Feed efficiency in ruminants:
feed digestion, methanogenesis and energy utilisation

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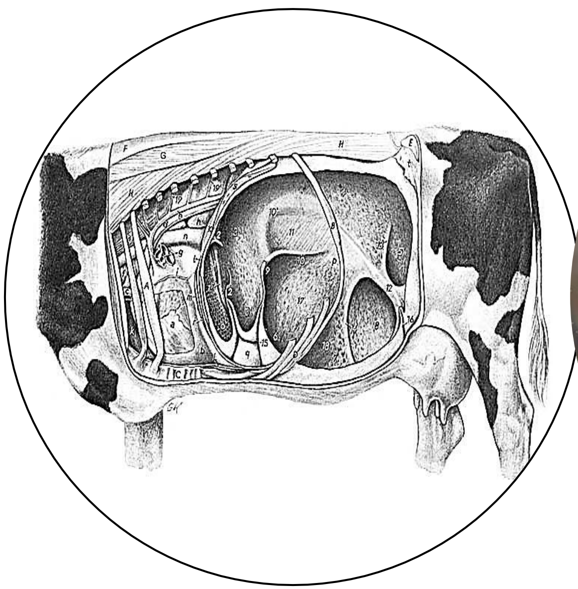

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ANIMAL CHANGE

Conversion of feed into animal product

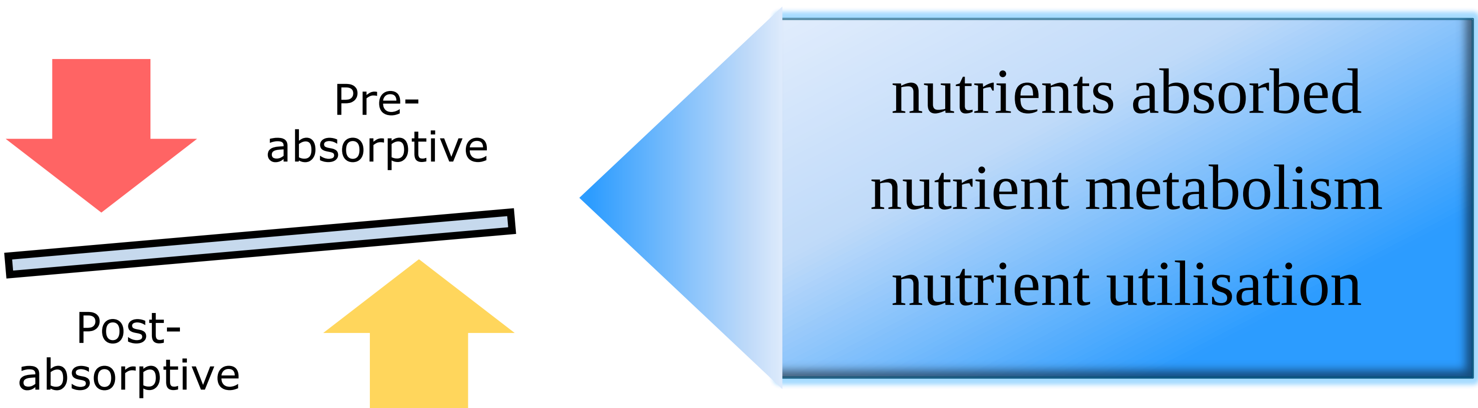
- Feed conversion efficiency (FCE) of ruminants
  - important because feeding is a high cost
  - roughage essential in most dairy farming systems
  - concentrates to achieve higher energy intake

- Efficiency gain with intensive management, but large environmental impacts & trade-offs

- Generally, there is interest and value to improve FCE by
  - feed intake / productivity
  - feed digestion

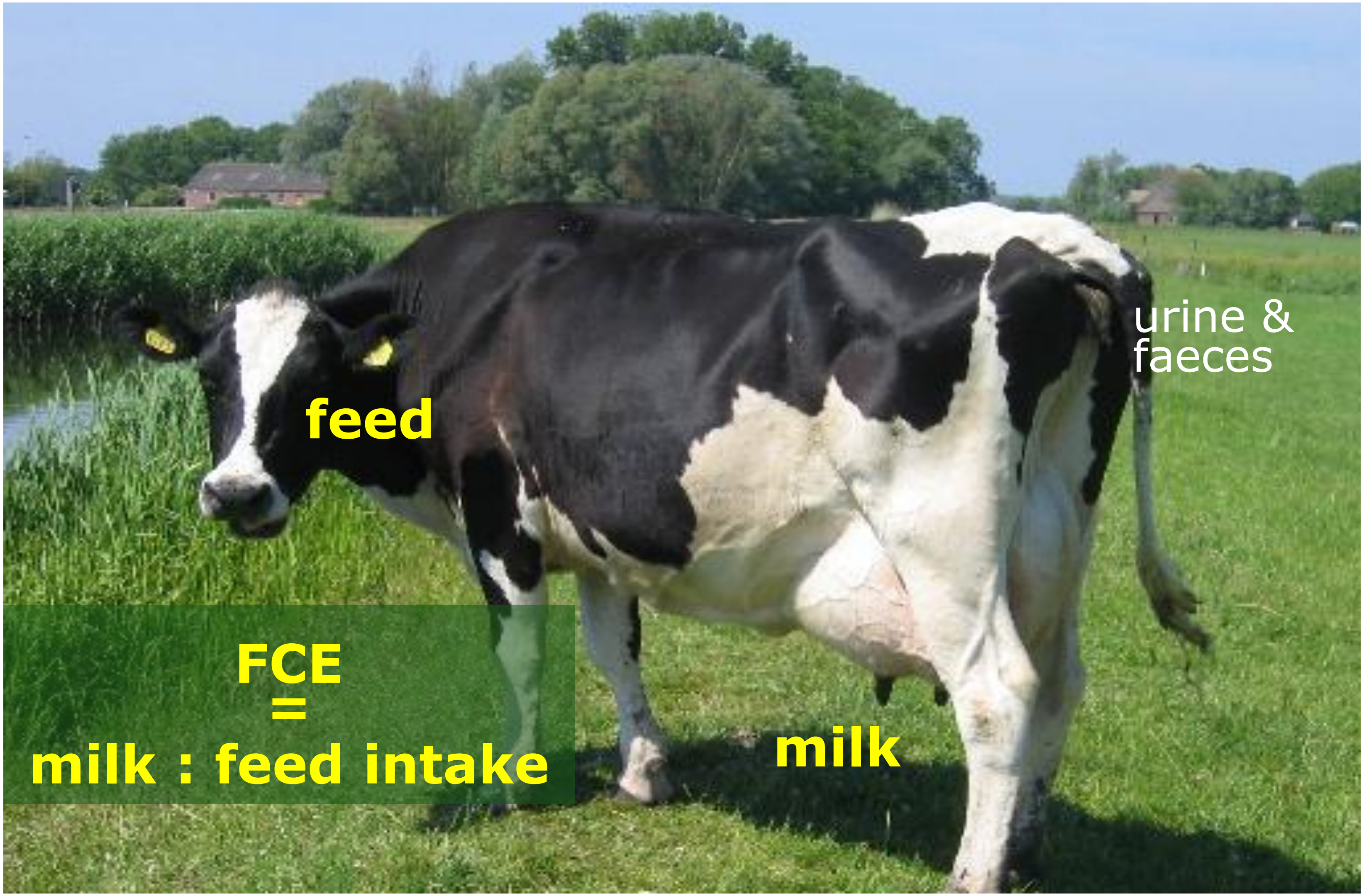
Improving FCE, pre- vs. post-absorptive

- Feeding management: <u>nutritional & digestive factors</u>
  - rumen fermentation & loss of methane energy
  - site of digestion
  - feed digestibility

