The use of novel phenotyping technologies in animal breeding

Henk Bovenhuis, ABG, Wageningen University & Research

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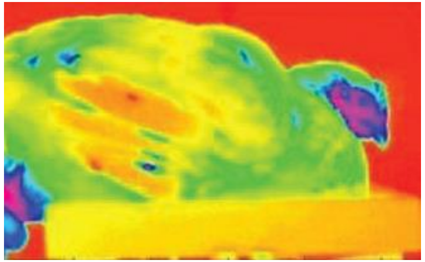
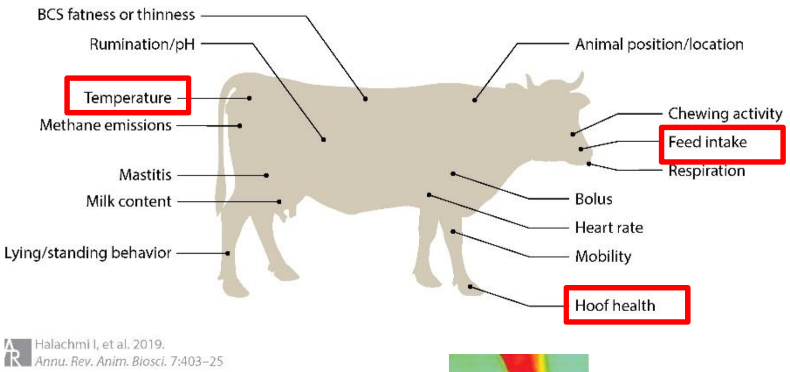
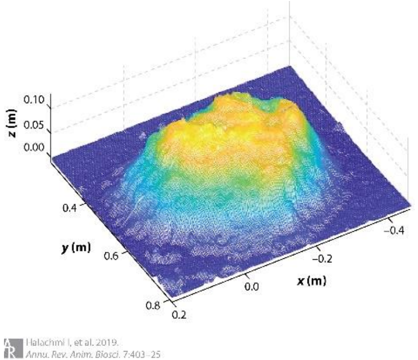
100years
1918 — 2018

Novel phenotyping technologies - sensors



Temperature

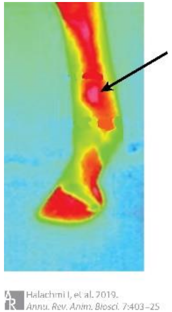




individual feed intake

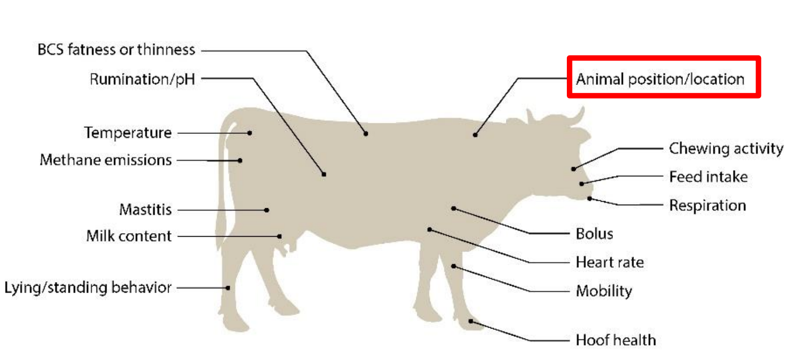
Sensors:

- **Machine vision (cameras)**
- Sound
- Accelerometers
- Electronic nose
- GPS
- ....

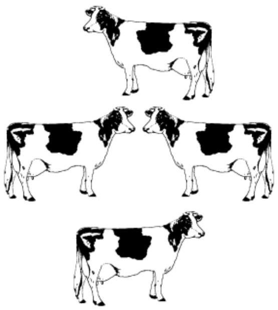


inflammation in the leg

Novel phenotyping technologies - sensors



Halachmi I, et al. 2019.
Annu. Rev. Anim. Biosci. 7:403–25



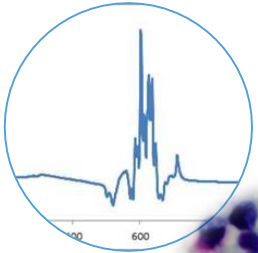
Behaviour: social interactions
Disease: Transmission Infection

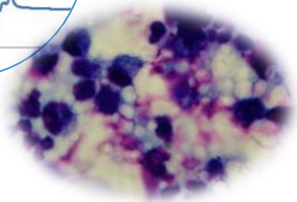
Sensors:
- Machine vision (cameras)
- Sound
- Accelerometers
- Electronic nose
- **GPS**
- ....

