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A stochastic animal life cycle simulation model and its herd structure

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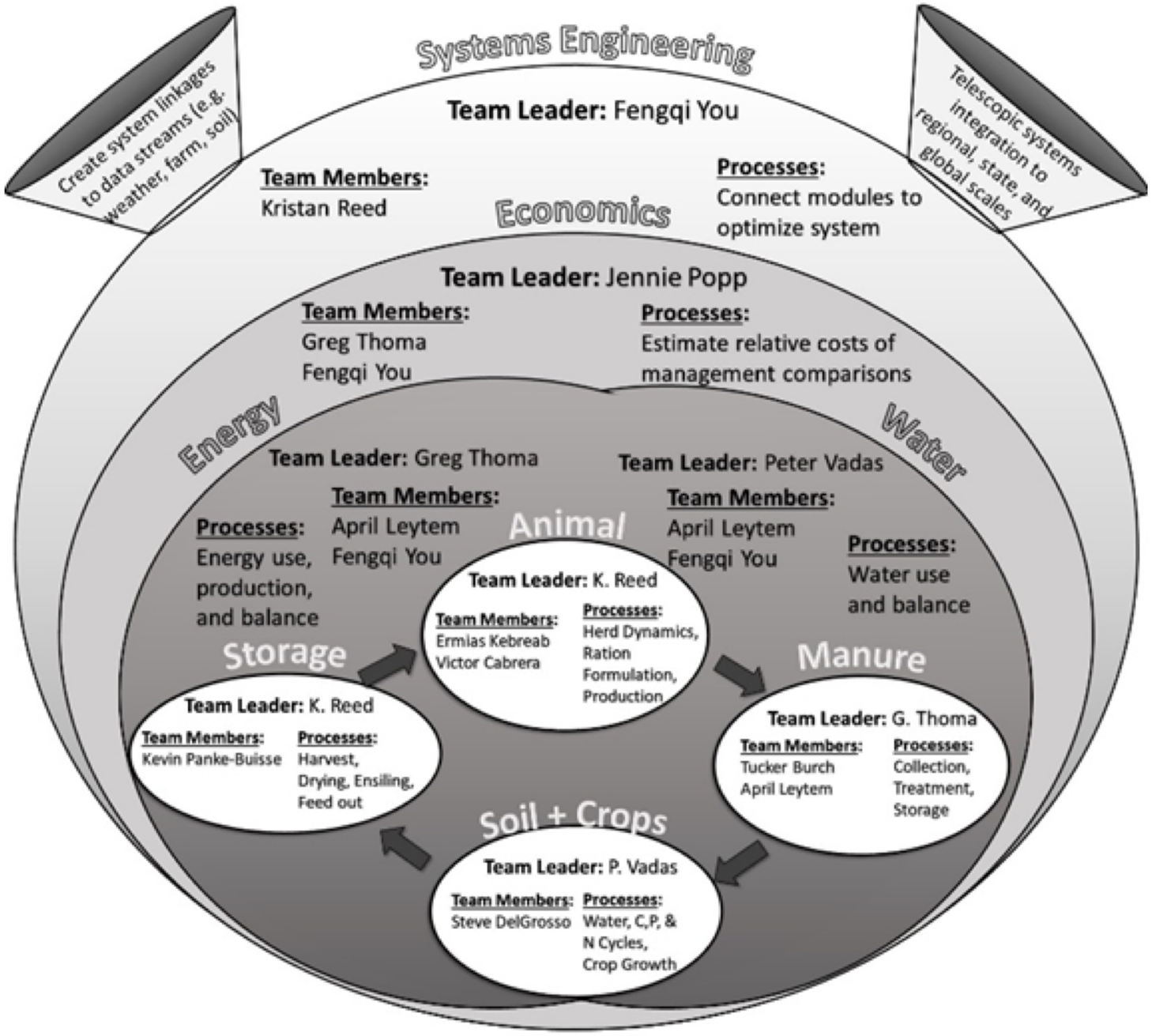
Ruminant Farm System (RuFaS) model





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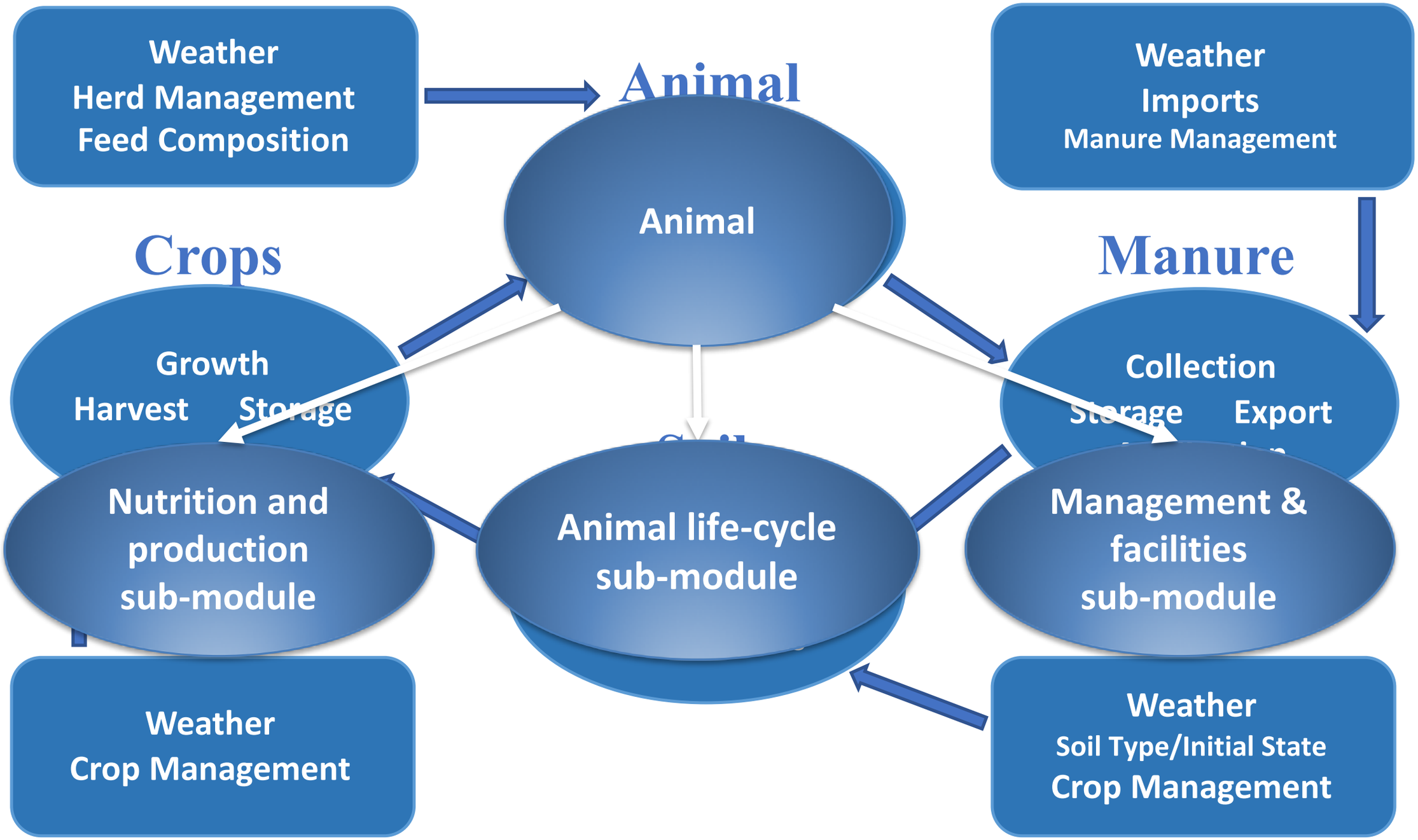
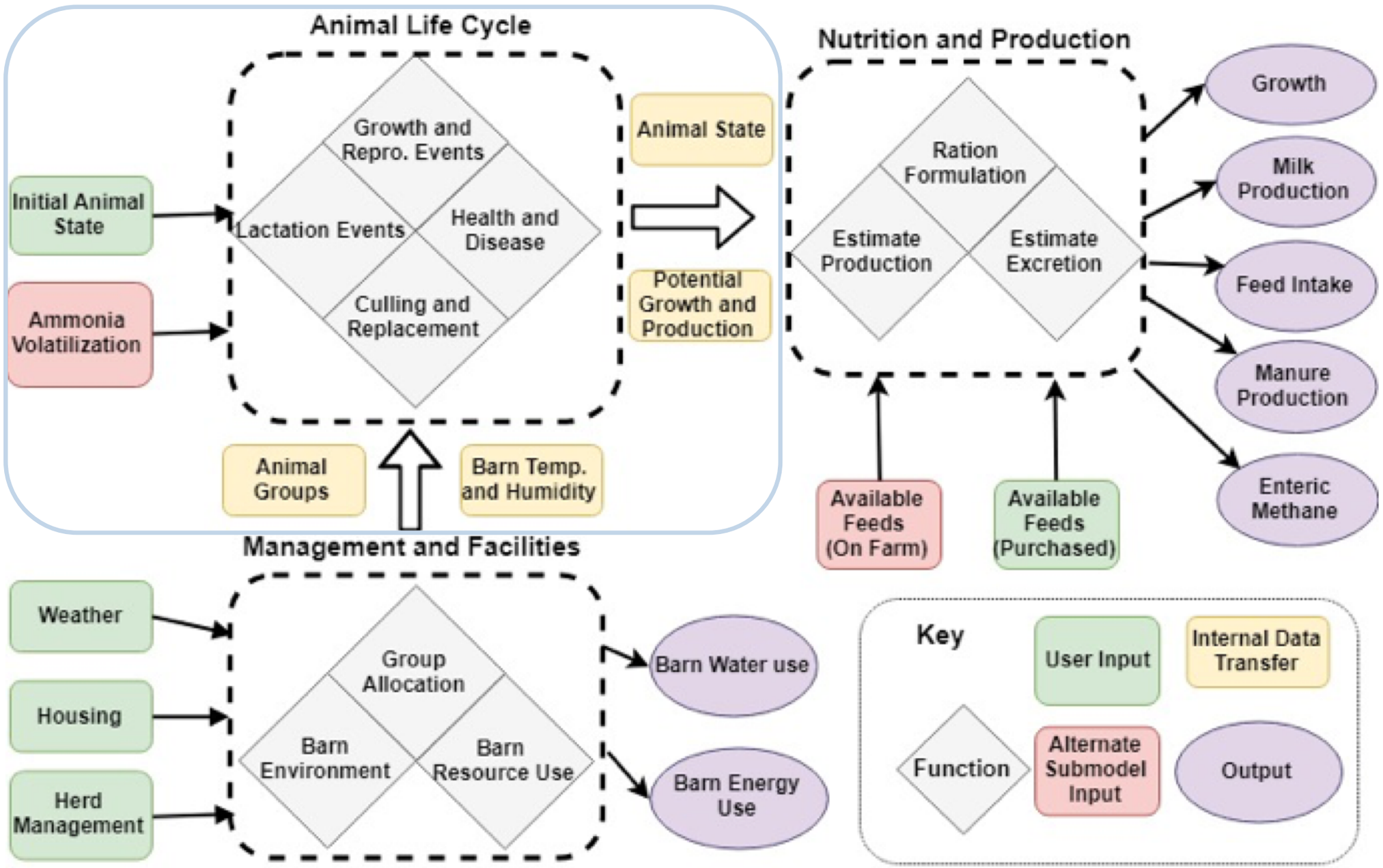




