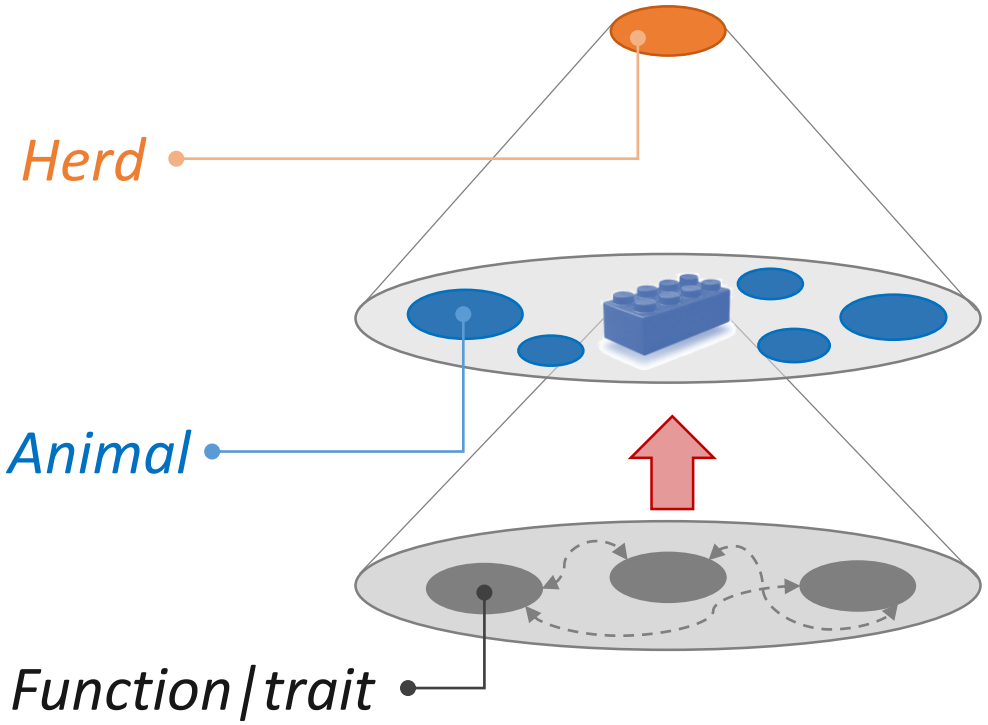
Birth

1st mating

1st kidding

#1 How does it work?

Animal building-block



Nutritional principles

Feed efficiency

Genetic background

GSP for acquisition | allocation

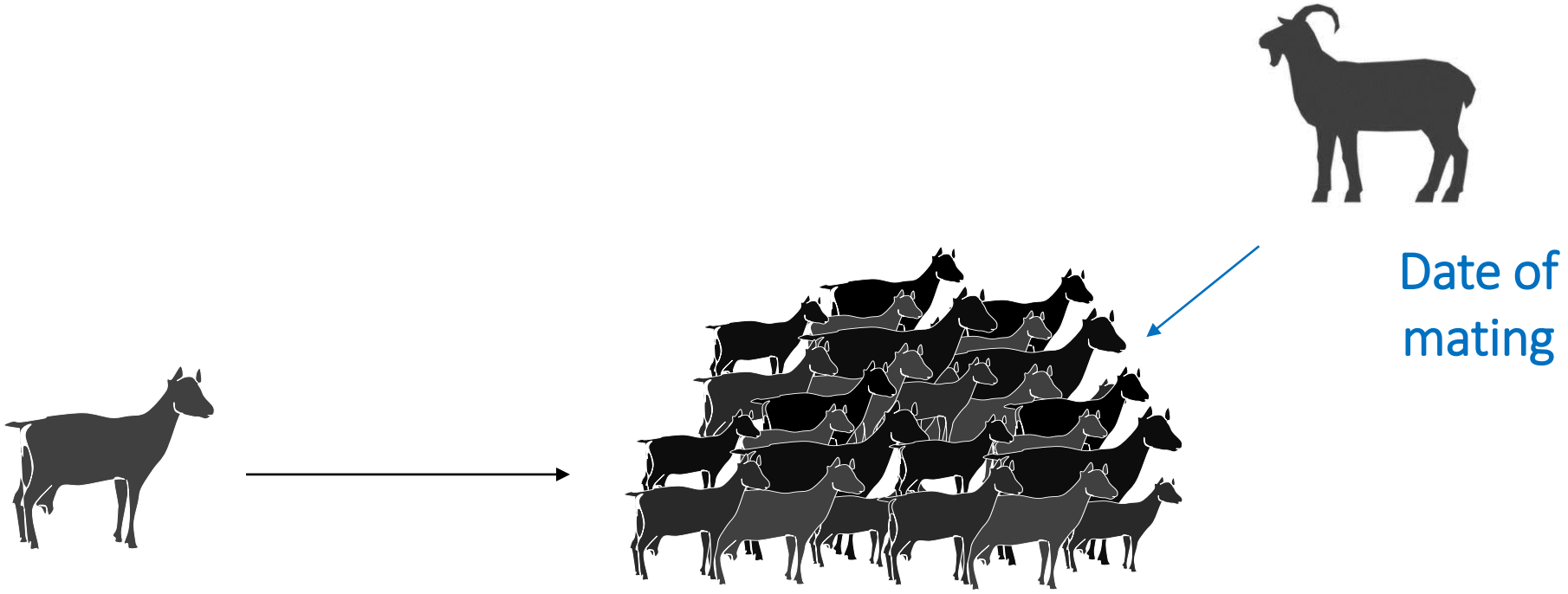
Adaptive capacities

Body reserves, responses to nutritional challenge

#1 How does it work?