Novel phenotyping technologies – **"omics"**

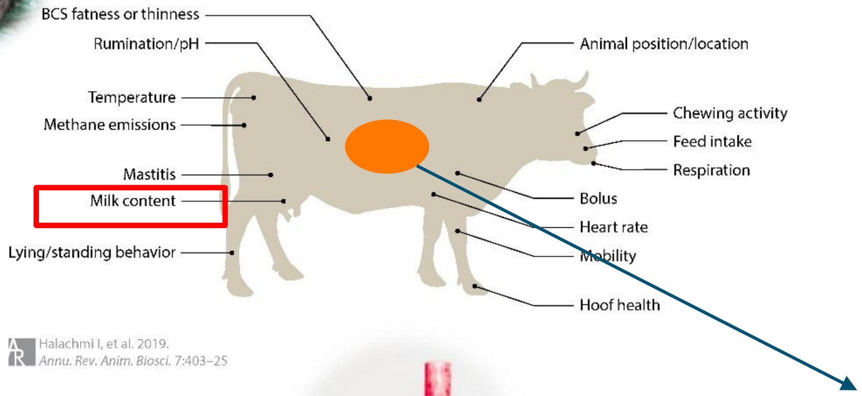
NIR

Milk
Infrared





Differential
SCC

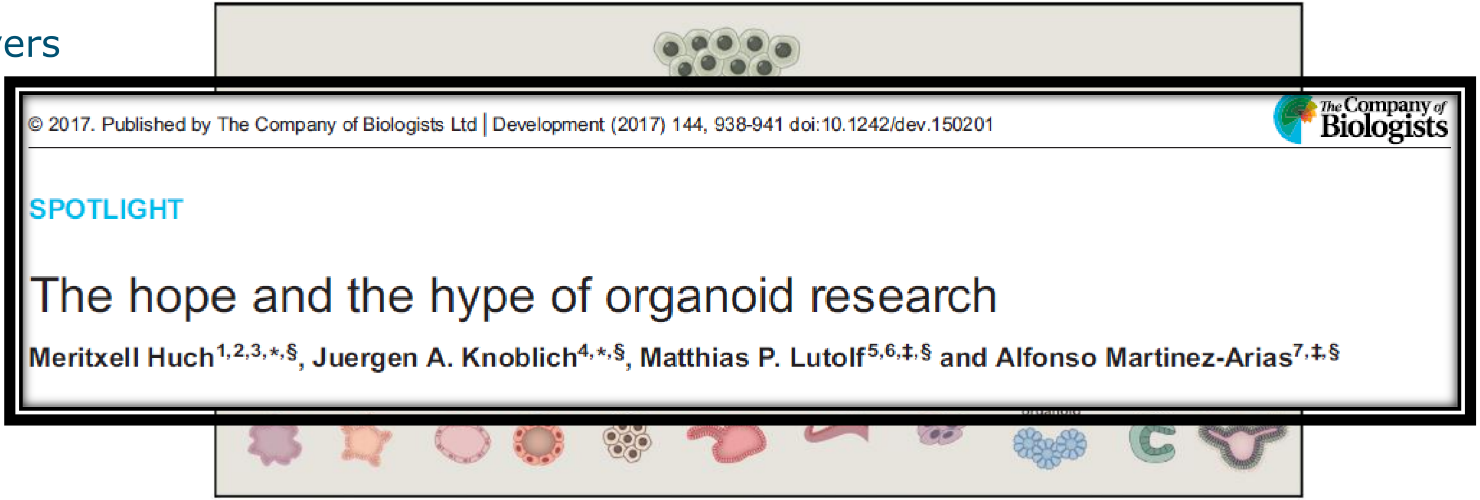


Microbiota

Immunoglobulins,
metabolites, hormones,
DNA methylation…

Novel phenotyping technologies – organoids

From Clevers (2016)



© 2017. Published by The Company of Biologists Ltd | Development (2017) 144, 938-941 doi:10.1242/dev.150201