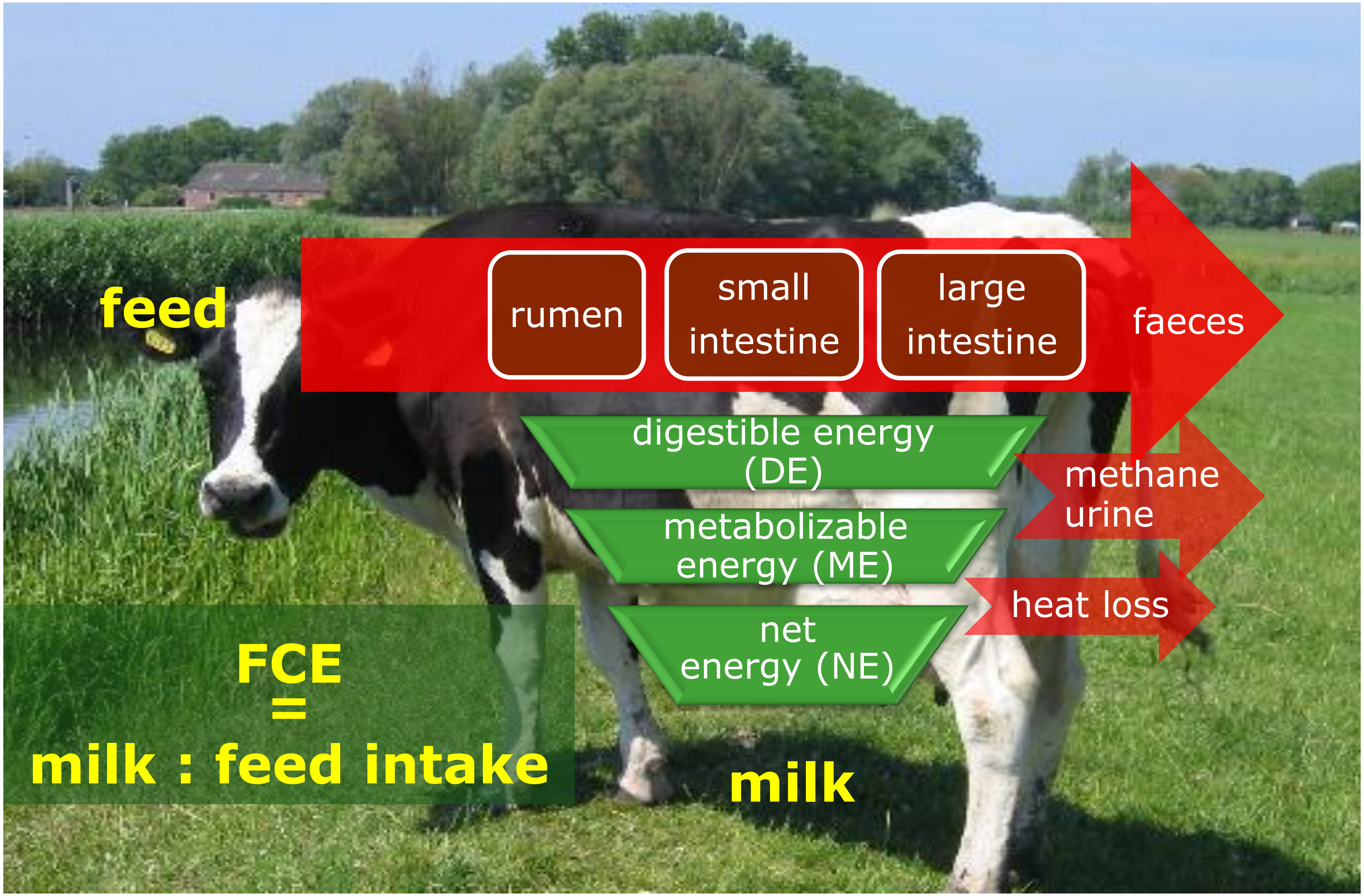


- On-going efforts by <u>genetics & technology</u>
  - selection for genetic potential
  - improved management: feed production, feeding, housing, animal care

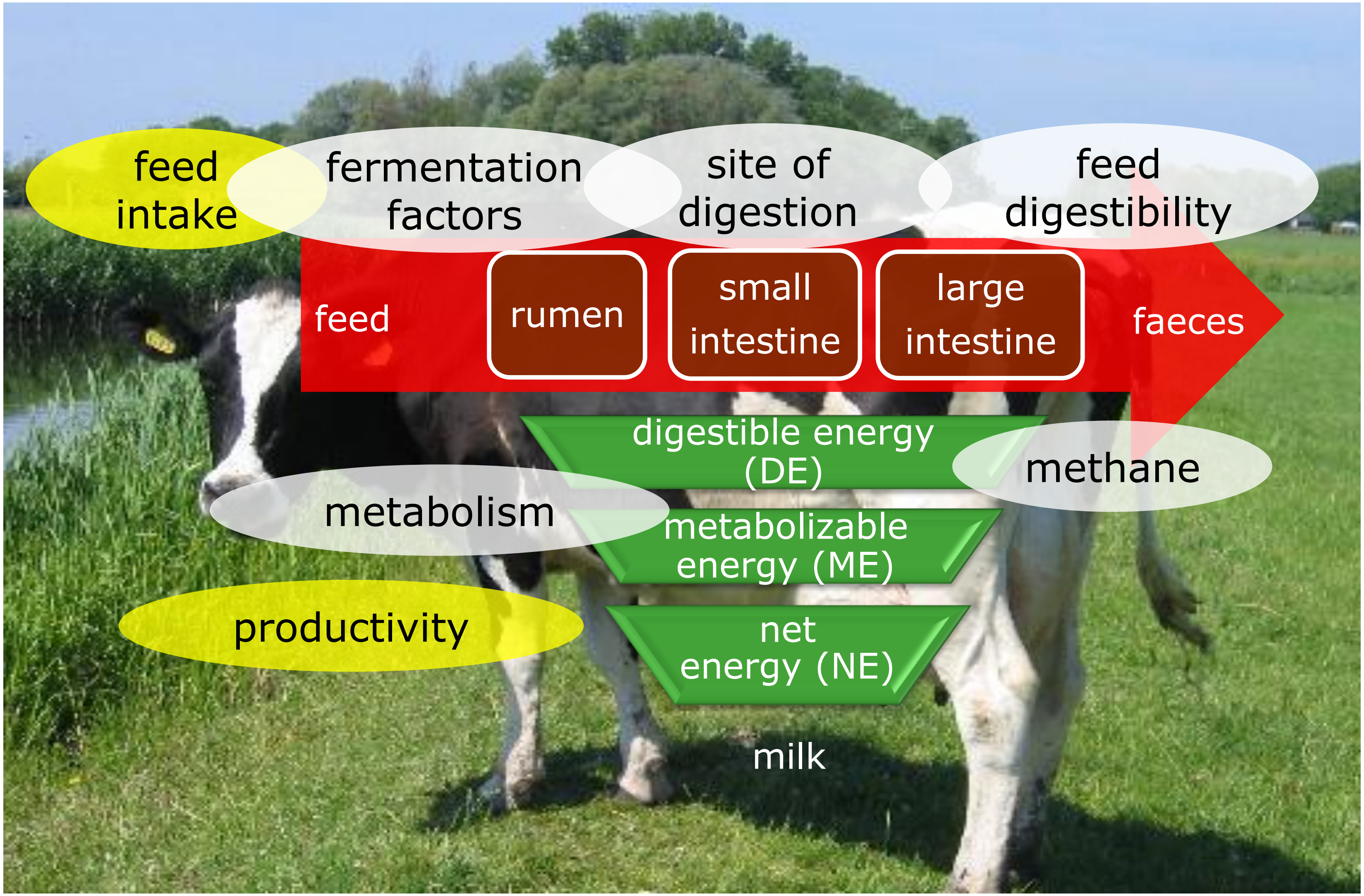
Definition cow FCE : 'milk from feed'