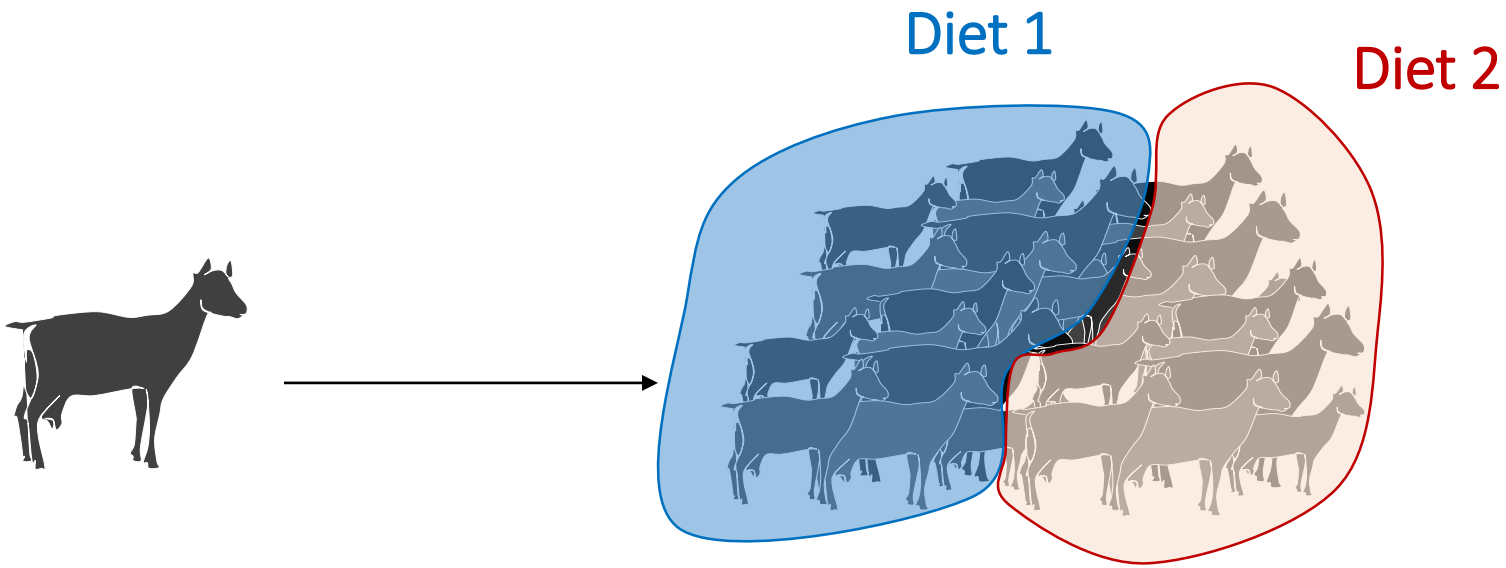
Herd level

- Multiplying individual models (IBM) to get a population
  - Managed by the farmer
    - Reproduction, (group) feeding, replacement, culling