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SPOTLIGHT

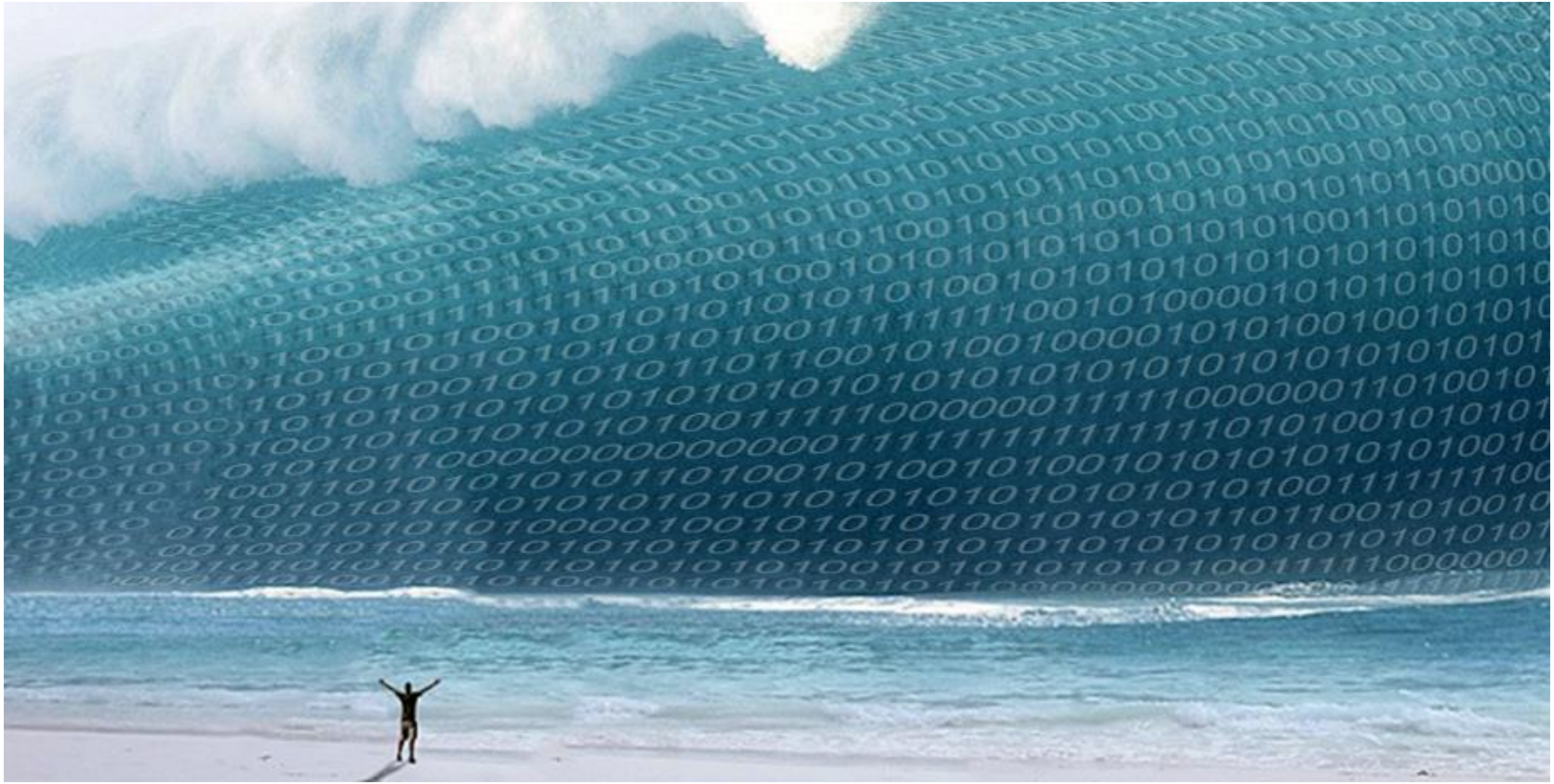
The hope and the hype of organoid research

Meritxell Huch[1,2,3,*,§], Juergen A. Knoblich[4,*,§], Matthias P. Lutolf[5,6,‡,§] and Alfonso Martinez-Arias[7,‡,§]

Feed efficiency?

NEB?

Stress?