FCE of a lactating cow



Pre- & post-absorptive factors affecting FCE



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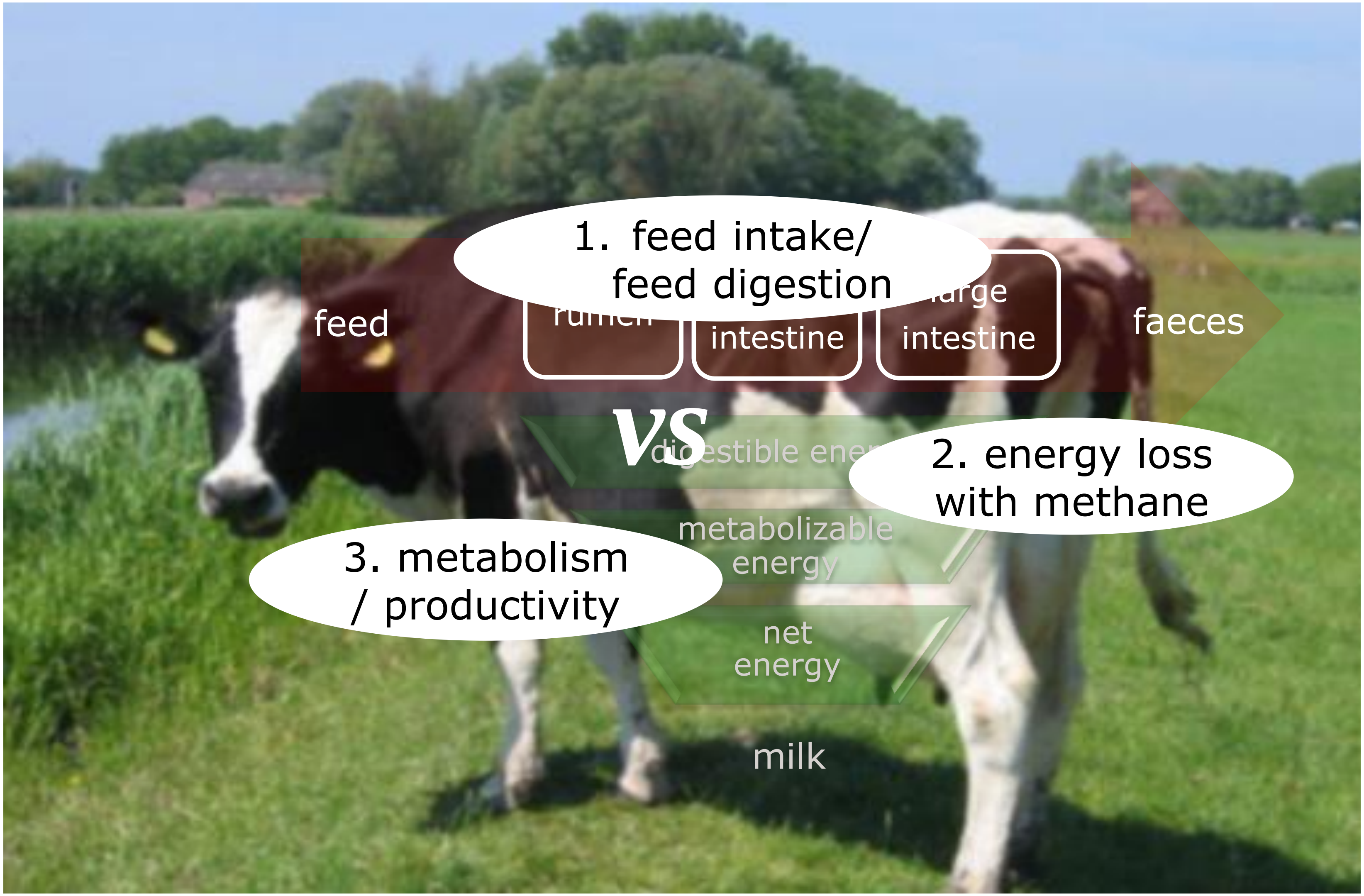
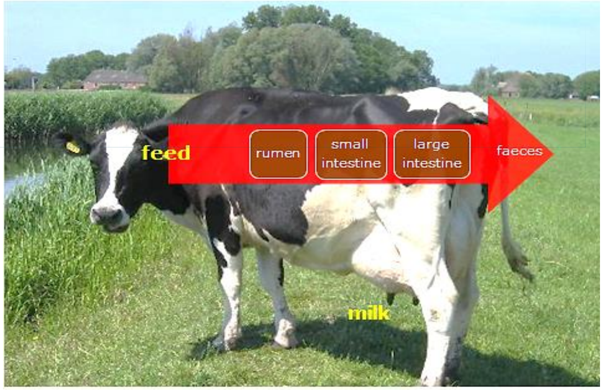
This presentation



1. Feed digestion & FCE



- Rumen main contributor to ME / NE
  - volatile fatty acids & microbiota
- Starch, protein, fat digestion in small intestine
- Fermentation of undigested feed in large intestine

- Variation in feed digestibility: main role rumen
  - passage rate/retention time
  - feed degradability
  - rumen conditions (pH, [ammonia], structural mat)

- Results on dietary protein content – feed digestibility

I. Feed digestion, effect CP *(Spek et al., 2013)*

Generally not <14% CP in DM, lower CP would affect digestion

<u>Tested **restricted** </u>feeding, to prevent confounding by DMI

CP (% DM)	**11.9**	**11.4**	**15.6**	**15.1**
Salt	**0.5**	**3.0**	**0.5**	**3.0**
Maize silage (% DM)	66	64	66	64
Soybean hulls	21	20	11	10
SBM protected	0	0	13	13
SBM	5	5	3	3
NE_L (MJ/kg DM)	6.61	6.45	6.63	6.47
DPV (g/kg DM) [1]	69	67	105	102
RDP balance (g/kg DM) [2]	-9	-9	-9	-9
RDP(g/kg DM) [3]	80	78	80	78