Animal model

- Animal module daily information flow





Animal life cycle model

- Objectives
  - To simulate the dairy herd accurately
    - Represent the underlying logic revealed by research
    - Show the real situation on farm
  - To build up a flexible framework
    - Have the ability to include components related to animals
    - Reflect the impact of changes on the dairy farm



Animal life cycle model

- Monte Carlo stochastic simulation
- Simulate individual animal events from birth until leaving on daily basis
- Herd level distributions affect animal level probabilities, and are represented when individual animals accumulates
- Modularized to allow flexibility to mix herd and management decisions
- Build a framework allowing incorporate more factors and findings



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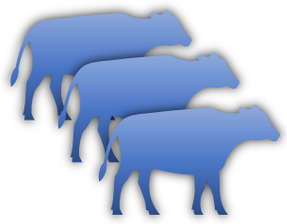
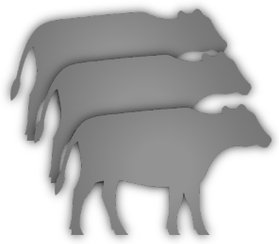
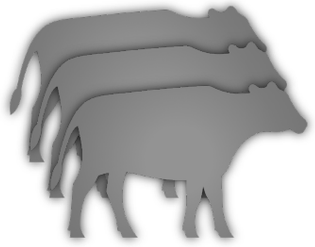
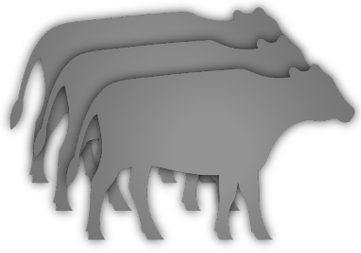
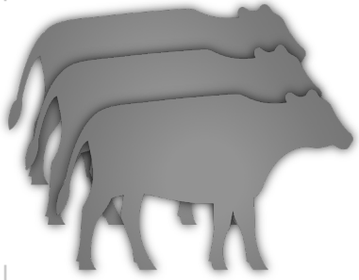
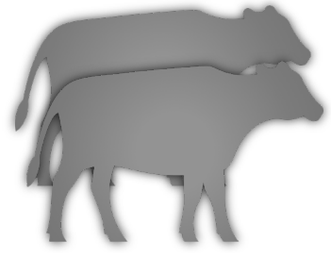
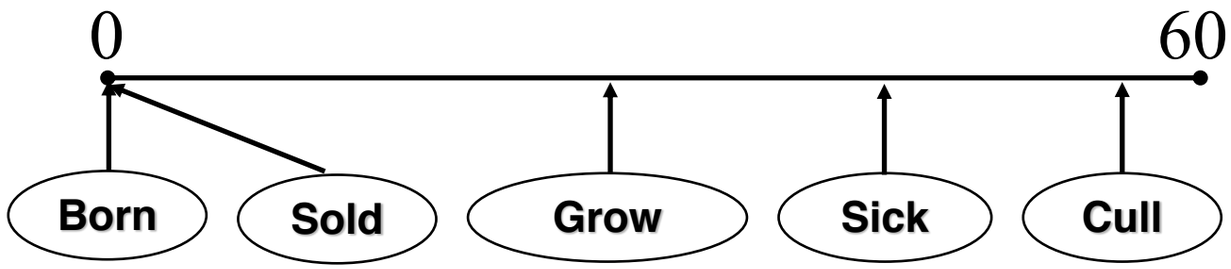
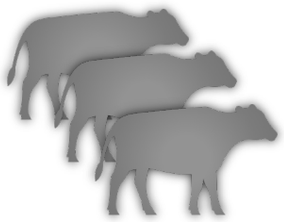
Stage and events

Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
					
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell

- Calves
  - Events:





- Born, gender assigned according to semen type
- Sold, as male/ female calf
- Grow, with initial birth weight and average daily gain
- Sick, calf specific health issues
- Cull, leaving the group before wean



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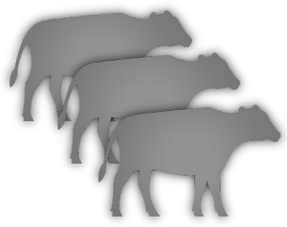	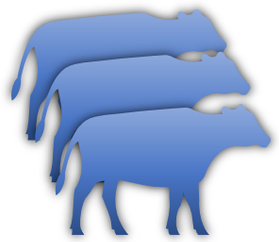	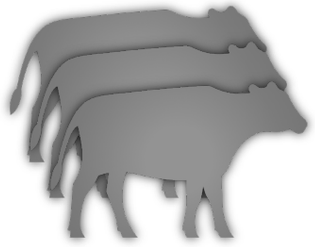	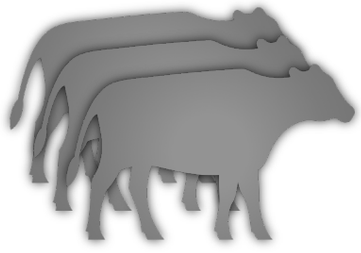	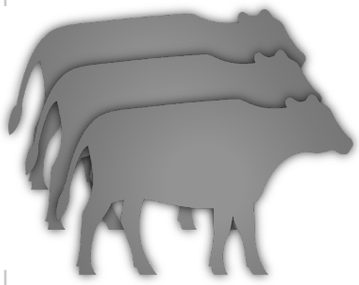	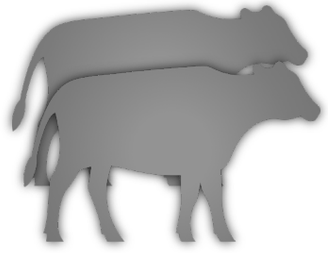
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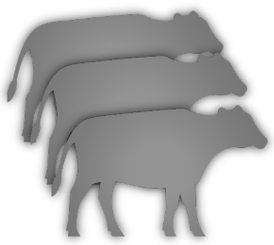
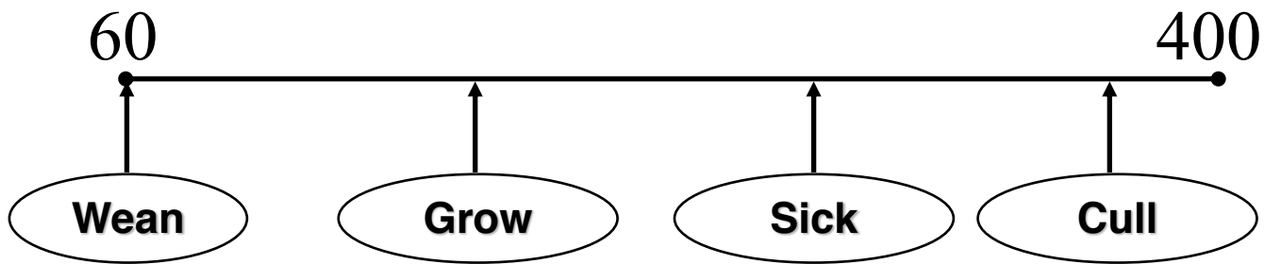
Heifers I