Management indicators

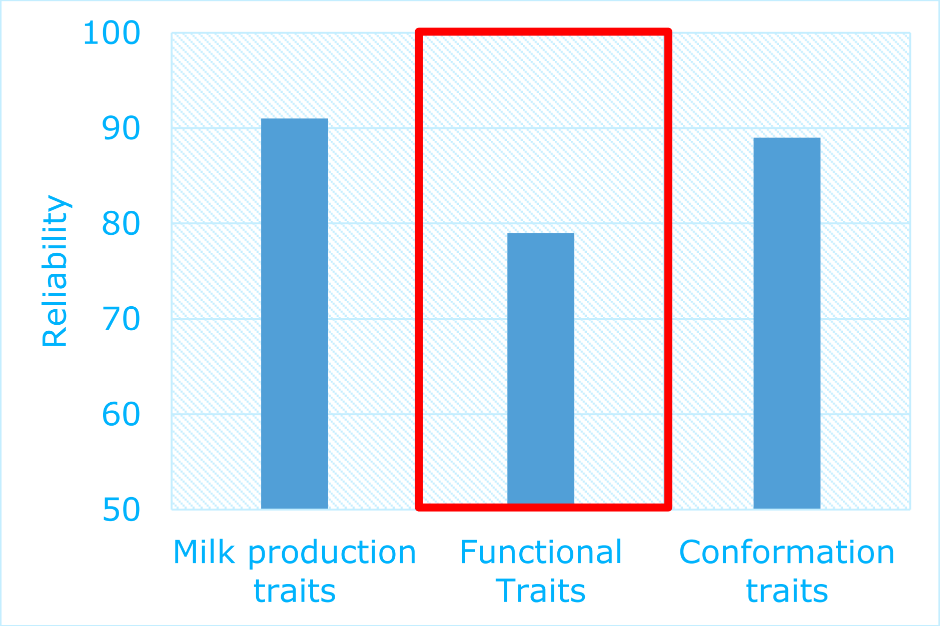
Larger farms / More cows per farmer

AMS

Less (quality) time individual cow

How does the farmer know what the cow needs/wants?

Do breeders need additional phenotypes??



Average reliability published EBV Dutch HF bulls (n=950, 12-2018)

$$H = v_1A_1 + v_2A_2 + \ldots\ldots.$$

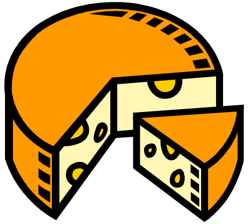
Additional breeding goal traits??

Do breeders need additional phenotypes??

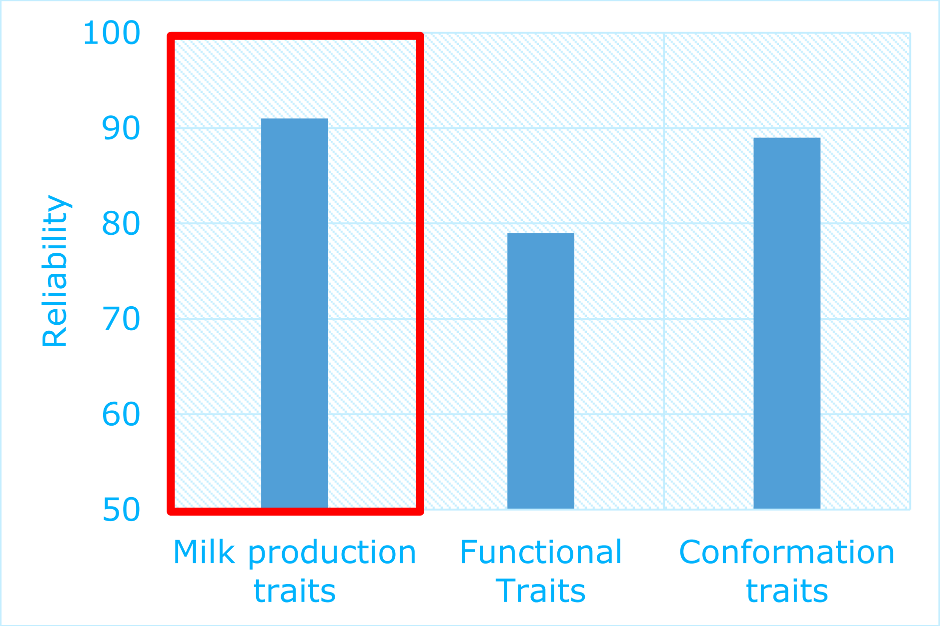
- Environmental impact
  Feed efficiency, Methane emission,
  Phosphorus efficiency, Nitrogen efficiency....

- Cow Health
  Disease resistance, longevity....

- Product quality
  Manufacturing, Nutritious value



Do breeders need additional phenotypes??



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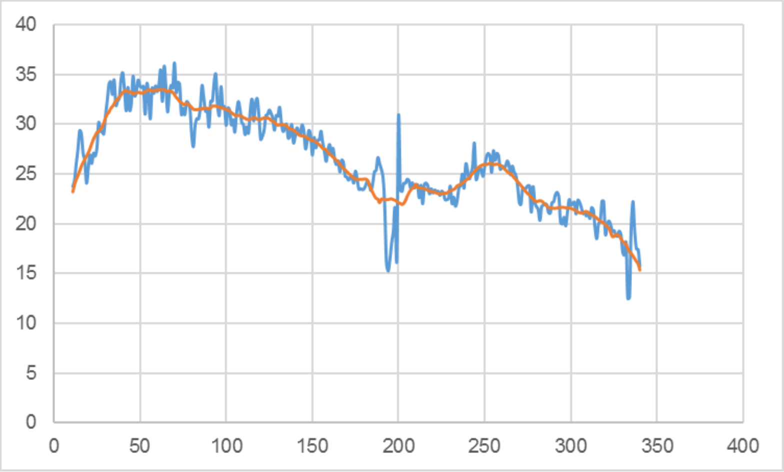

Fluctuations in milk yield as resilience indicator – Han Mulder.