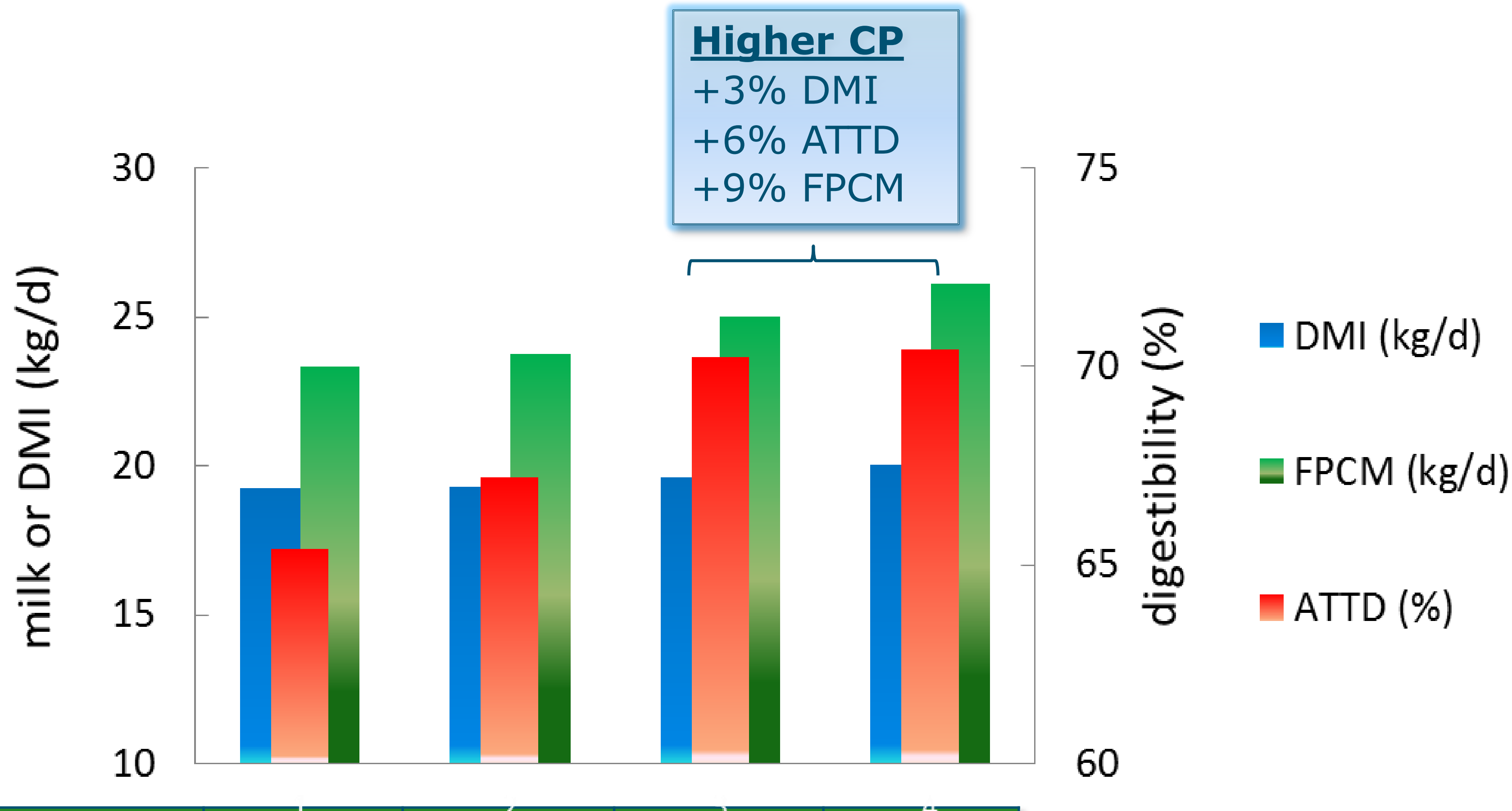
Dietary protein and salt affect the concentration of milk urea nitrogen (MUN; mg of N/dL) and the relationship between MUN and excretion of urea nitrogen in urine (UUN; g of N/d) of dairy cattle. The aim of the present study was to examine the effects of dietary

content: UUN = −17.7 ± 7.24 + 10.09 ± 1.016 × MUN + 2.26 ± 0.729 × MUN (for high NaCl); R^2 = 0.85. Removal of the MUN × NaCl interaction term lowered the coefficient of determination from 0.85 to 0.77. In conclusion, dietary protein content is positively related

At start 34.0 kg milk/d; 146 DIM; BW 645 kg

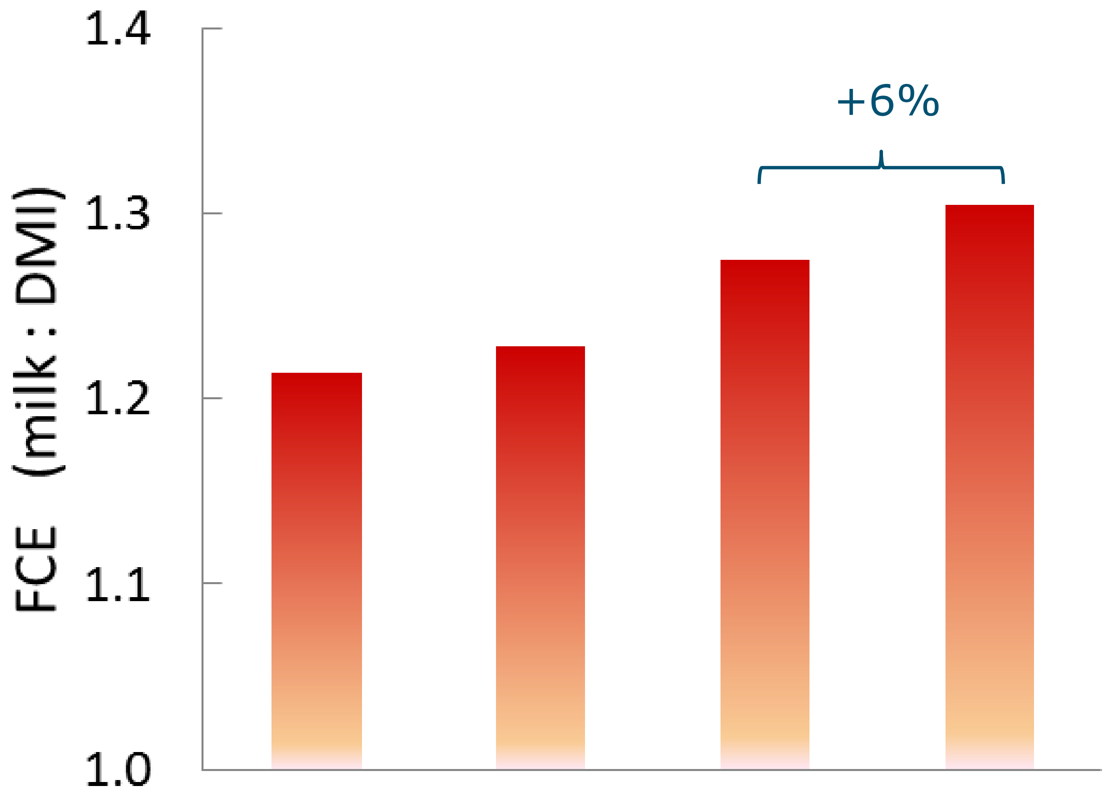
[1] Intestinal digestible protein
[2] Rumen degraded protein balance
[3] Rumen degraded protein

Feed digestion, effect CP (Spek et al., 2013)



CP (% DM)	11.9	11.4	15.6	15.1
Salt (% DM)	0.5	3.0	0.5	3.0

Feed digestion, effect CP (Spek et al., 2013)



CP (% DM)	11.9	11.4	15.6	15.1
Salt (% DM)	0.5	3.0	0.5	3.0

Higher CP

+3% DMI
+6% ATTD
+9% FPCM

+6% FCE

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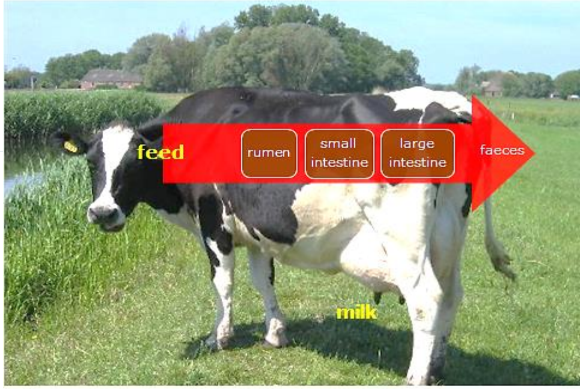
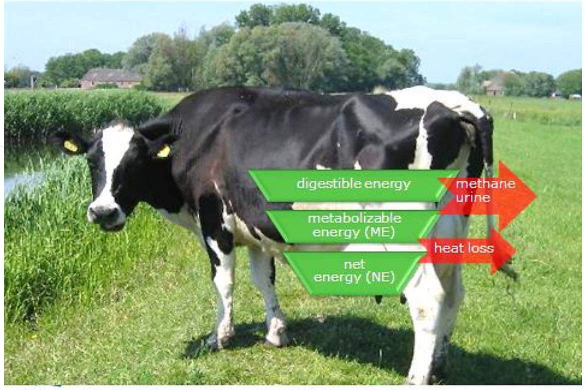
Feed digestion & FCE