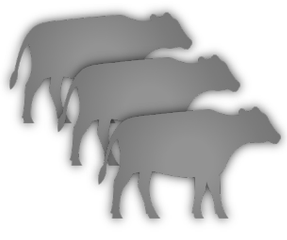
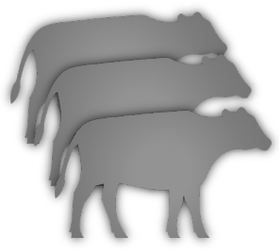
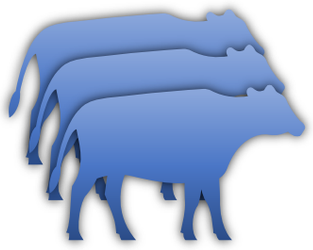
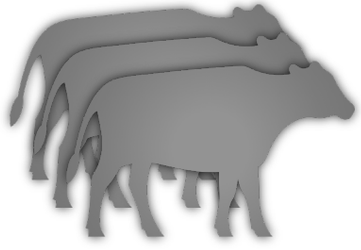
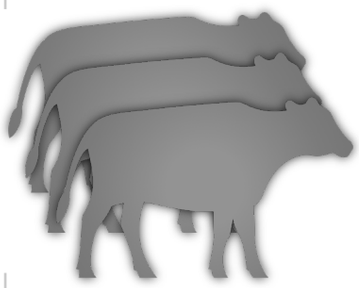
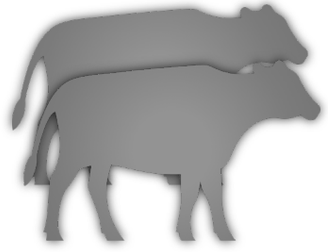


- Events:



- Wean, feed
- Grow, with ADG
- Sick
- Cull, leaving the group before breeding

Stage and events

Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
					
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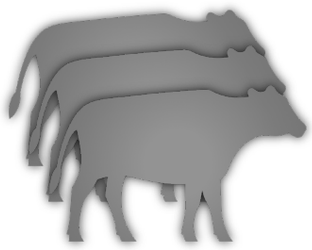
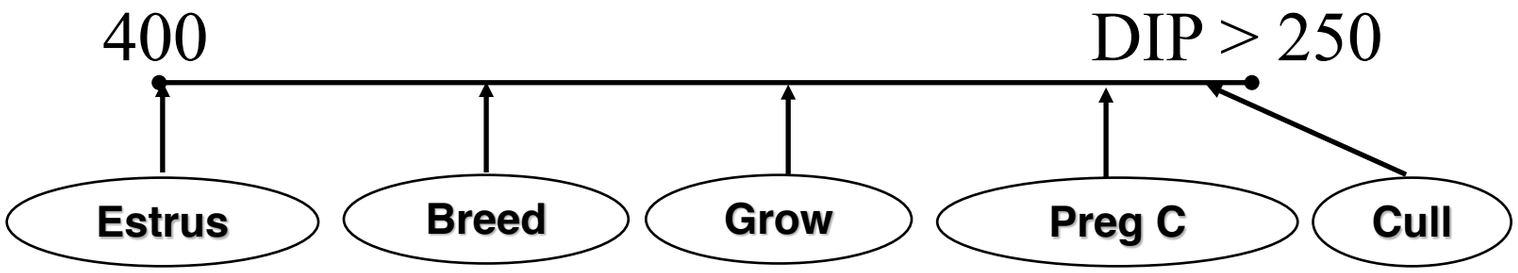
- Heifers II

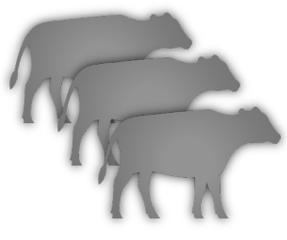
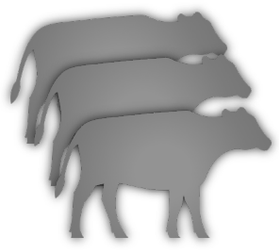
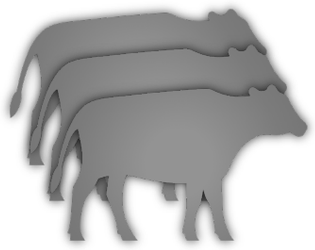
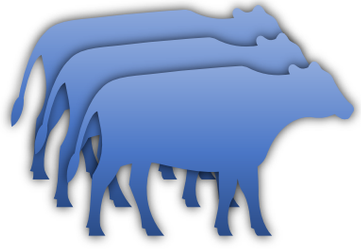
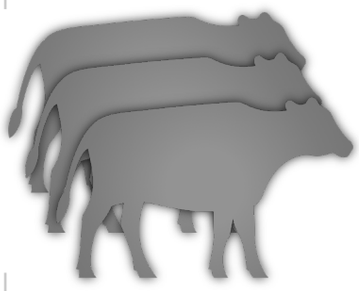
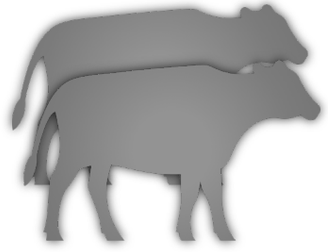


- Events:



  - Estrus, if estrus detection involved, estrus ~ N(21,2.5)
  - Breed, AI after ED and TAI protocols
  - Grow, related to nutrition and pregnancy status
  - Preg checks, three times on day 32, 91, 200
  - Cull, reproductive failure and health issue

Stage and events

Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
					
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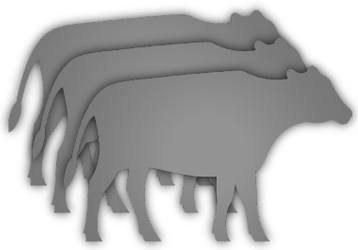
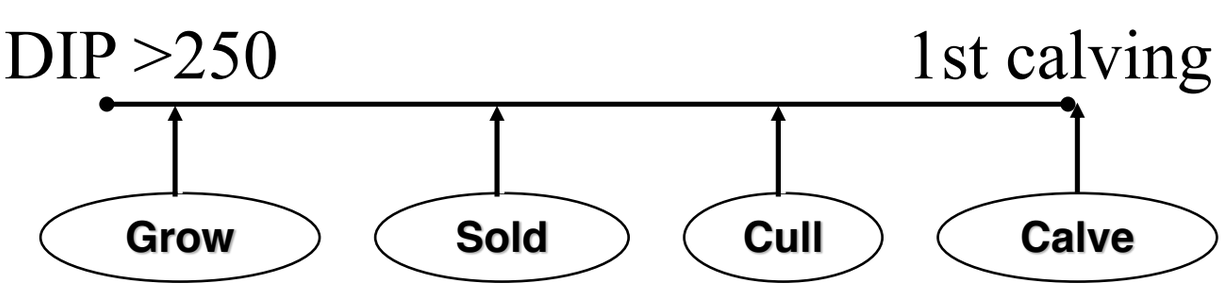
- Heifers III





  - Events:
    - Grow, nutrition needs and supply
    - Sold, as pregnant heifer
    - Cull, leaving the group before enter
    - Calve, at the end of the gestation ~ N(278,6)



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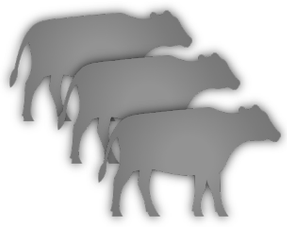	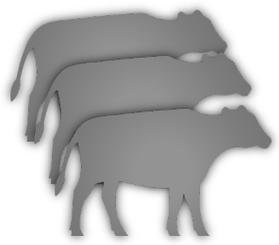	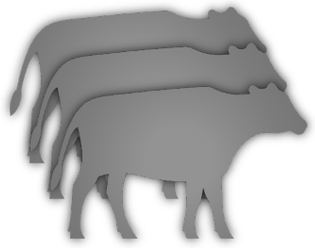	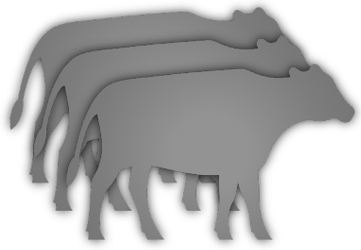	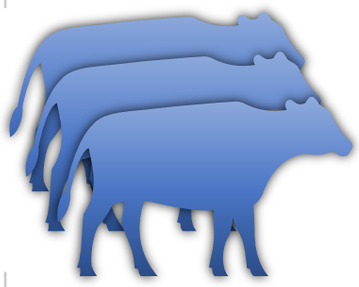	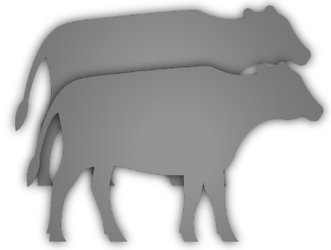
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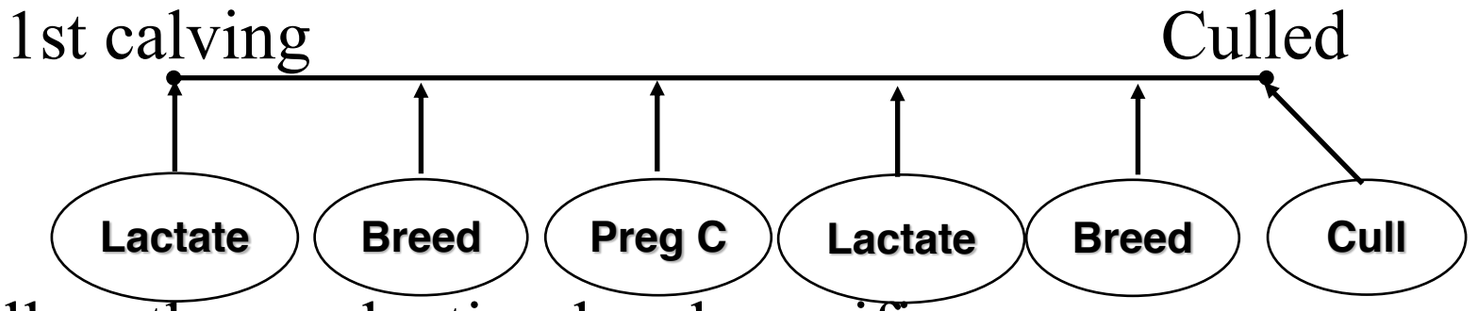
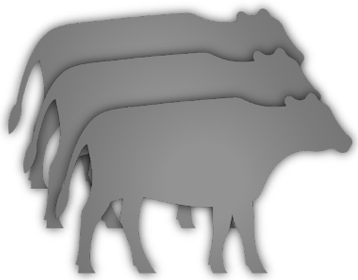
- Cow
  - Events:





- Lactate, follow the production level specific curve
- Breed, AI after ED and TAI protocols
- Preg checks, three times on day 32, 91, 200
- Calve, at the end of the gestation ~ N(278,6)
- Sick, calf sensitive illness
- Cull, leaving the group before wean



Stage and events

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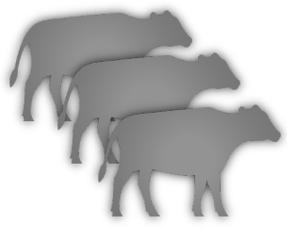	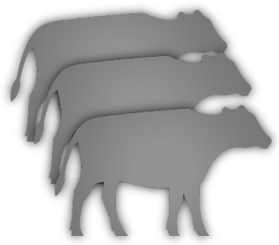	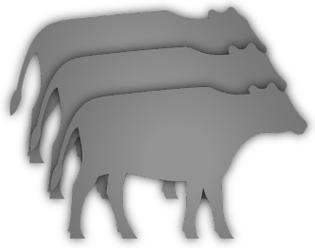	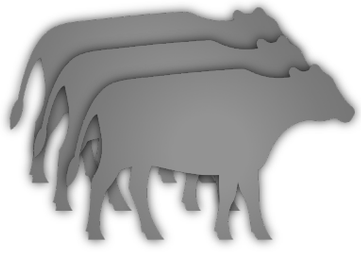	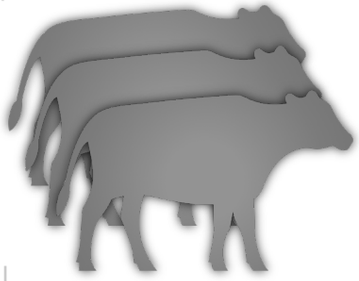	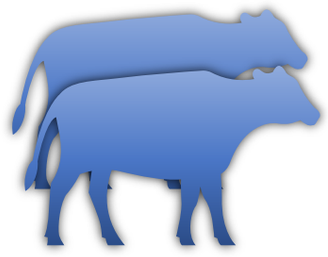
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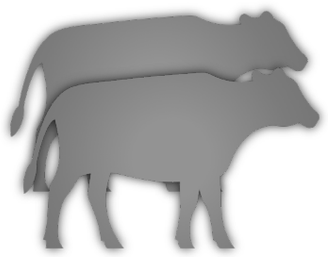
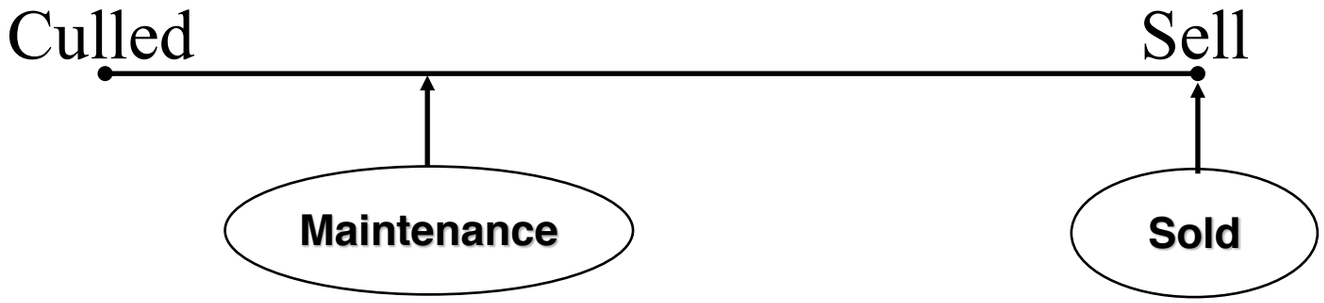
- Culled

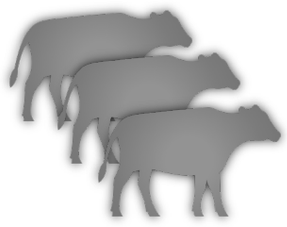
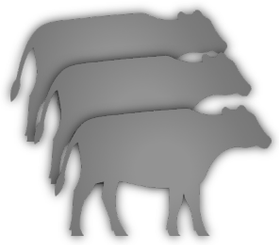
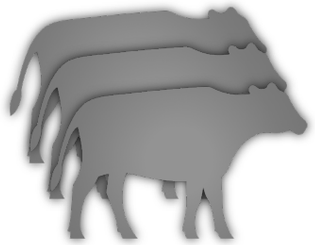
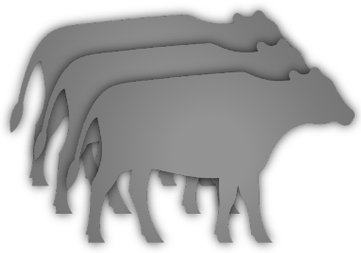
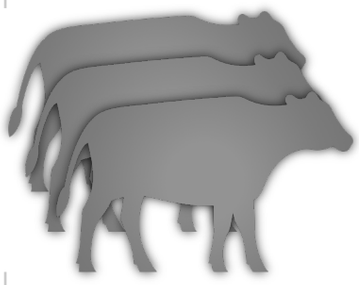
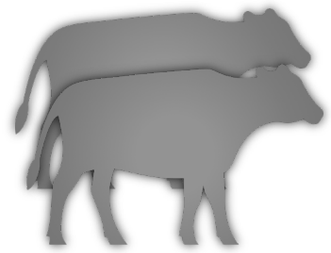


  - Events:
    - Maintenance
    - Sold





Stage and events

Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
					
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell

- Programmed in detail:
  - Life events and herd structure ~ (Pinedo et al. 2010)
  - Repro protocols ~ Dairy Cattle Reproduction Council protocols
  - Lactation curves ~ Wood's / MilkBot models
  - Health culling ~ (Kalantari et al., 2016)



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Stage and events

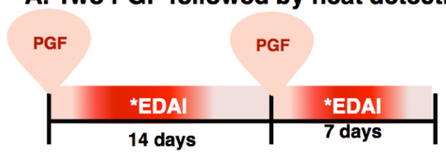
DCRC
DAIRY CATTLE REPRODUCTION COUNCIL

"Helping farmers optimize fertility in dairy cattle"

Reproductive Management Strategies for Dairy Heifers

Artificial insemination after detection of estrus

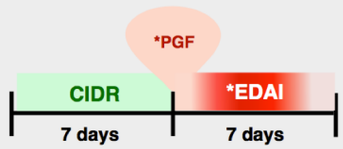
A. Two PGF followed by heat detection



Definitions and comments:

PGF = Prostaglandin $F_{2\alpha}$. ***Intensity of color in EDAI** indicates estrus intensity. Most heifers are in estrus 2-7 days after PGF. Approximately 70% of the heifers will be in estrus in the first 14 days after the first PGF. The remaining heifers should be in estrus after the second PGF. Non-responding heifers might be prepubertal. TAI can be used to provide a breeding opportunity of heifers not detected in estrus

B. CIDR program with PGF at removal



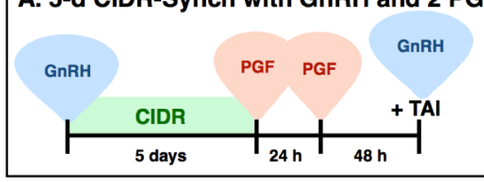
Definitions and comments:

CIDR = Controlled internal drug release. Approximately 70% of heifers should be in estrus during 7 days after the CIDR removal. Non responding heifers may be prepubertal. CIDR-based programs may induce fertile entrees in some prepubertal heifers. ***PGF** can be given on day 6 instead of 7 (One day before CIDR removal) to increase synchrony of estrus in the program

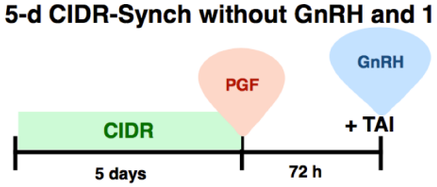
Programs for timed AI

GnRH = Gonadotropin-releasing hormone.
For the timed AI program presented below, the option A yields greater number of pregnancies per insemination than option B

A. 5-d CIDR-Synch with GnRH and 2 PGF



B. 5-d CIDR-Synch without GnRH and 1 PGF



Calendar options

A. Two PGF followed by heat detection

SUN	MON	TUE	WED	THU	FRI	SAT
	PGF	EDAI	EDAI	EDAI	EDAI	EDAI
EDAI	EDAI	EDAI	EDAI	EDAI	EDAI	EDAI
EDAI	PGF	EDAI	EDAI	EDAI	EDAI	EDAI
EDAI	EDAI					

B. CIDR program with PGF at removal

SUN	MON	TUE	WED	THU	FRI	SAT
	CIDR	CIDR	CIDR	CIDR	CIDR	CIDR
CIDR	CIDR PGF	EDAI	EDAI	EDAI	EDAI	EDAI
EDAI	EDAI					

C. 5-d CIDR-Synch with GnRH and 2 PGF

SUN	MON	TUE	WED	THU	FRI	SAT
			CIDR GnRH	CIDR	CIDR	CIDR
CIDR	CIDR PGF	PGF		GnRH TAI		

Note: This reproductive management sheet was assembled by the Dairy Cattle Reproductive Council (DCRC). Programs are intended to promote sustainable food production through sound dairy practices. The DCRC recommends working with a licensed veterinarian for the proper administration of all treatments.