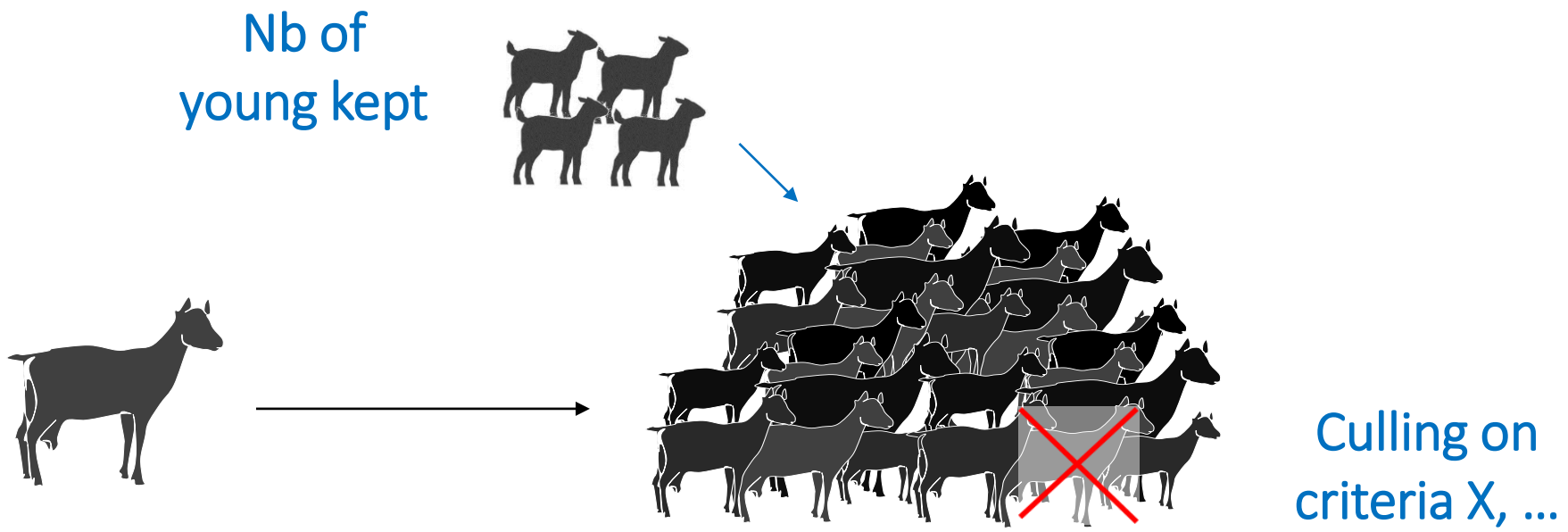
#1 How does it work?
Herd level

- Multiplying individual models (IBM) to get a population
  - Managed by the farmer
    - Reproduction, (group) feeding, replacement, culling



#1 How does it work?
Herd level

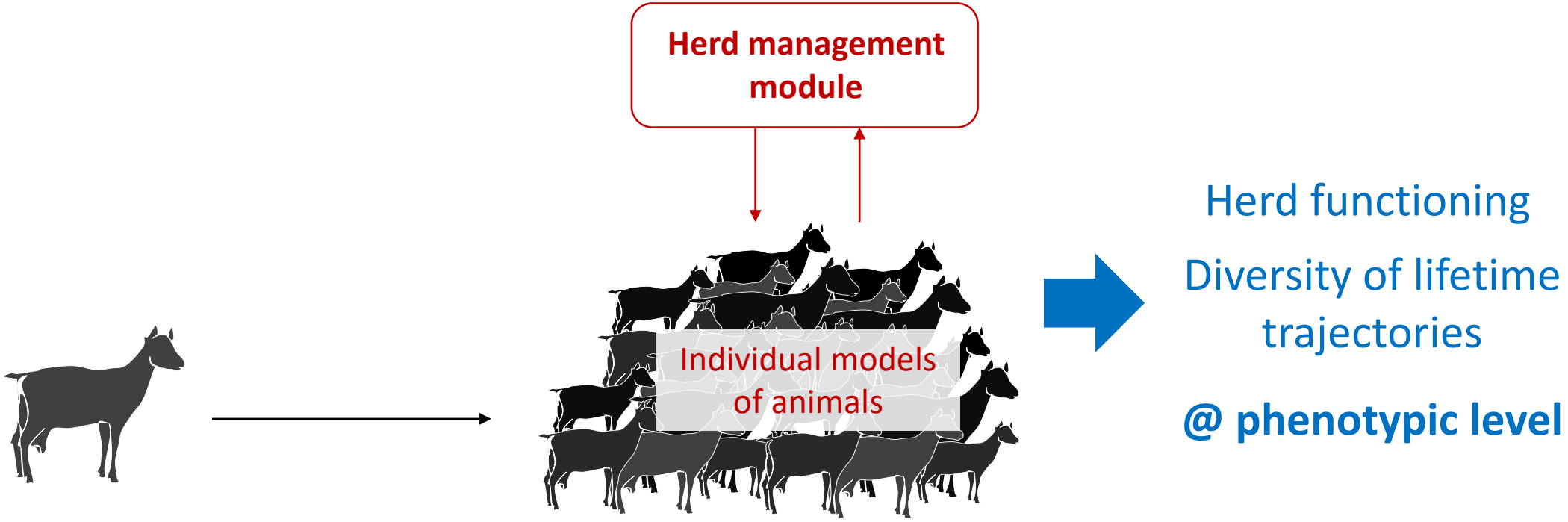
- Multiplying individual models (IBM) to get a population
  - Managed by the farmer
    - Reproduction, (group) feeding, replacement, culling



#1 How does it work?