- Low feed digestion ~ low FCE
    - CP limiting at very low levels
    - CP stimulatory for milk (protein) yield & feed intake
- To increase FCE, attention for improved feed intake & feed digestibility
- Large individual variation in feed digestion and FCE
    - in size comparable to treatment effect (feeding strategy)
    - individual differences in anatomy, physiology & behaviour
    - despite its high importance, digestive aspects do not become apparent from observed FCE = *f*ion (feed intake; milk)

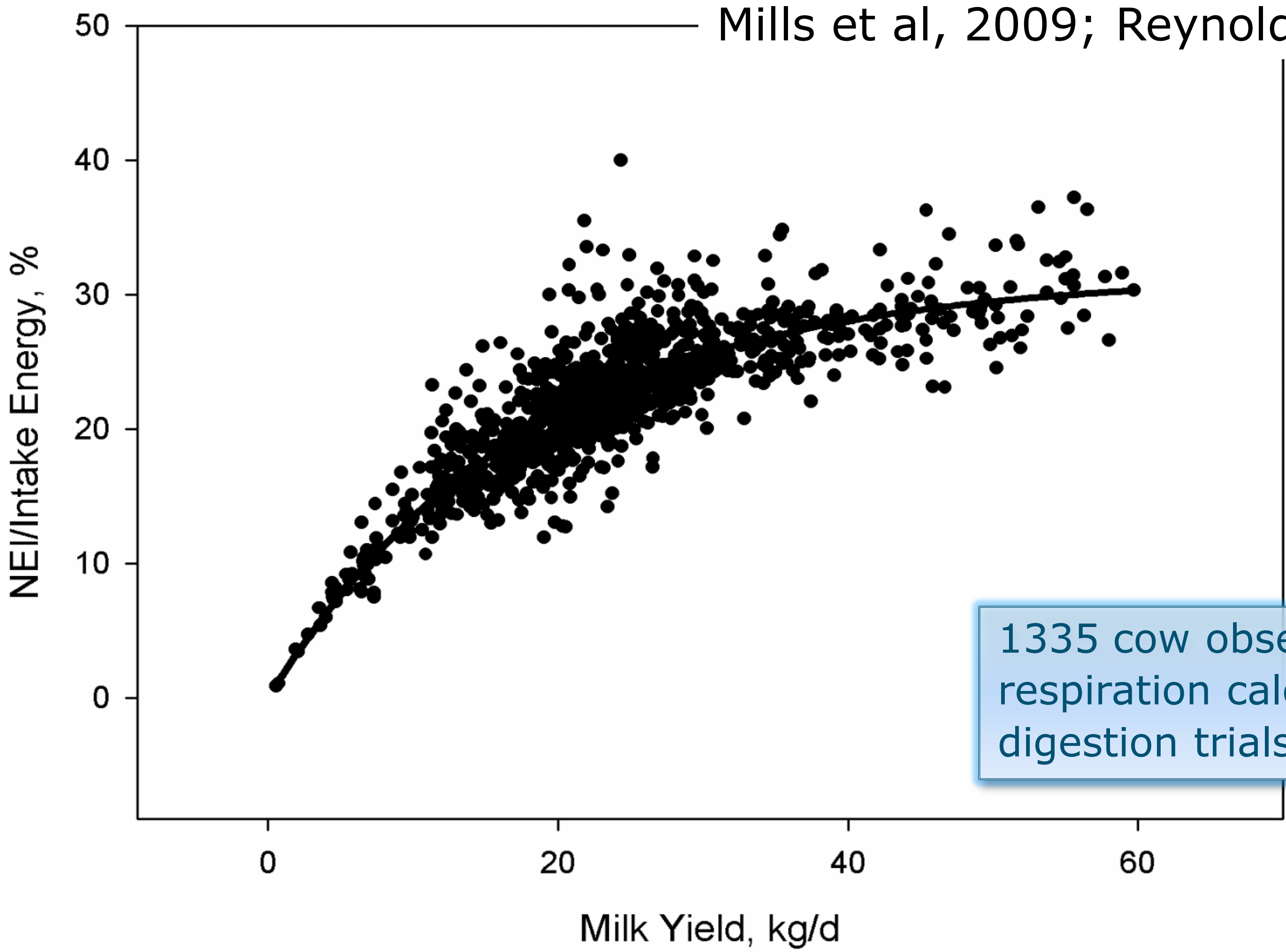
2. Energy metabolism & FCE



- Post-absorptive utilisation nutrients
- Energy utilisation
  - compared to variation in GE to DE,
    less variation in conversion of DE to ME, or ME to NE,
    within specific productive state
- Variation due to
  - 'digestive' tissues (≈50% total heat produced)
  - physical activity, body composition, nutrient storage, protein turnover, other metabolic processes and maintenance
  - e.g. if protein in excess, than ME/NE reduced
    (due to protein catabolism)

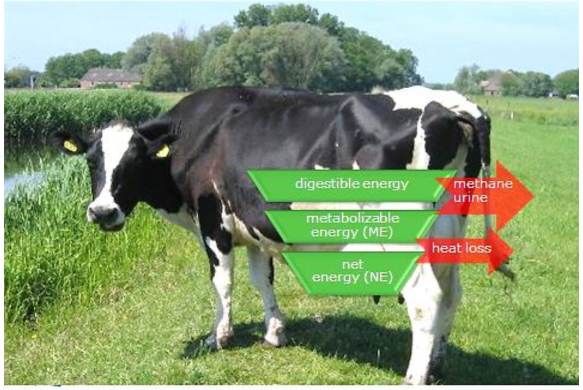
Meta-analysis: efficiency of feed energy use

Mills et al, 2009; Reynolds et al., 2009



1335 cow observations with respiration calorimetry & digestion trials

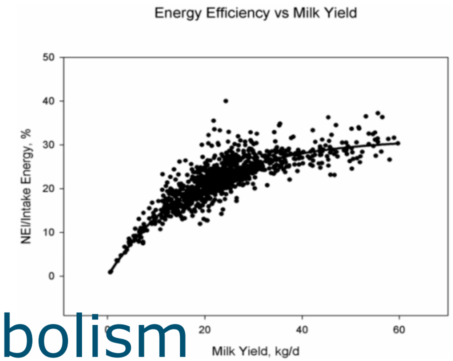
Energy metabolism & FCE



- Profound effect of maintenance dilution with increase in milk yield
- Selecting for more milk has
    - low effect on maintenance requirement
    - low effect on efficiency energy / nutrient utilization

      (Strathe et al. (2011) could not establish a relationship with genetic improvement during 2 decades)
    - high effect on feed intake, nutrient partitioning and nutrient storage

      (Bauman et al., 1983; Reynolds et al., 2009)



- Variation between animals in energy metabolism
    - due to type of nutrient type, metabolism of absorbed energy/nutrients, and nutrient partitioning
- Again, not apparent from observed FCE

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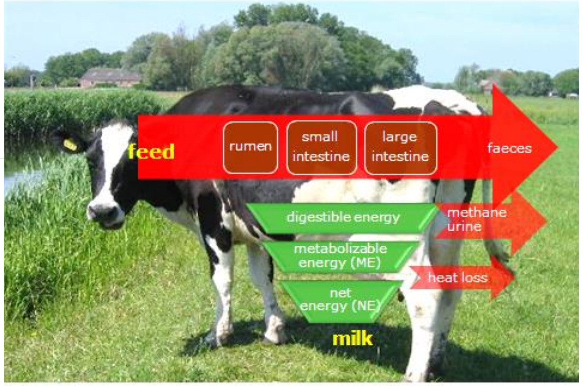
3. Methane loss & FCE