DAIRY CATTLE REPRODUCTION COUNCIL

Reproductive Management Strategies for Dairy Cows

Detection of estrus followed by timed AI

For herds with efficient and accurate estrus-detection systems

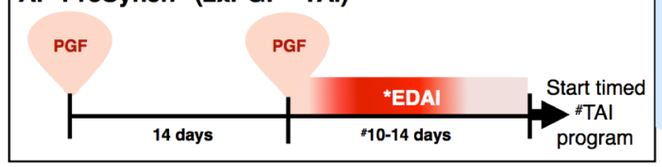
Definitions and comments:

EDAI = Estrous detection followed by AI
***Start** and **stop dates** for EDAI depend on voluntary waiting period **(VWP)** and the reproductive goals of the each herd

Presynchronization methods used before TAI

Used with TAI programs below to increase pregnancy per AI (P/AI). Can be used with or without EDAI

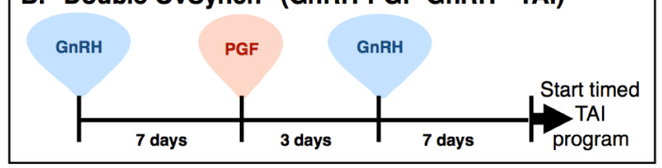
A. "PreSynch" (2xPGF - TAI)



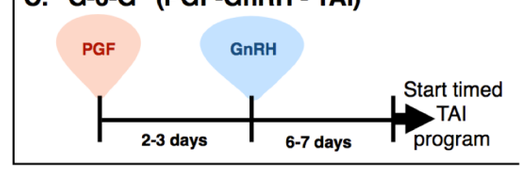
Definitions and comments:

PGF = Prostaglandin $F_{2\alpha}$
GnRH = Gonadotropin-releasing hormone
***Intensity of color in EDAI** denotes period (2-7 days) to expect most cows in estrus; **#TAI** program starting 10-12 days after PGF results in higher fertility

B. "Double OvSynch" (GnRH-PGF-GnRH - TAI)



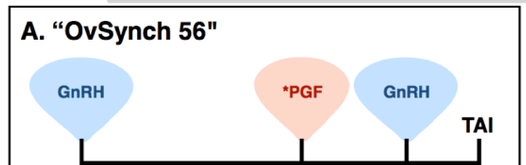
C. "G-6-G" (PGF-GnRH - TAI)



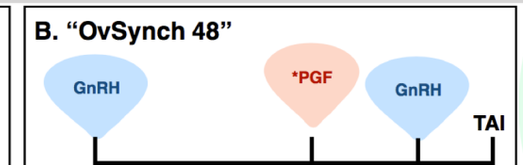
Synchronization methods for TAI

Can be used alone or with presynchronization (see above), and with or without EDAI detection.
Presynchronization increases fertility. The use of the CIDR benefits fertility of cows with no CL starting TAI.

A. "OvSynch 56"

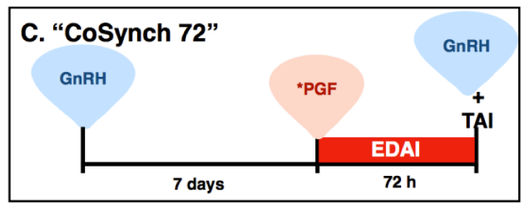


B. "OvSynch 48"

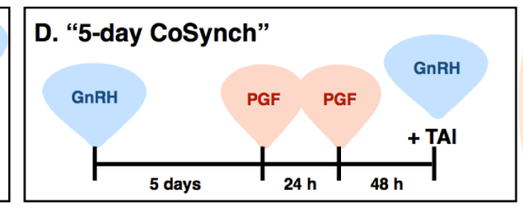


CIDR can be used in any program being inserted at 1st GnRH and removed at PGF

C. "CoSynch 72"



D. "5-day CoSynch"



**A second PGF 24 h after the first PGF improves luteolysis and fertility*



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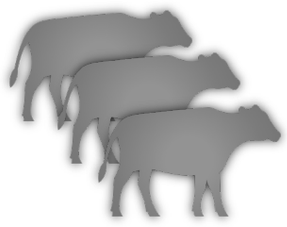
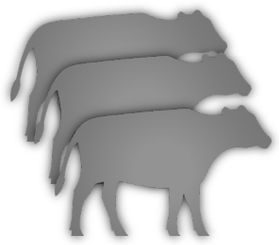
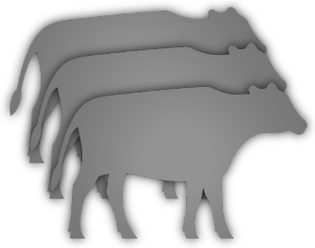
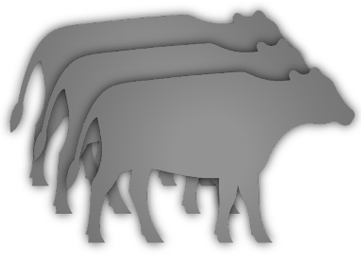
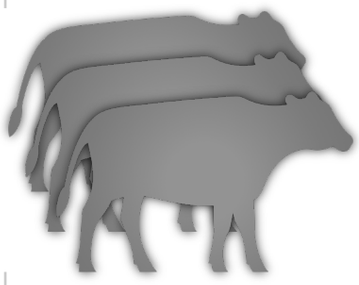
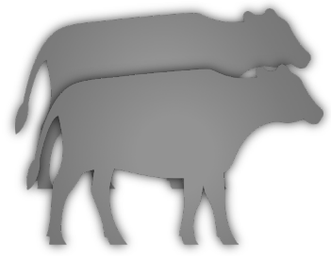
Stage and events

Calves	Heifers I	Heifers II	Heifers III	Cow	Culled
					
Birth - wean	Wean - breed	Breed - calve	Close to calving	Start lactating	For culling
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull	Culled - sell