Herd level

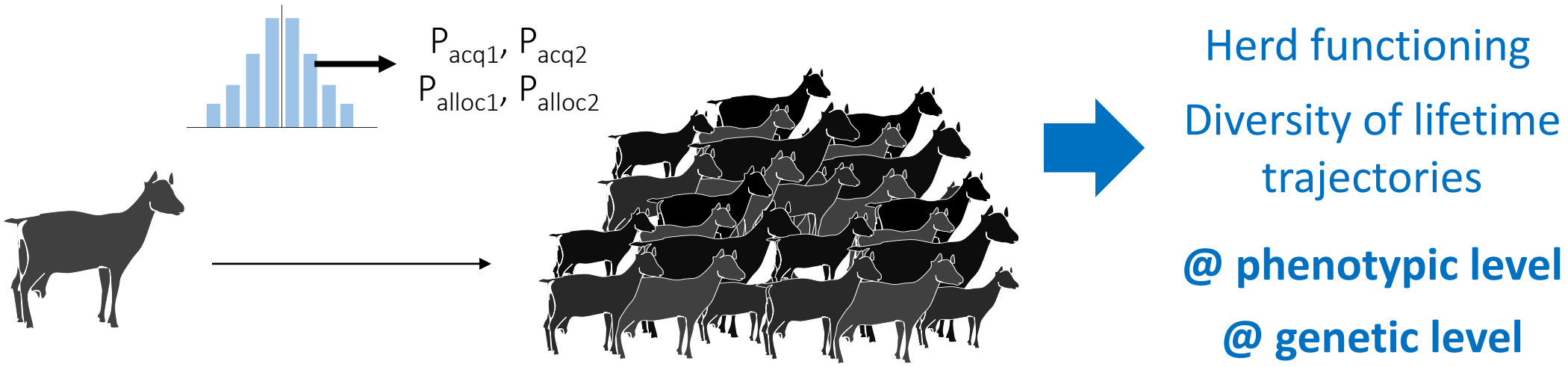
- Multiplying individual models (IBM) to get a population
  - Managed by the farmer
    - Reproduction, (group) feeding, replacement, culling



#1 How does it work?

Herd level

- Multiplying individual models (IBM) to get a population
  - Managed by the farmer
    - Reproduction, (group) feeding, replacement, culling
  - With a genetic diversity
    - Genetic-scaling parameters (GSP) → different genotypes



Herd functioning

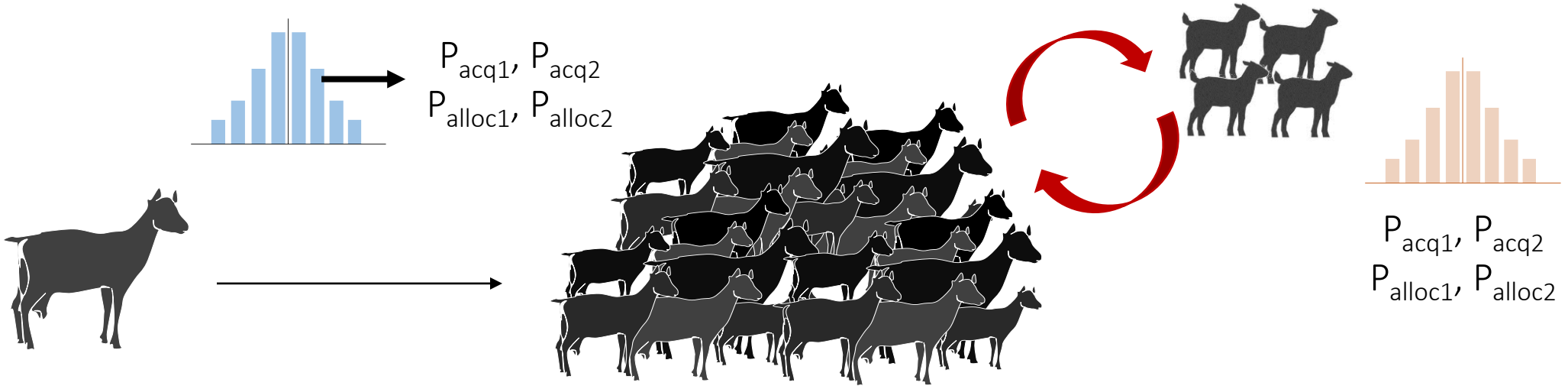
Diversity of lifetime trajectories

@ phenotypic level

@ genetic level

#1 How does it work?
Herd level

- Multiplying individual models (IBM) to get a population
  - Managed by the farmer
    - Reproduction, (group) feeding, replacement, culling
  - With a genetic diversity
    - Genetic-scaling parameters (GSP) → different genotypes
    - Pedigree + GSP transmissions → effects of selection strategy