- Energy loss with methane emission
- Reducing methane should benefit cow

- Results on dietary effects on enteric methane

  I. same meta-analysis (Mills et al., 2009; Reynolds et al., 2009)

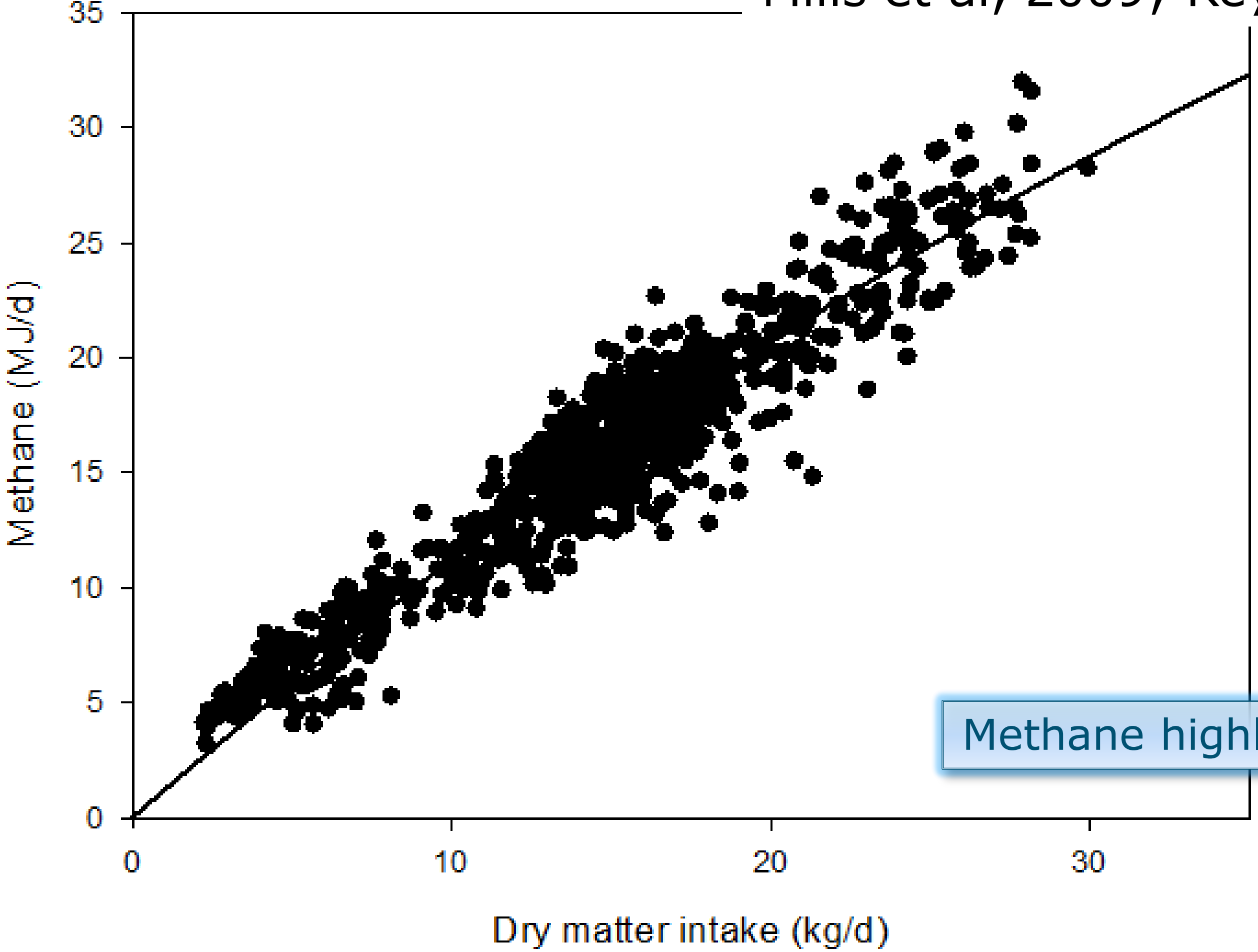
  - energy metabolism & methane

  II. methane mitigation by nitrate in cows for 90 days (Van Zijderveld et al., 2011)

  - iso-nitrogenous/iso-caloric; urea vs. nitrate
  - effects on ME, NE, cow performance

I. Meta-analysis: methane & DMI

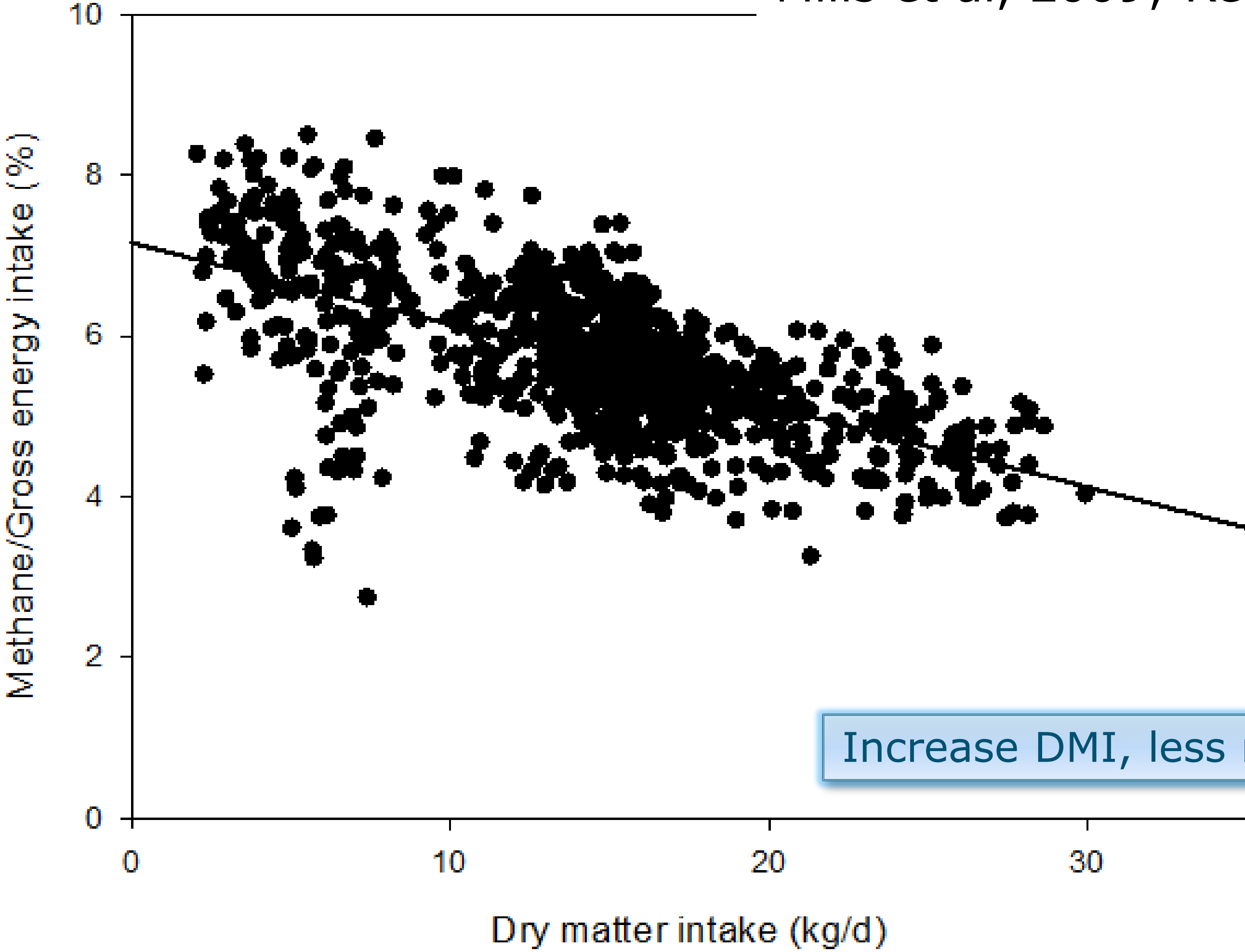
Mills et al, 2009; Reynolds et al., 2009