- Programmed in detail:
  - Life events and herd structure ~ (Pinedo et al. 2010)
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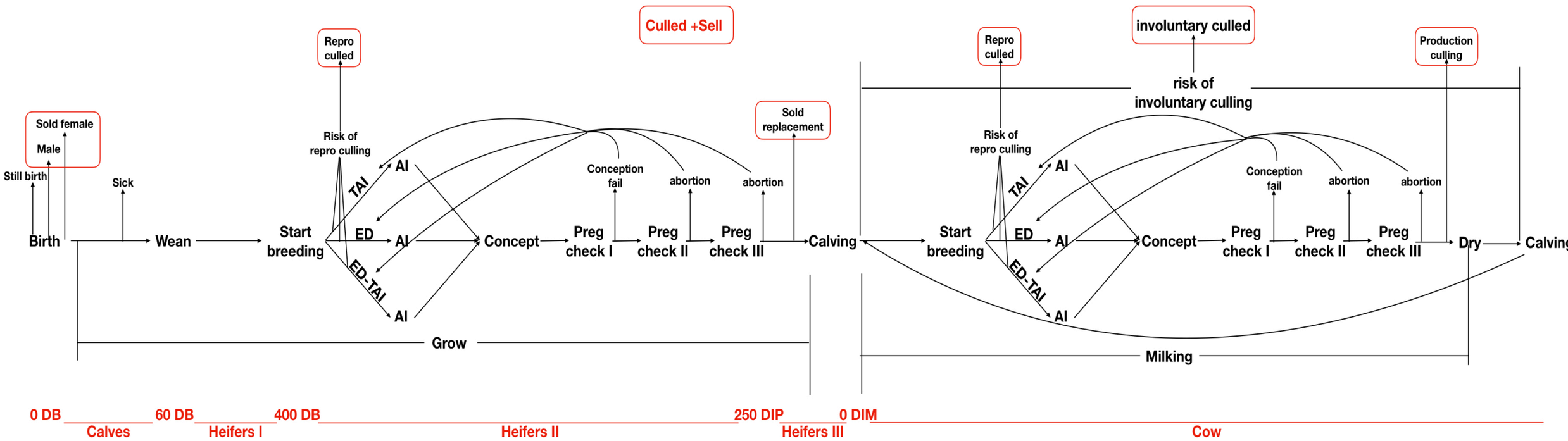
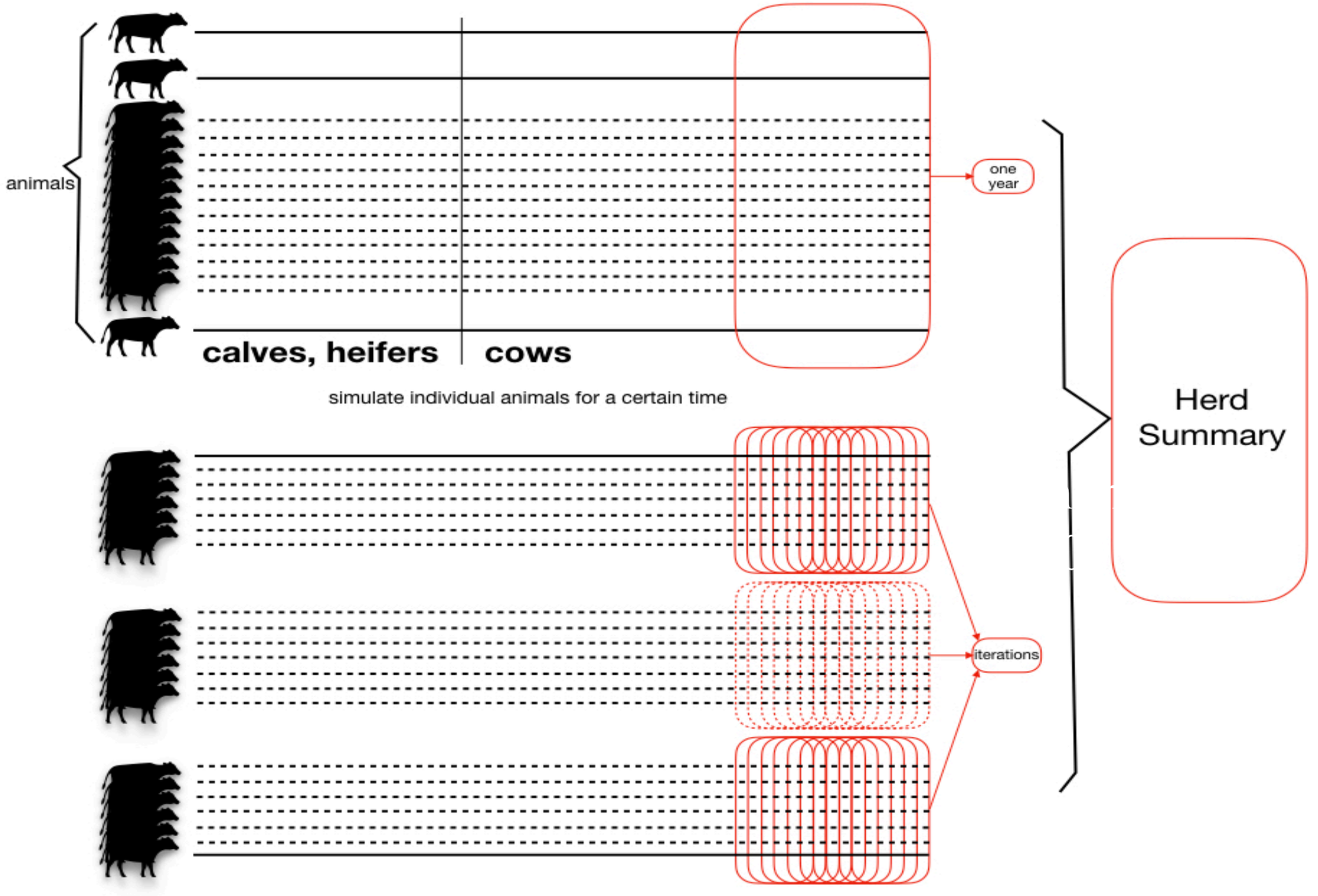
Individual animal life story



Herd simulation and iteration





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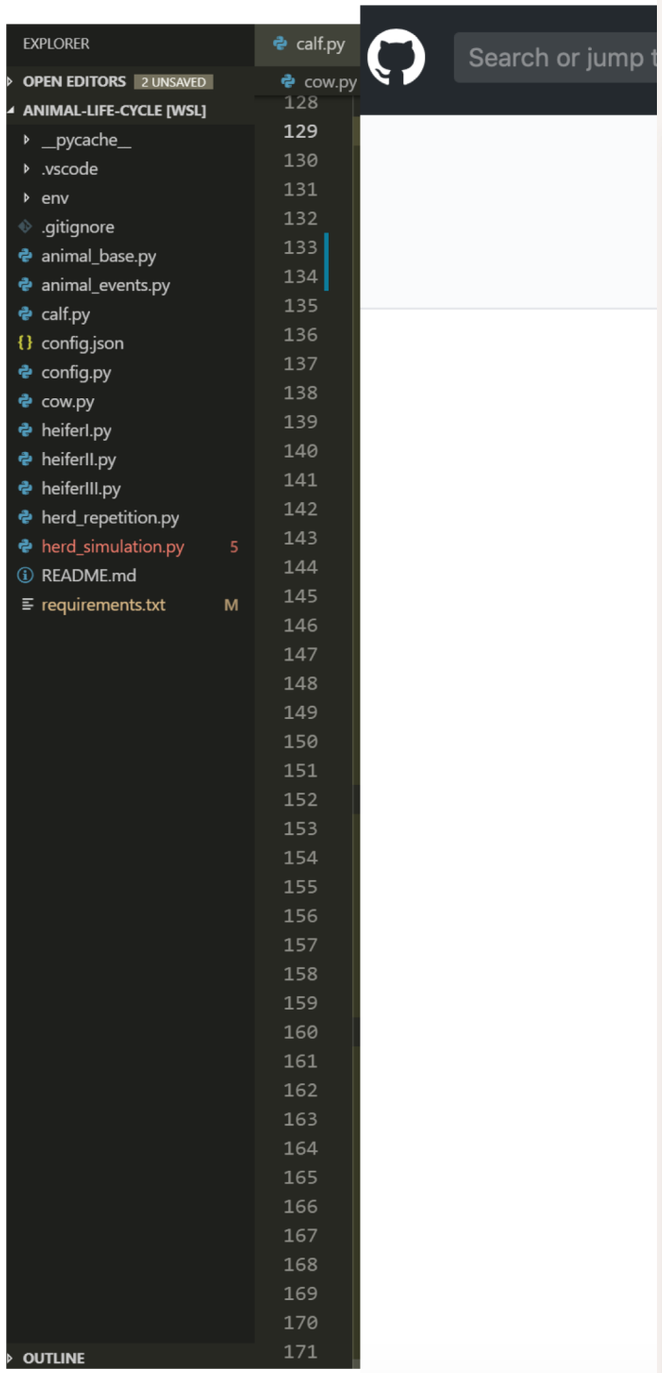
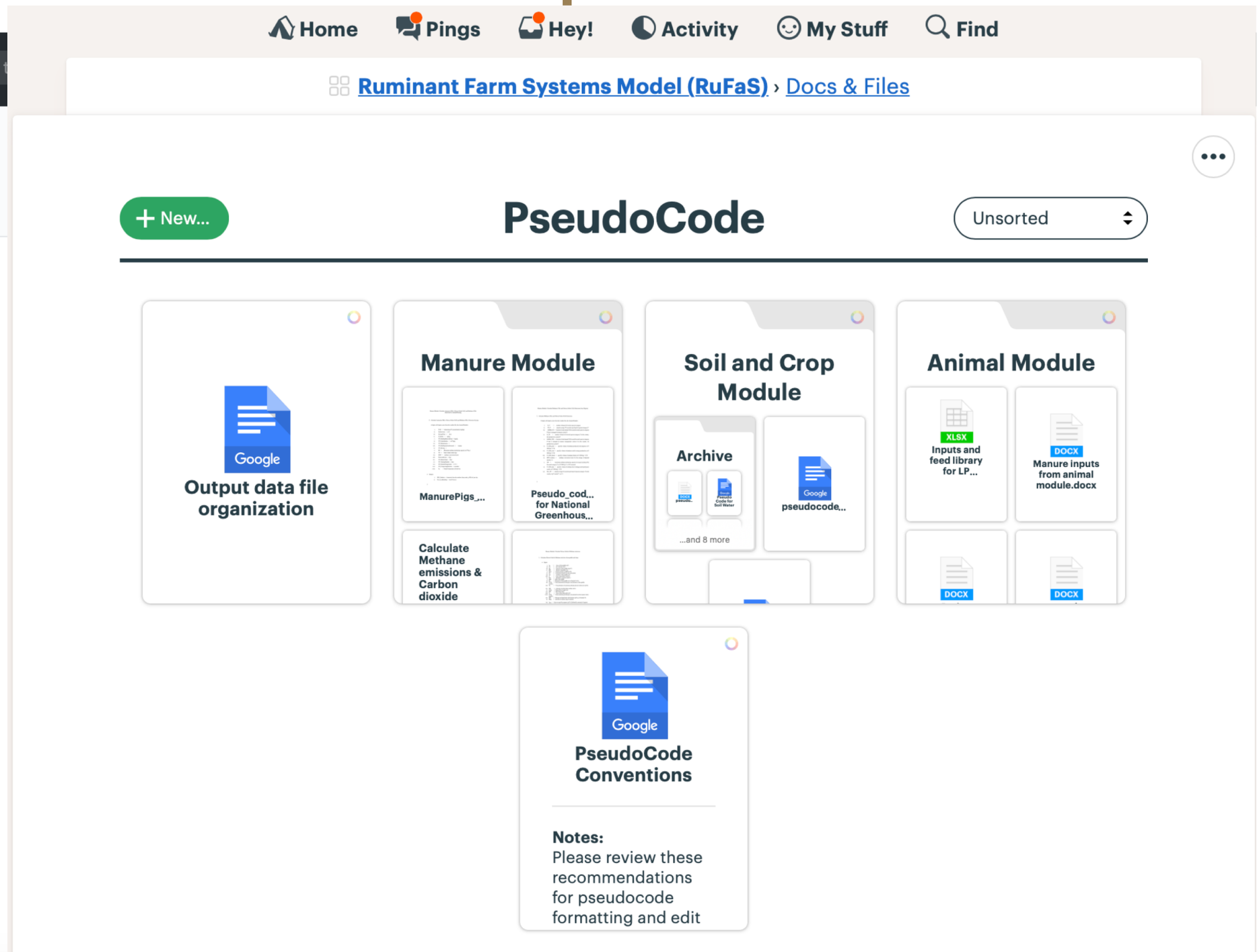
Code sample