#1 How does it work?
Herd level

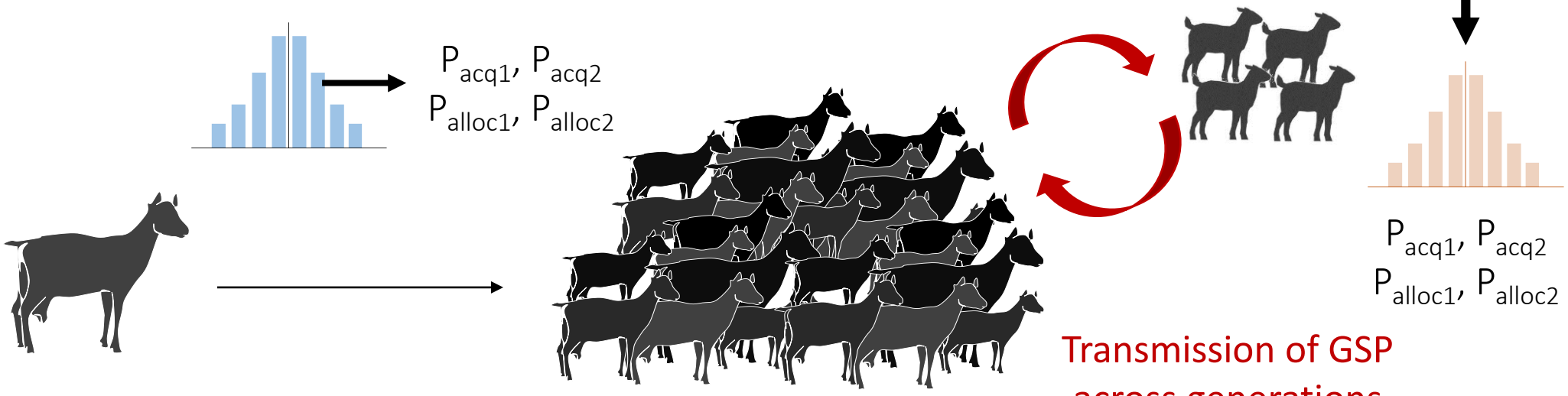
- Multiplying individual models (IBM) to get a population
  - Managed by the farmer
    - Reproduction, (group) feeding, replacement, culling
  - With a genetic diversity
    - Genetic-scaling parameters (GSP) → different genotypes
    - Pedigree + GSP transmissions → effects of selection strategy

