Capturing indirect genetic effects on phenotypic variability

Jovana Marjanovic, H.A. Mulder, L. Rönnegård, DJ de Koning, P. Bijma

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WAGENINGEN UNIVERSITY & RESEARCH

100years 1918 — 2018

SLU Swedish University of Agricultural Sciences

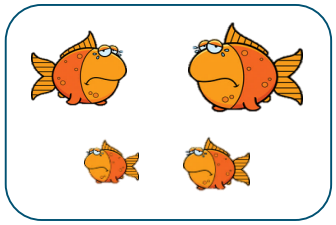
EGS ABG

Erasmus Mundus

Inherited variability

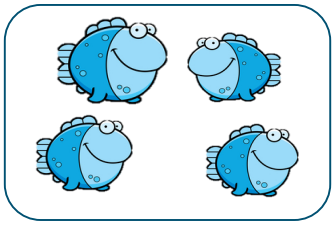
- Phenotypic variability of a genotype – quantitative trait

Family A



variability

Family B



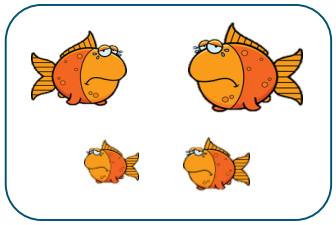
uniformity

$$P_i = A_i + E_i$$

Inherited variability

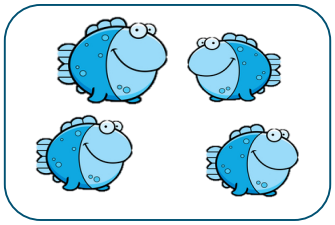
- Phenotypic variability of a genotype – quantitative trait

Family A



variability

Family B



uniformity

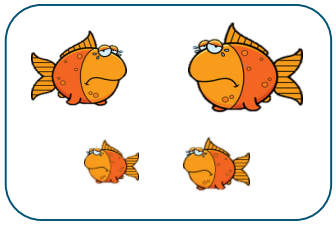
$$P_i = A_i + E_i$$

$$Var(E_i) = A_{v,i} + E_{v,i}$$

Inherited variability

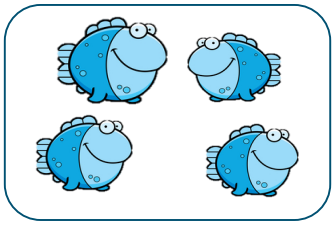
- Phenotypic variability of a genotype – quantitative trait

Family A



variability

Family B



uniformity

Photo by Mark Prein, 2006,
https://www.flickr.com/photos/theworldfishcenter/6242575169/in/photostream

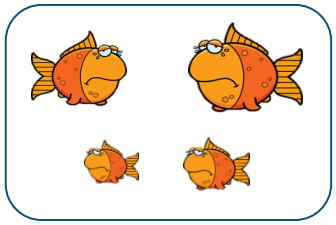
Selective breeding

Photo by Heba El-Begawi, 2013,
https://www.flickr.com/photos/61545321@N06/10569262434

Inherited variability

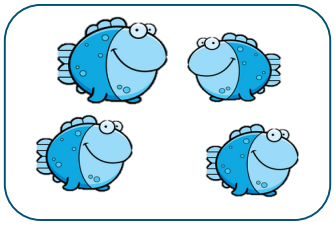
- Phenotypic variability of a genotype – quantitative trait