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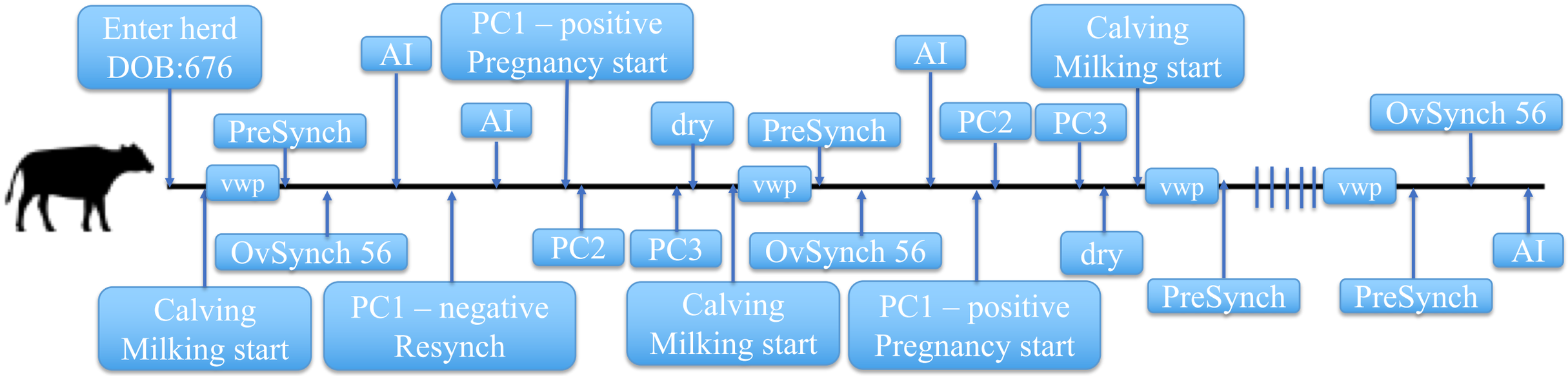
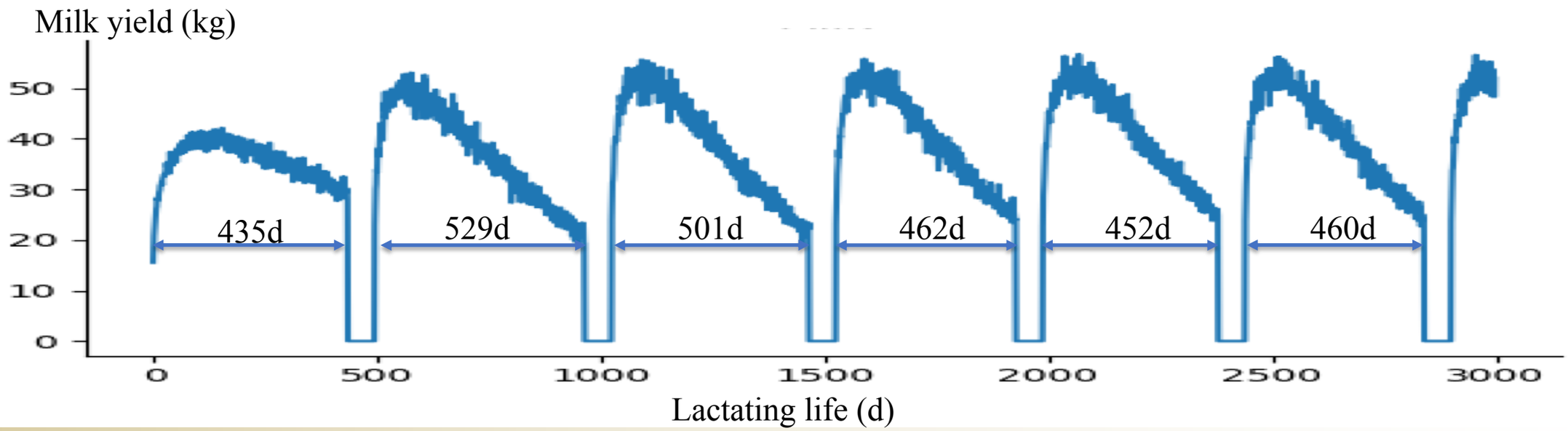
Output sample - animal

1000 targeted herd size, 3000days, 1 individual:



Days Born: 3673; Body Weight: 720.72kg; Repro program: TAI, PreSynch + OvSynch 56 + TAIafterPD
Parity: 7; Curve: Wood's; Days in milk: 98d; Milk produced: 52.01kg; Days in preg: 0d; Gestation Length: 0d.





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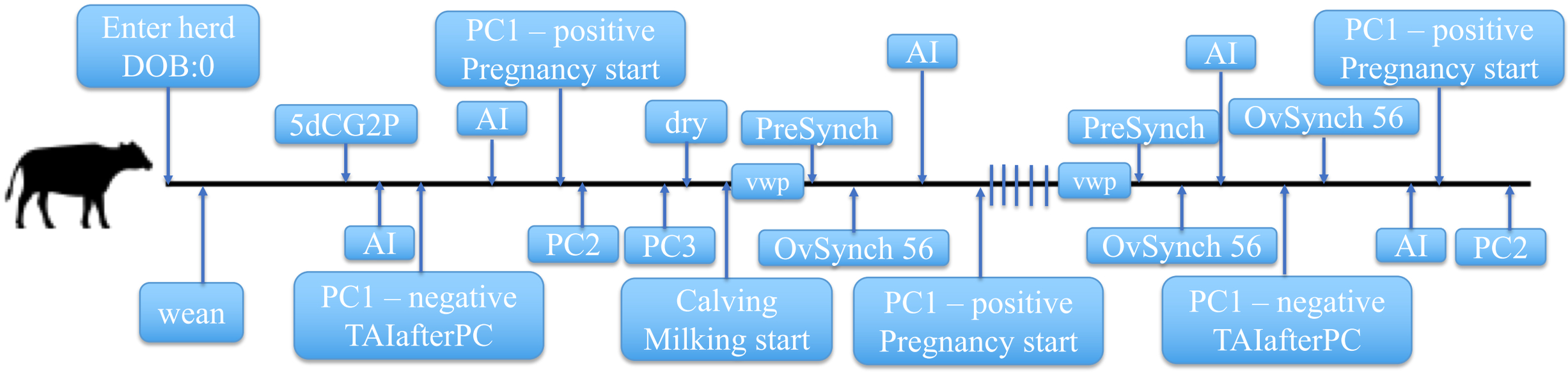
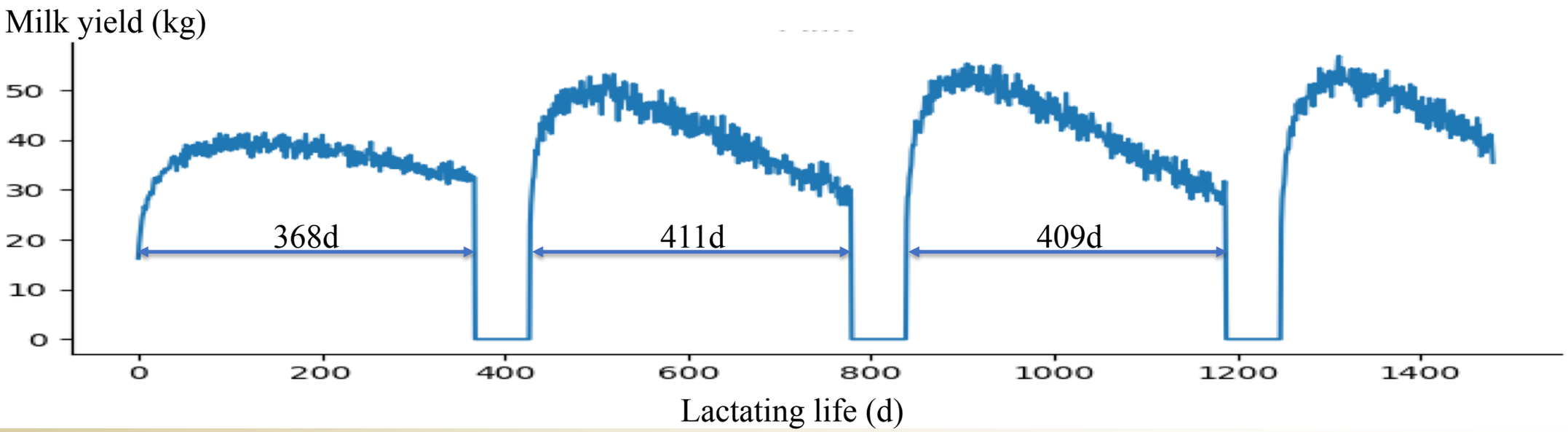
Output sample - animal