Virtual sire population

Breeding values for GSP

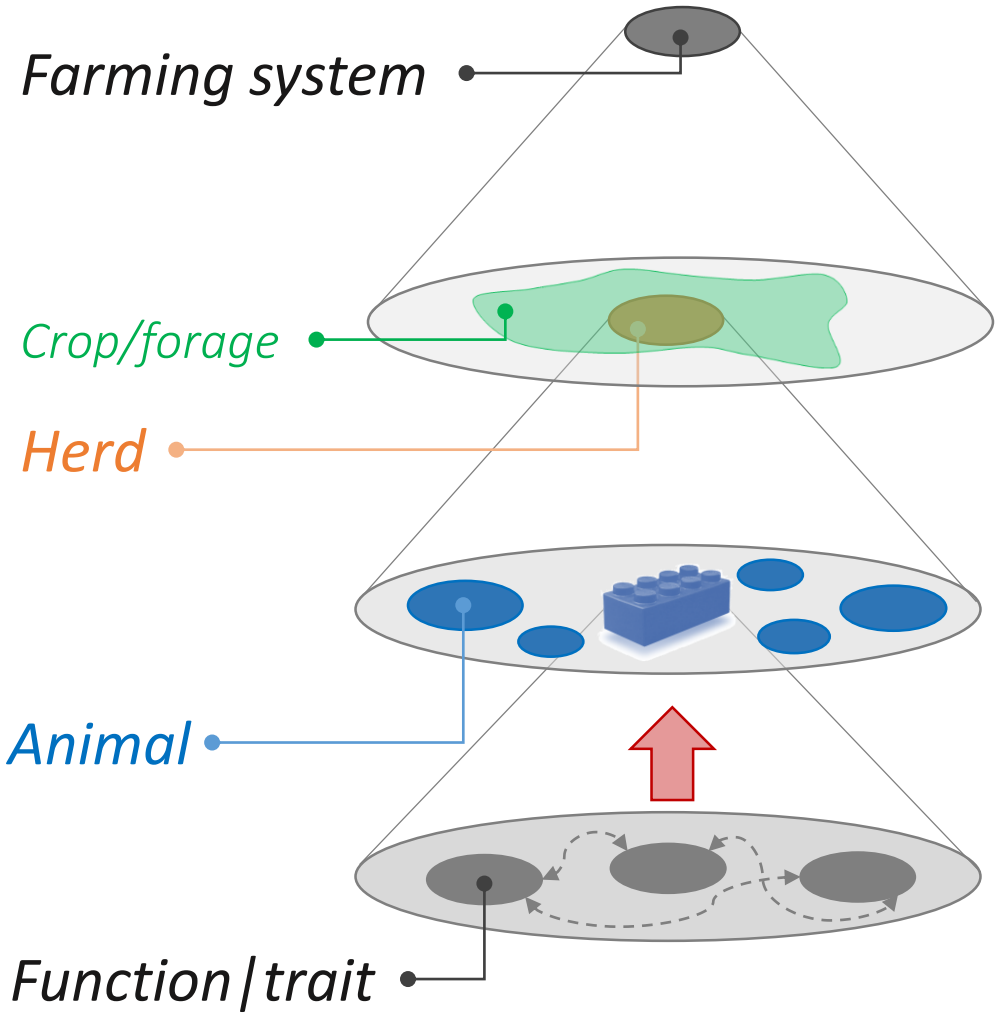
h^2, r_G

Pedigree



Transmission of GSP across generations

#1 How does it work?
Herd level

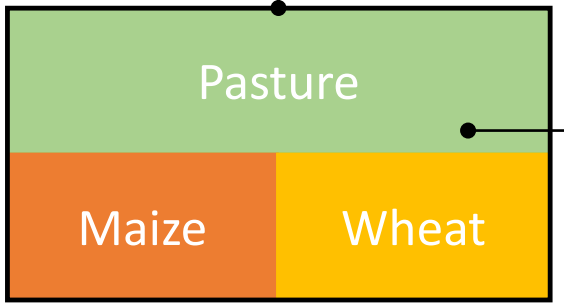


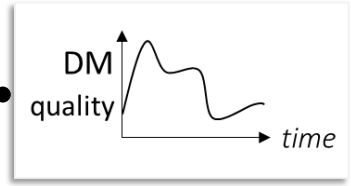
#1 How does it work?
Farm level

- Farm representation → connection between herd and feed resource

Surface allocation (nb ha/type of surface)

Surfaces





Production for each type of surface

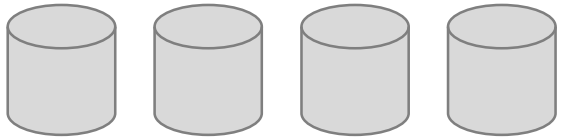
Benefits of integrating modelling and on-farm surveys

Rules for loading stocks (cutting grass)

Feeding plan from herd module (animal demand)

Rules for subsitution/purchase of feedstuff in diet

Stocks



Maize silage | Hay | Grass silage | Cereals

Distributed diets

#1 How does it work?
Farm level

Feed resource module

Herd module

Demand in feed

Surfaces

Surface allocation (nb ha/type of surface)

Pasture

Maize | Wheat

DM quality / time

Production for each type of surface

Rules for loading stocks (cutting grass)

Stocks

Maize silage | Hay | Grass silage | Cereals

Rules for subsitution/purchase of feedstuff in diet

Distributed diets

Farmer's practices

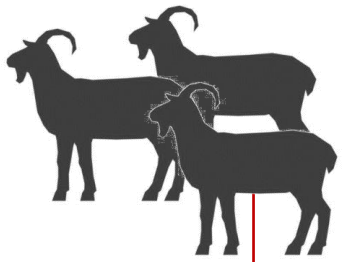
Culling | Replacement

Herd size | Reproduction

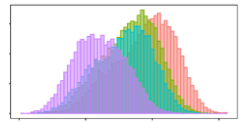
Feeding plan

	Period 1	Period 2	[...]
Maize			
Hay			
Silage			
Cereals			

Sire population



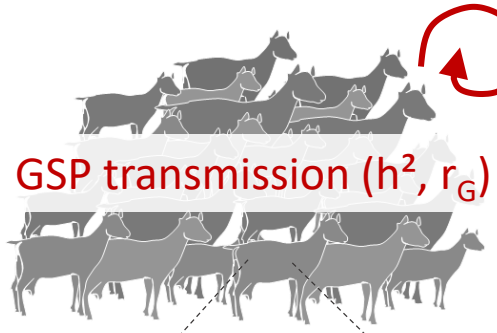
GSP distribution



GSP

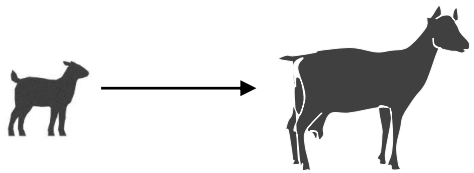
Breeding rules (pedigree)