Methane highly related to DMI

Meta-analysis: methane & GE intake

Mills et al, 2009; Reynolds et al., 2009



Increase DMI, less methane from feed

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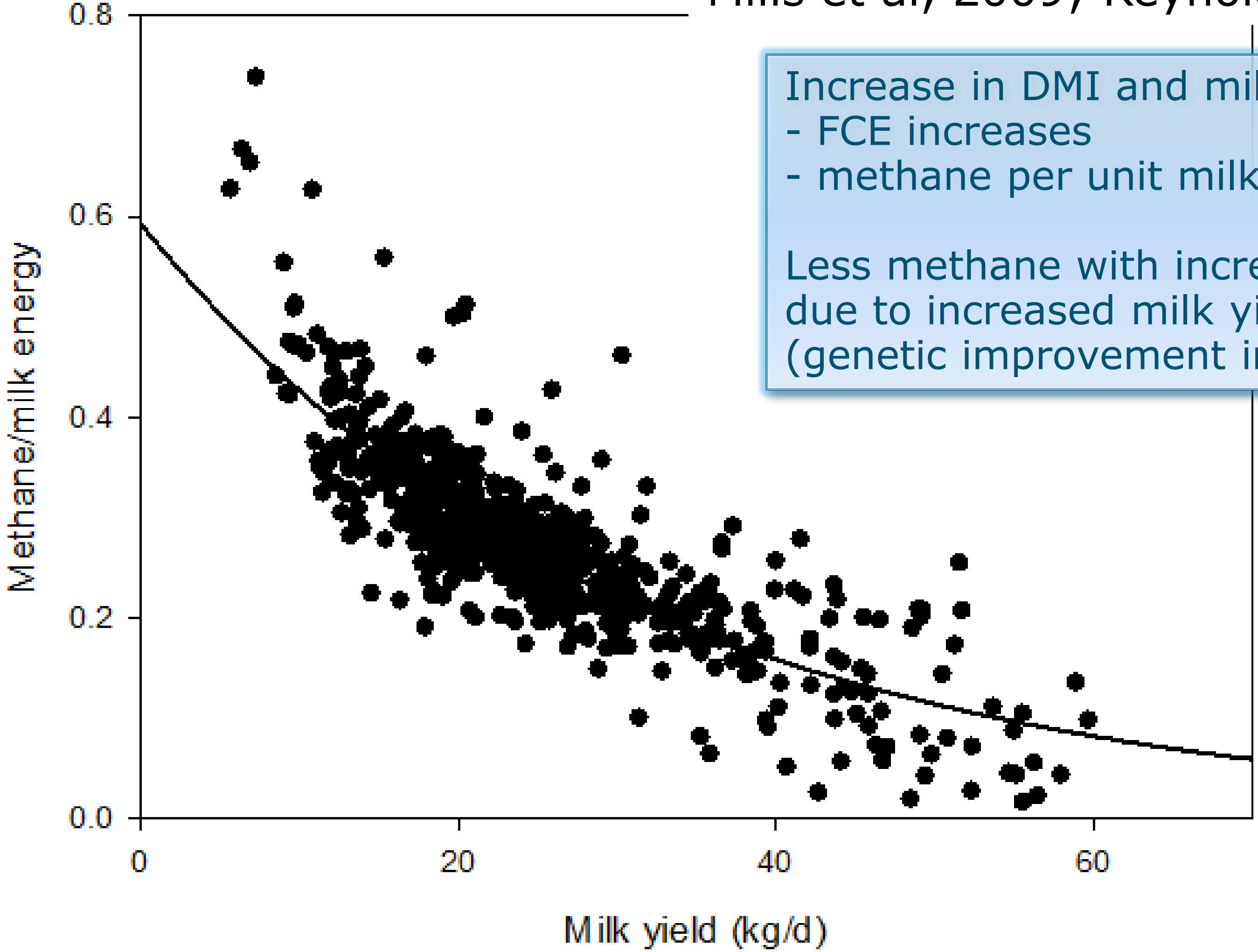
Meta-analysis: methane & milk yield

Mills et al, 2009; Reynolds et al., 2009



Increase in DMI and milk yield
- FCE increases
- methane per unit milk decreases

Less methane with increase FCE mainly due to increased milk yield (genetic improvement in past decades)

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II. Reducing methane of benefit to FCE

- Can a significant reduction in methane increase FCE ?

  it probably can with

  - more propionate at expense of acetate
    (ME propionate 1.6 vs. ME acetate 0.9 MJ/mol)
  - more digestible substrates bypassing rumen fermentation
  - due to more energy / nutrients absorbed

  but, it seems unlikely with

  - nitrate to ammonia
  - other (more) reduced end-products formed that deliver no extra energy / nutrients

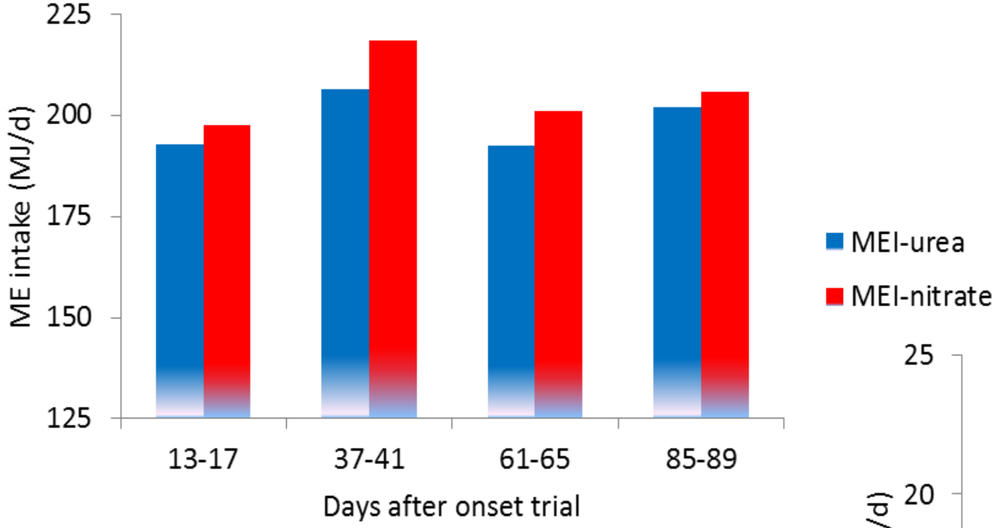
- Example: testing 2% (DM basis) nitrate as feed additive
  - methane persistently reduced
  - no significant effects on DM intake