Novel phenotyping technologies

Requirements ??

- Accuracy and bias
- Price
- High-throughput
- Non-destructive
- ……

Novel phenotyping technologies

Use??

- Research
- Management
- Breeding value estimation
- Payment
- ……….

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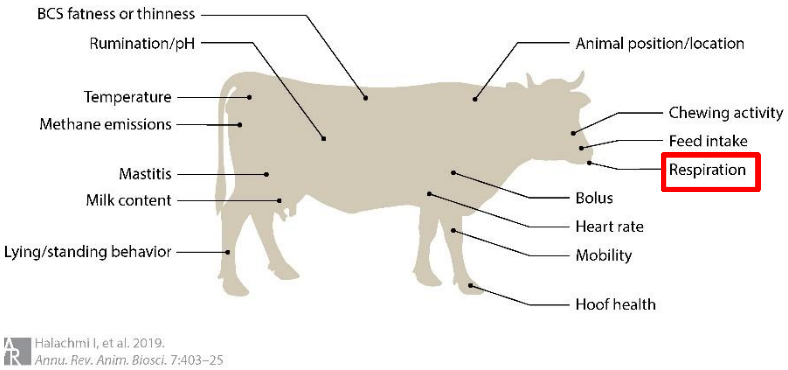

Sensors:

- Machine vision (cameras)
- Sound
- Accelerometers
- **Electronic nose**
- GPS
- ….

Breath sensor CH_4 "sniffer"

Sniffer CH4

- $h^2 \approx 0.10$
- $r \approx 0.25$
- herd ≈ 0.60

J. Dairy Sci. 101:9619–9620
https://doi.org/10.3168/jds.2018-14704

Letter to the Editor: Challenging one sensor method for screening dairy cows for reduced methane emissions

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†Department of Animal Science, The Pennsylvania State University, University Park 16802

"… the need for high throughput methodology, e.g. for screening large numbers of animals for genomic studies, **does not in itself justify the use of methods that are inaccurate, imprecise, or biased**" (Hammond et al., 2016).

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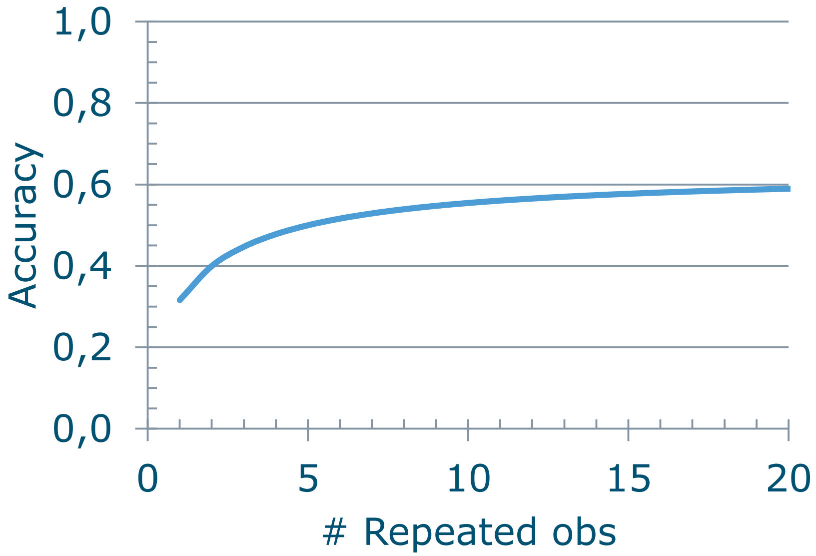
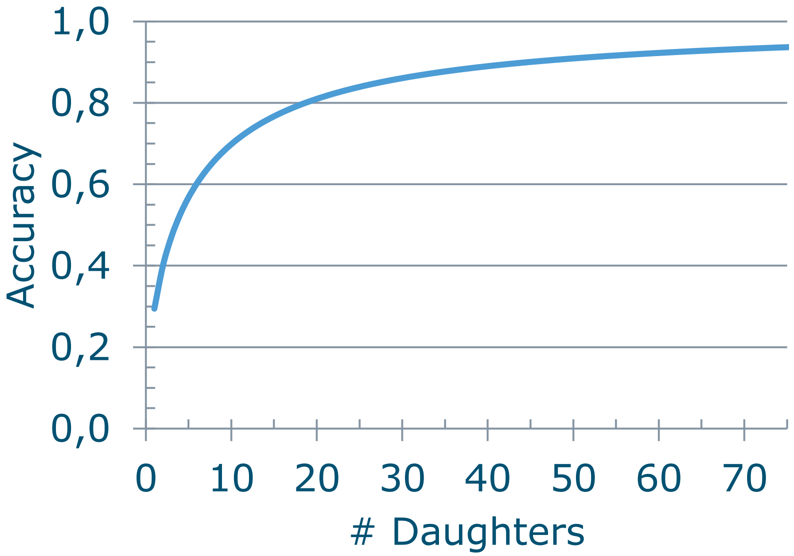
Accuracy of EBV- h^2=0.10, **r=0.25**