Herd



Technical variables
(DM consumption, milk, animal numbers, ...)
→ R&E indicators

Animal



Genetic scaling parameters

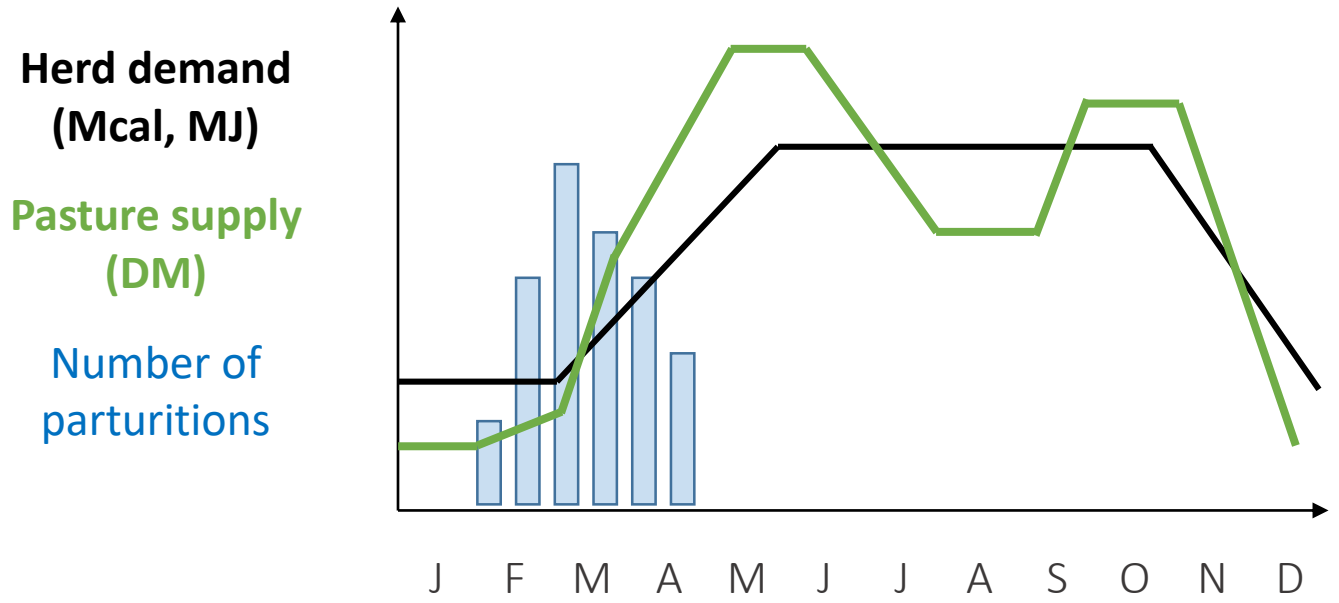
GSP

Outline

- Context of the modelling approach
- How does it work?
  - Key features for integrating disciplines
- What is it for?
  - Potentialities for bench-testing
- Conclusion

#2 What is it for?
Interactions among elementary components

- Testing combinations of reproduction and feeding options
  - Matching herd demand and resource supply
  - Managing on-farm stocks



#2 What is it for?
Scaling-up effects

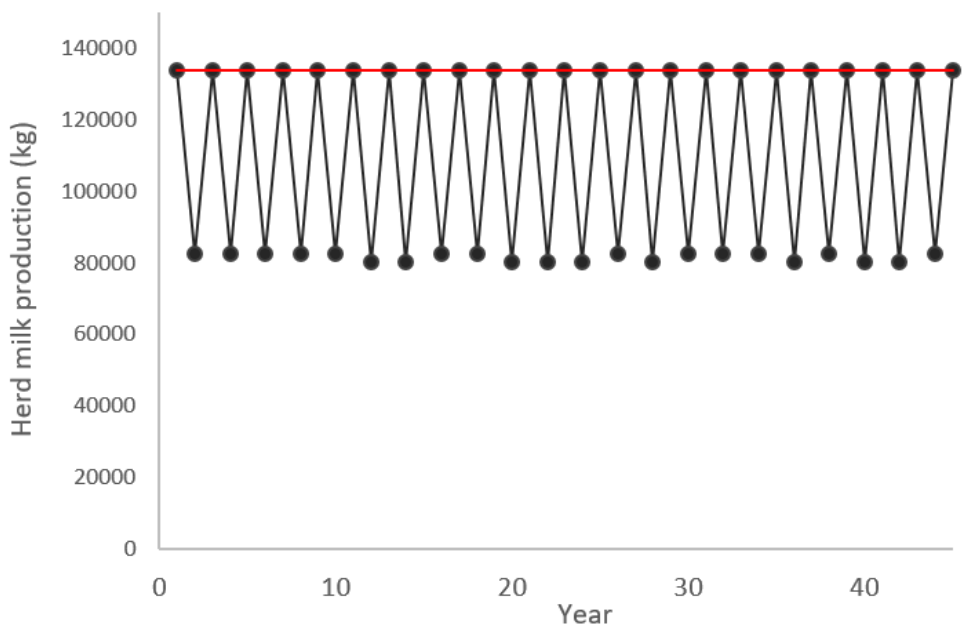
- Testing if herd resilience emerge from the variability in adaptive capacities of animals