1000 targeted herd size, 3000days, 1 individual:



Days Born: 2213; Body Weight: 748.90kg; Repro program: TAI, 5dCG2P+PreSynch+OvSynch56+TAIafterPC
Parity: 4; Curve: Wood's; Days in milk: 232d; Milk produced: 35.44kg; Days in preg: 137d; Gestation Length: 265d





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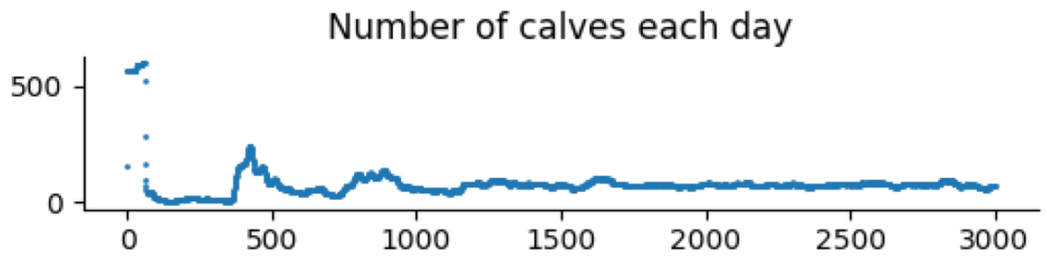
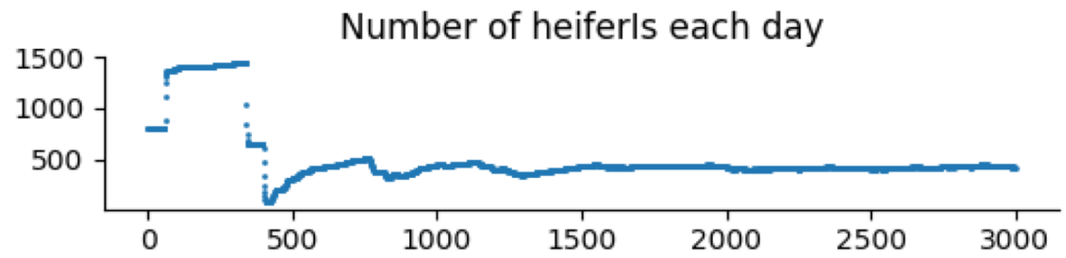
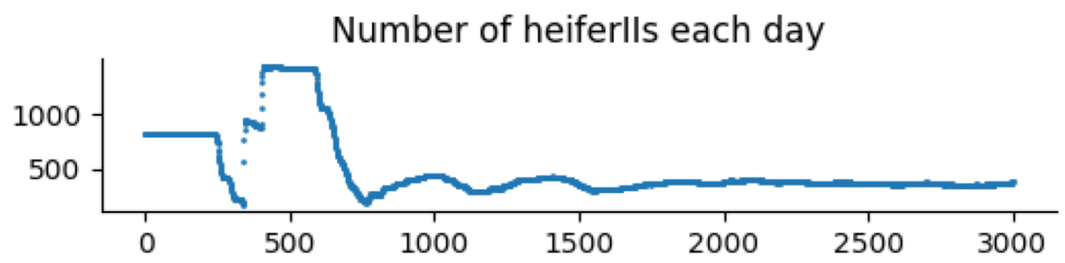
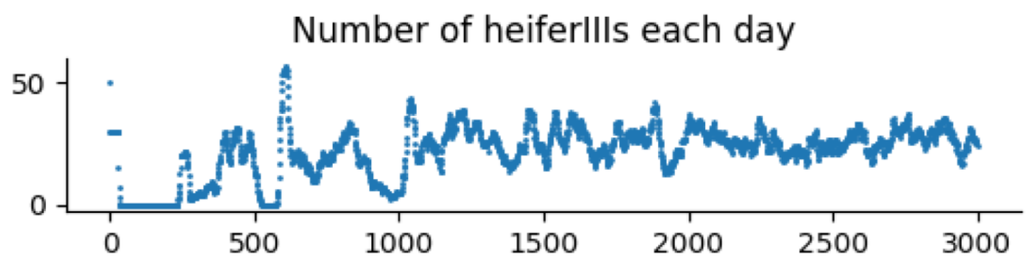
Output sample - herd

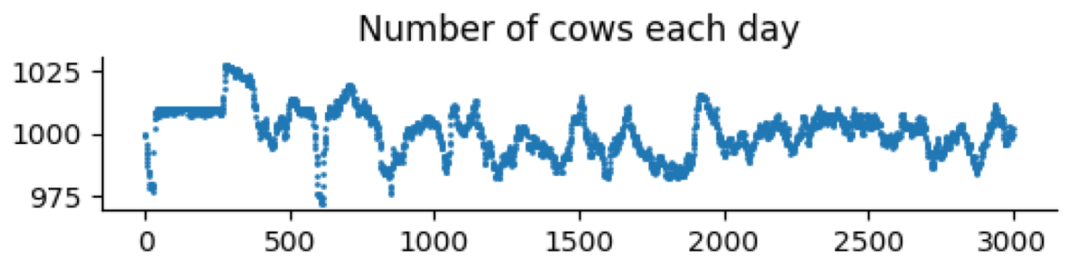
1000 targeted herd size, 3000days, overall:

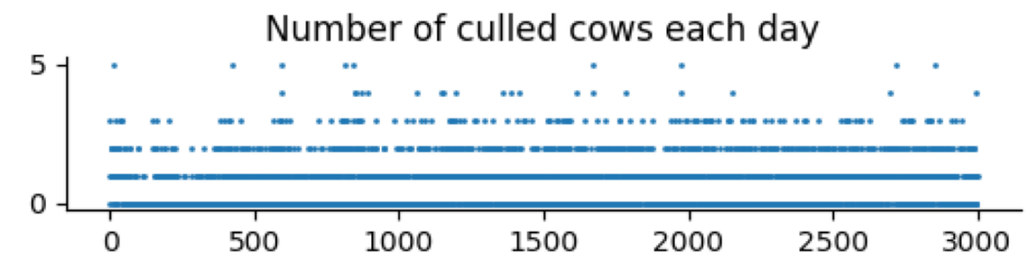


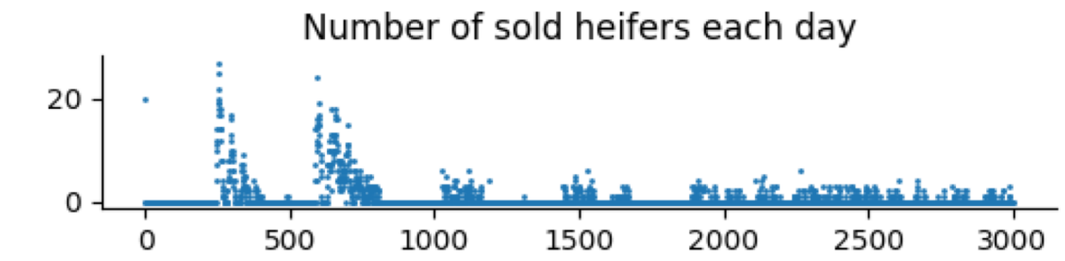


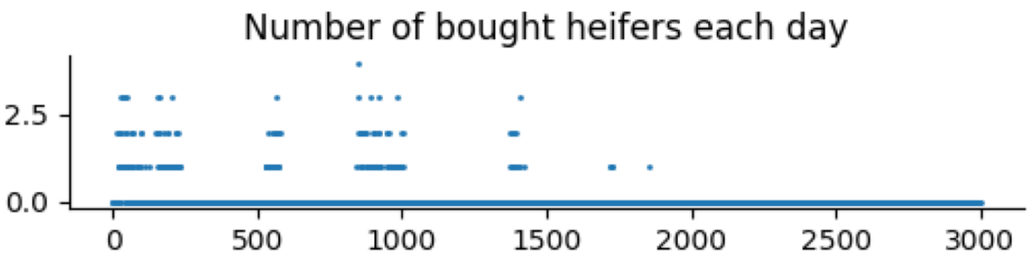














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Output sample – with iterations

100 iterations, 1000 targeted herd size, 3000days:

Herd structure (averaged through 100 iterations) at the end of the simulation								
Calves	HeiferI	HeiferII	HeiferIII	Cows	Cows pregnant	Cows milking	Parity 1	Parity 2	Parity 3
86.8	419.2	351.1	31.5	999.4	635.4	872.8	363.0	239.6	396.8

Herd stats (averaged through 100 iterations) for last 365 days of the simulation							
Feed cost	Fixed cost	Repro cost	Milk income	Slaughter value	Service rate	Conception rate	Pregnancy rate
$/cow/day				$/cow		%	
5.44	2.17	0.15	14.08	481.05	54.91	28.23	26.49

Culled numbers (averaged through 100 iterations) for last 365 days of the simulation							
Total culled	Culling reasons						
	Lameness	Injury	Mastitis	Low production	Disease	Udder	Others
321.6	43.5	79.7	69.1	47.3	40.0	17.9	24.1



Future steps

- Merge with other modules and models
  - Ration formulation
  - Management and facility
  - Weather
  - Feed storage
- Validate with real farm data
  - Using Dairy Brain
- Keep adding related components:
  - Genetics
  - Diseases
  - Calf/heifer culling



Mooving Forward.

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Thanks!