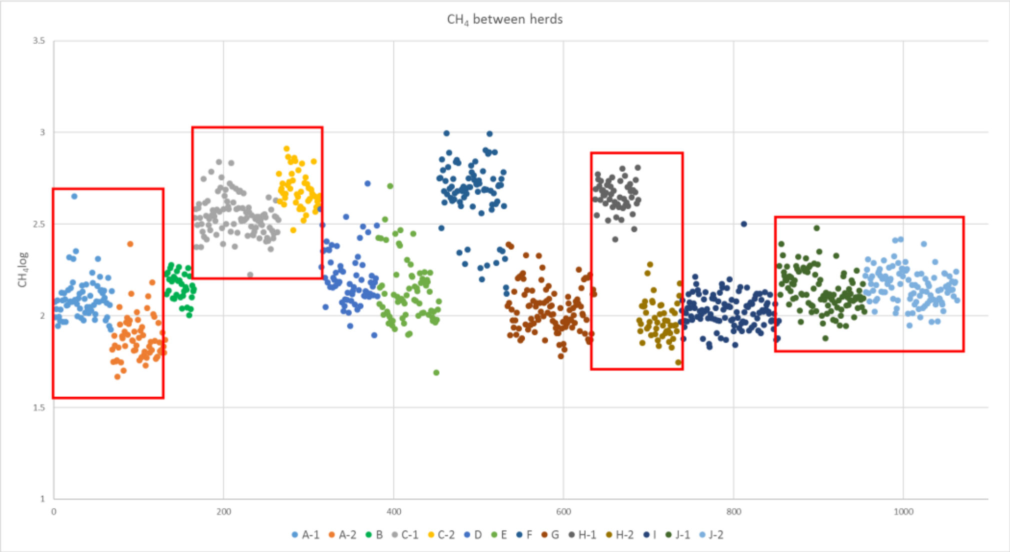
Cows

Progeny tested bull

20 repeated obs./ daughter



Bias due to Herd effects



$$Y = HTD + \ldots\ldots.Anim + PE + e$$

$$anim \sim N(0, A\sigma_a^2)$$

Systematic “errors”

$$H = v_1A_1+v_2A_2+.......+v_nCH_4$$

Genetic correlation

$$I = b_1X_1 +b_2X_2+......+b_nCH_4\text{-sniffer}$$

Sniffer CH4 as **indicator** for “true” CH4.

Sniffer CH_4

Use??

- Research ☒
- Management ☒
- Breeding value estimation ☑
- Payment ☒
- ……….

Inaccurate and biased sensor data can provide valuable information for selective breeding.

“Nice to have” vs “Need to have”

Novel phenotyping technologies – **"omics"**

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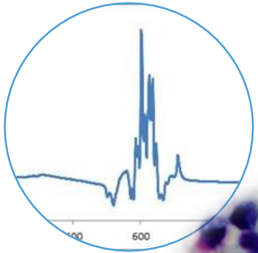
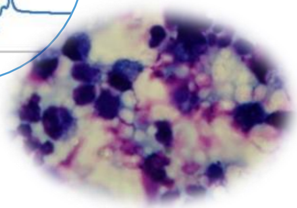
Milk
Infrared