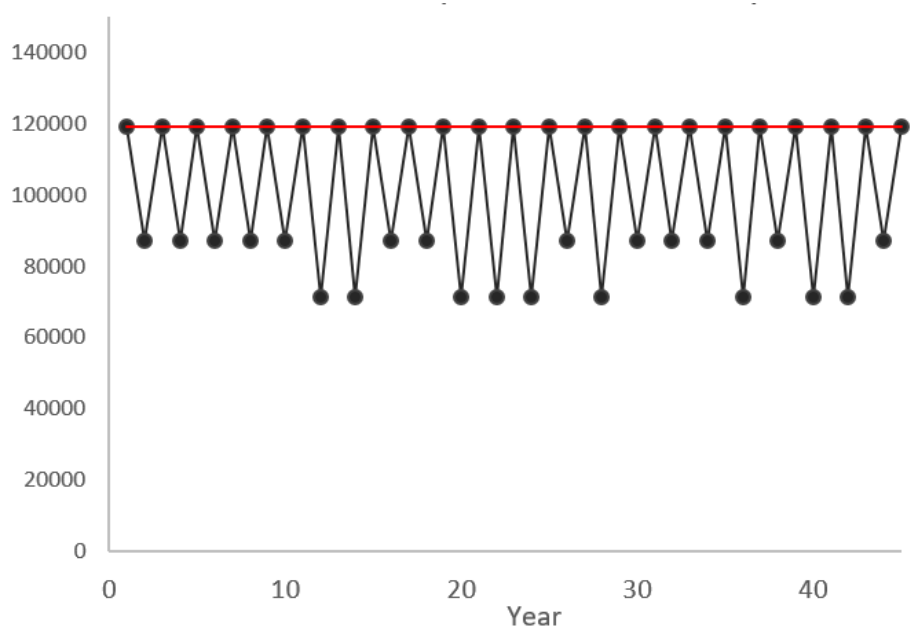
Tichit et al., 2012
Blanc et al., 2013

- Let's consider…
  - 3 environmental challenges, occuring randomly every 2 years
    - Feed shortage, health and thermal stress
  - 3 types of dairy sheep
    - Type 1: 340L/y in normal conditions and – 40% in all challenges
    - Type 2: 280L/y in normal + feed shortage and – 40% in health + thermal stress
    - Type 3: 280 L/y in normal + health and – 40% in feed shortage + thermal stress

#2 What is it for?
Scaling-up effects

- 2 herds, different in the type of females composition
  - "Specialized" → 90% type 1, 5% type 2 and 5% type 3
  - "Diversified" → 30% type 1, 35% type 2 and 35% type 3





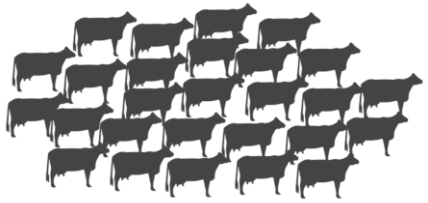
Specialized herd has a higher baseline production

Diversified herd has a lower variability in production level

#2 What is it for?
Long-term effects

- Testing how selection strategy is impacted by environmental change
  - Comparison of 2 identical populations (clones) in 2 ≠ environments

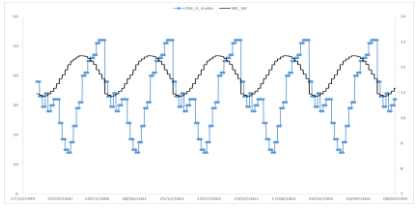
n = 20000



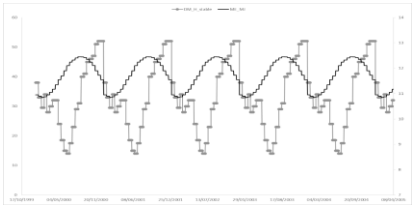
Genetic variation in acquisition and allocation strategies (GSP)

Pedigree structure with 200 sires

High feed resource



Low feed resource



Simulated traits in favourable environment

Cow	Sire	Efficiency	Longevity	MY	….	…..
1	1					
2	1	Genetic parameters				
3	1					

Simulated traits in poor environment

Cow	Sire	Efficiency	Longevity	MY	….	…..
1	1					
2	1	Genetic parameters				
3	1					

#2 What is it for?
Long-term effects

High and stable	2nd lactation production	2nd lactation efficiency	Lifetime efficiency	BW at 2nd calving	Body reserves at 2nd calving	Delay to 2nd conception
n	*17945*	*17945*	*17945*	*18171*	*18171*	*18171*
2nd lactation production	0.301					
2nd lactation efficiency	0.697	0.348				
Lifetime efficiency	0.708	0.854	0.123			
BW at 2nd calving	0.265	-0.425	-0.394	0.396		
Body reserves at 2nd calving	0.136	-0.225	0.184	0.366	0.307	
Delay to 2nd conception	0.126	0.432	0.080	-0.251	-0.473	0.008
Low and stable						
n	*13640*	*13640*	*13640*	*17019*	*17019*	*17019*
2nd lactation production	0.185					
2nd lactation efficiency	0.983	0.311				
Lifetime efficiency	0.526	0.477	0.211			
BW at 2nd calving	-0.528	-0.598	-0.768	0.390		
Body reserves at 2nd calving	0.011	-0.139	0.616	0.015	0.263	
Delay to 2nd conception	0.241	0.402	-0.314	-0.285	-0.862	0.011

When feed resource became limited

r_G between lactation and life efficiency decreased

r_G between life efficiency and body reserves increased

Importance of a balanced breeding-goal for selection

Puillet et al., 2021

Conclusion and perspectives

- “Just another model”
  - Missing elements (e.g. focus on animal component, not resource)
- But a concrete example of:
  - A framework for integrating different disciplines/approaches
    - Nutrition, genetics, farming systems
    - Mixing concepts, experimental data, surveys, computer code
    - Determinants of R & E
- An evolving framework
    - Having genetic-scaling parameters + genetic architecture
      - Open the door for genomics
    - Lifetime trajectories
      - Open the door for PLF

Thanks for your attention

The PRIMA programme is supported under Horizon 2020, the European Union's Framework Programme for Research and Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 772787

Join the next generation publication model for open and transparent science

Peer Community In

Animal Science

Free and transparent preprint and postprint recommendations in animal science

https://animsci.peercommunityin.org

contact@animsci.peercommunityin.org

PCI_AnimSci