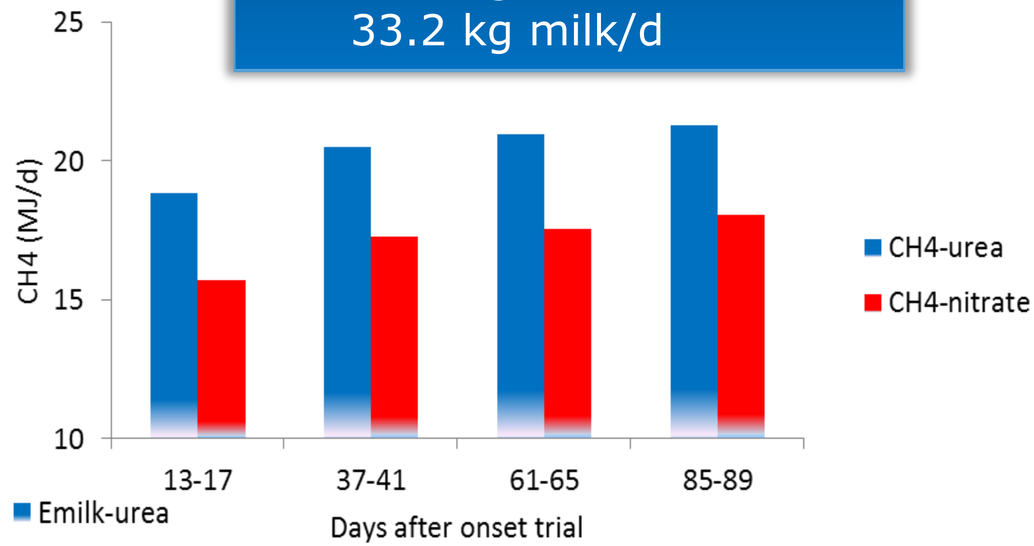
Iso-N exchange urea/nitrate & iso-caloric

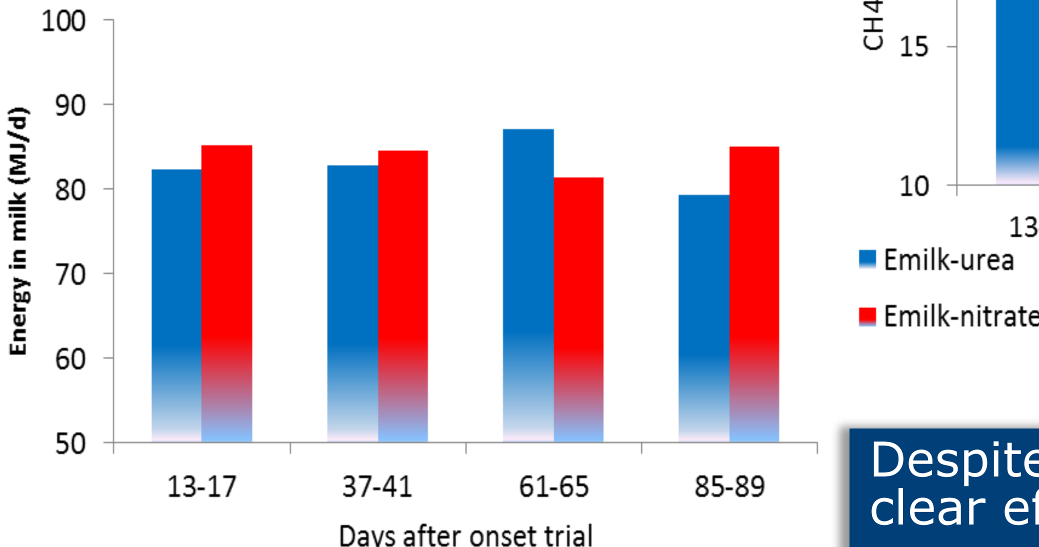
Van Zijderveld, et al., 2011

2.1% nitrate in dietary DM
Nitrate-N exch. with urea-N

20 lactating cows
104 days in milk
19.1 kg DM intake/d
33.2 kg milk/d







Despite 16% reduction in methane and clear effect on ME intake (+4%),

FPCM yield same (+1%, but DMI +1%)

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Energetic benefit of reducing methane

- Heat production in energy balance trials (Brouwer equation)

$$\text{Heat (kJ/d)} = 16.2 \times O_2 + 5.0 \times CO_2 - 6.0 \times N - 2.2 \times CH_4$$

O_2, CO_2, CH_4 in L/d; N in g urine N/d

- Effect methane reduction is overestimated if hydrogen used for alternative reduced end-products delivers more heat than hydrogen used for methanogenesis

(ΔG -125 kJ/mol H_2 nitrate to ammonia; ΔG -17 kJ/mol H_2 to CH_4)

- Spared methane energy benefits animal and hence FCE less than assumed, depending on the type of reduced end-products formed

(PhD Thesis, Van Zijderveld, Wageningen University, 2011)

- No clear effect on milk was found by Van Zijderveld et al. (2011)

Concluding

- Feed digestion: variation profound and likely largest proportion of variation in observed FCE across diets

- Feed intake: historic changes in FCE particularly due to genetic improvement for milk yield, diluting maintenance
  - metabolic characteristics (energetic efficiencies, maintenance, absorption) did not change dramatically

- Metabolism: large individual differences in feed intake (capacity), feed digestion, type of nutrient absorbed, nutrient metabolism & partitioning
  - note: in practice or when selecting high FCE individuals, no observations available on digestion or metabolism !

  Bauman et al. (1983) : ' improvement in FCE will depend on our ability to understand the control of nutrient metabolism, partitioning and feed intake '

- Methane: inhibition not/not fully beneficial to FCE

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for **research & experimentation**

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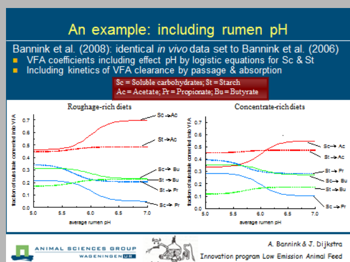
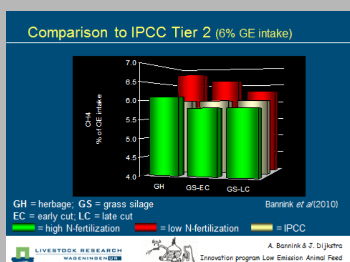
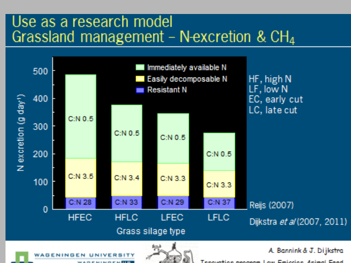
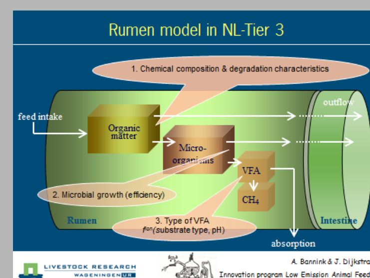
for **practice** (on farm)

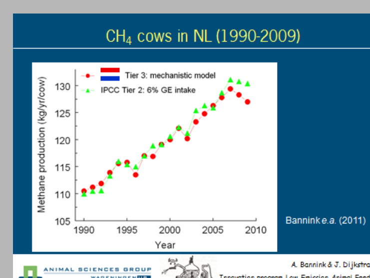


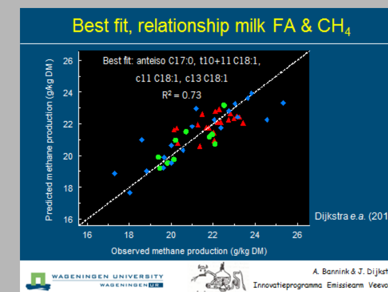


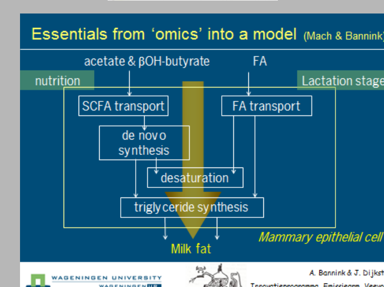


for **inventories** (Tier 3)









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