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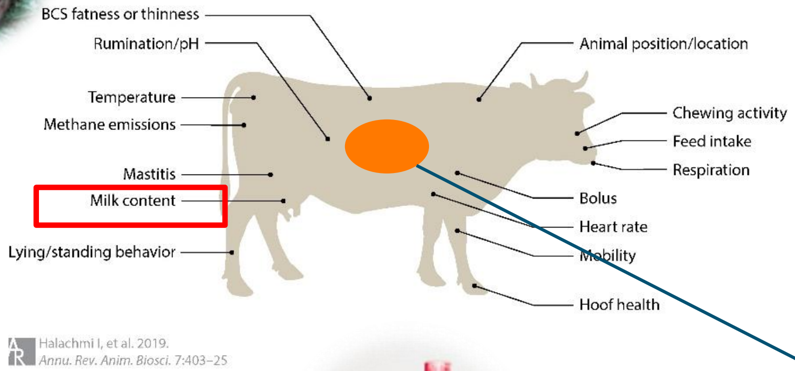

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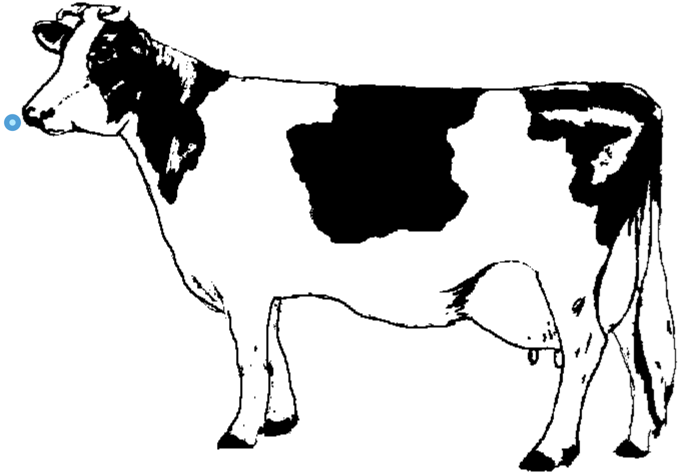
J. Dairy Sci. 102:6288–6295
https://doi.org/10.3168/jds.2018-15684

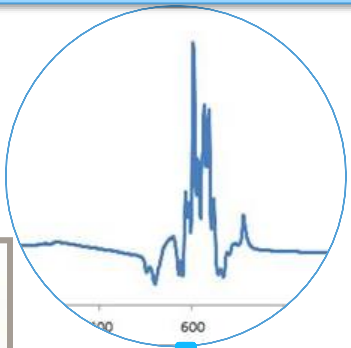
Validation strategy can result in an overoptimistic view of the ability of milk infrared spectra to predict methane emission of dairy cattle

Qiuyu Wang and Henk Bovenhuis*
Animal Breeding and Genomics Group, Wageningen University, PO Box 338, 6700AH, Wageningen, the Netherlands

Breath sensor CH_4
"sniffer"



Milk IR spectra



Milk IR Prediction
equation CH_4

Data

- CH_4
  Sniffer in AMS
  Average over 5-day period: 2 days before, during and 2 days after milk recording

- IR spectra - Qlip
  Selected set of 275 IR wavenumbers

- Animals
  801 cows on 10 commercial herds

Methods

- Partial Least Squares Regression

- Validation Strategy - Random Cross-Validation

Random cross validation

Calibration

n=640 (80%)

Validation

n=161 (20%)

Results – validation R^2

Prediction	Random CV R^2
Infrared	0.49

R_{cv}^2 = 0.49 is within the range of published values (0.13-0.72)

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Random cross validation

Calibration

n=640 (80%)

Validation

n=161 (20%)

Block cross validation

Calibration

9 herds

Validation

Herd 10

Results – validation R^2

Prediction	Random CV R^2	Block CV R^2
Infrared	0.49	0.01

Cross validation strategy has a big impact on the results (and conclusions)!!

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“Negative control”

Selected 114 wavenumbers from the Water Absorption Regions:

- ✓ contain mainly “noise”
- ✓ not informative for predicting milk composition – Expected $R^2 \approx 0$

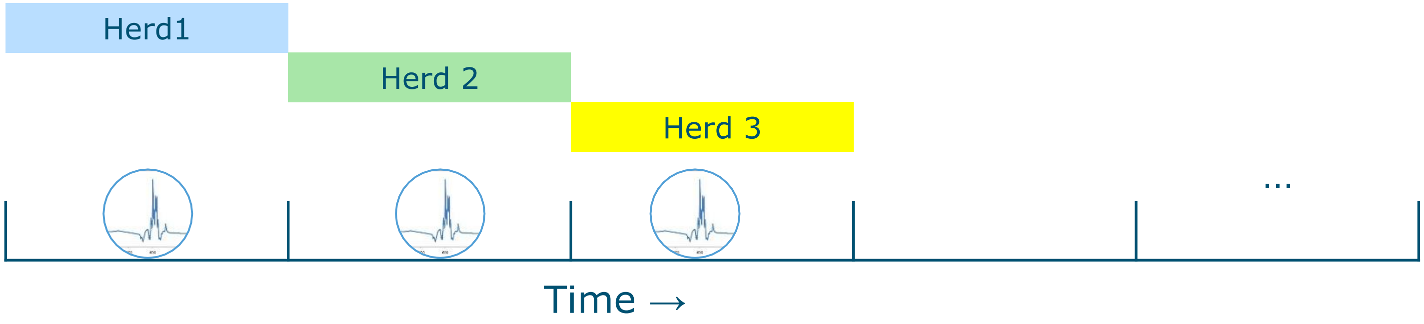
“Negative control”

Prediction	Random CV R^2	Block CV R^2
Infrared	0.49	0.01
Negative control	**0.25**	**0.03**

Conclusion

- ✓ There is a problem with the random cross validation strategy.
- ✓ Negative control can identify these problems.

Diagnosis



- Confounding of “herd” and “date of IR” analysis

- Random Cross Validation:
  errors associated with “date of IR” analysis explain between herd differences in CH_4

Is this a special case??

- Confounding “herd” and “date of IR” analysis
- Differences due to herds – 60% variation
- CH_4 respiration chambers???
  Ring test calibration of respiration chambers in the UK suggest substantial “batch effects” (Gardiner et al. 2015)

OPINION

Tackling the widespread and critical impact of batch effects in high-throughput data

Jeffrey T. Leek, Robert B. Scharpf, Héctor Corrada Bravo, David Simcha, Benjamin Langmead, W. Evan Johnson, Donald Geman, Keith Baggerly and Rafael A. Irizarry

NATURE REVIEWS | GENETICS VOLUME 11 | OCTOBER 2010 | 733

"One often overlooked complication with such studies is batch effects, which occur because measurements are affected by laboratory conditions, reagent lots and personnel differences.

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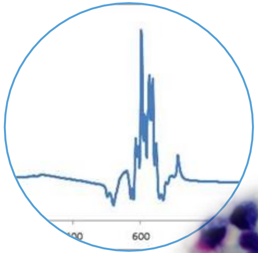
Novel phenotyping technologies – **“omics”**

H0: there are “batch effects”

Milk Infrared



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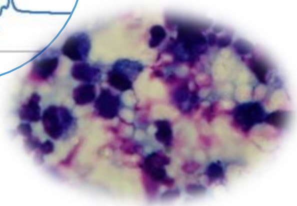
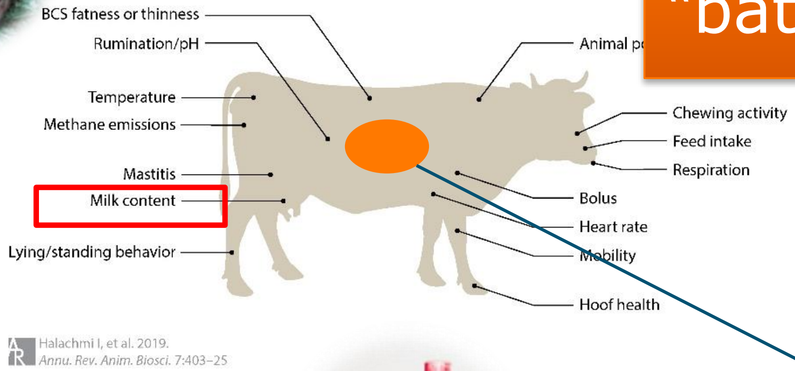


Differential SCC



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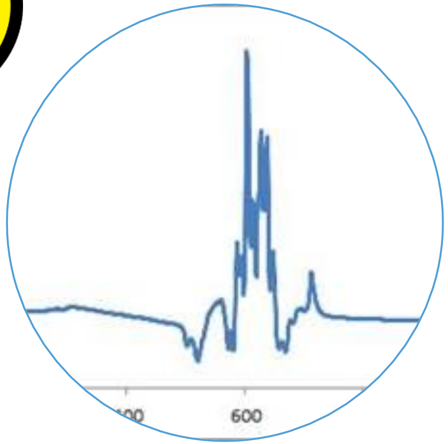
Immunoglobulins, metabolites, hormones, DNA methylation…

Conclusions

- Inaccurate and biased sensor data can provide valuable information for selective breeding.

- Choose your validation strategy carefully.



- H0: high throughput data are affected by "batch effects".