Family A



variability

Family B



uniformity

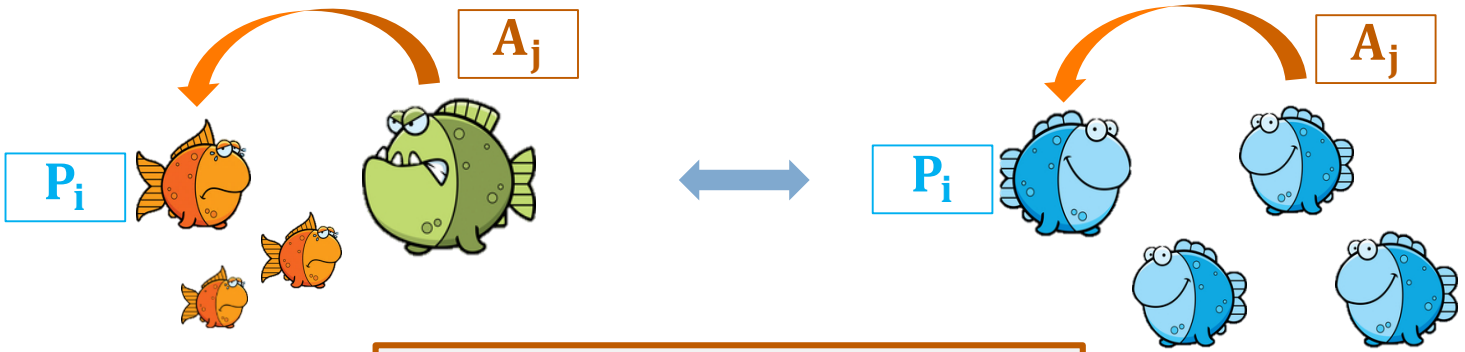
$$P_i = A_i + E_i$$

$$Var(E_i) = A_{v,i} + E_{v,i}$$

Direct genetic effect

Social interactions and variability

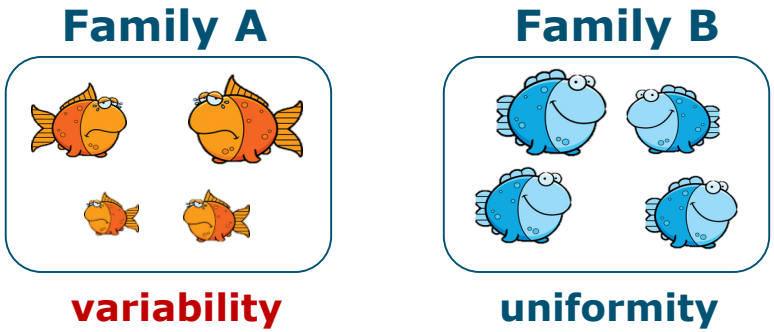
Competition vs. cooperation



Indirect genetic effect (IGE)

Inherited variability

- Phenotypic variability of a genotype – quantitative trait

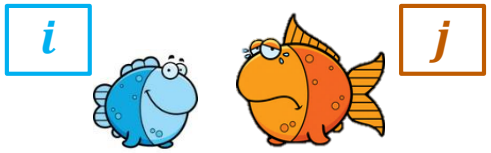


$$P_i = A_i + E_i$$

$$Var(E_i) = A_{v,i} + E_{v,i} + A_j + E_j$$

Indirect genetic effect

New QG-model - Connects IGE and inherited variability

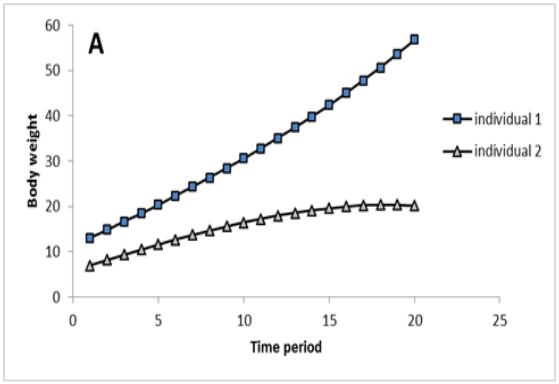


$$P_{t,i} - P_{t-1,i} = \mu_{GR} + A_{GR,i} + b_{ij}\left(P_{t-1,j} - P_{t-1,i}\right)$$

$$b_{ij} = \bar{b} + A_{D,i} + A_{I,j}$$

Genetic sensitivity to competition

Genetic cooperativeness



Objective

Heredity
https://doi.org/10.1038/s41437-018-0068-z

the geneticssociety

ARTICLE

Modelling the co-evolution of indirect genetic effects and inherited variability

Jovana Marjanovic[1,2] · Han A Mulder[1] · Lars Rönnegård[2,3] · Piter Bijma[1]

- IGE and variability may co-evolve
- **b** can respond to selection

$$\mathbf{b}_{ij} = \bar{\mathbf{b}} + \mathbf{A}_{D,i} + \mathbf{A}_{I,j}$$

Can we capture genetic effects of competition?

With existing statistical models

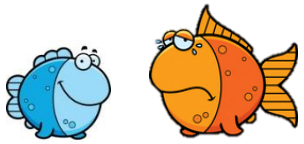
- Inherited variability
- Trait value

} Direct and indirect

Simulation

- Family structured population
- 1 sire x 100 dams -> 10 or 100 offspring/dam

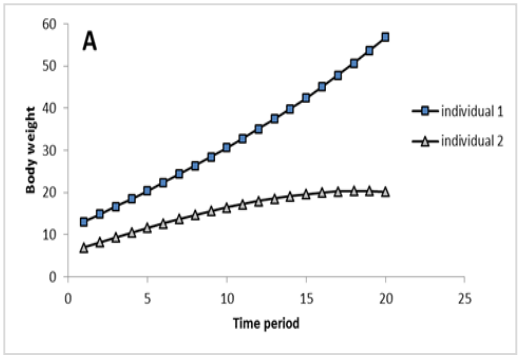
- Groups of 2 individuals
- Phenotypes based on the model
- Growth curves 10 time points



$$P_{t,i} - P_{t-1,i} = \mu_{GR} + A_{GR,i} + b_{ij}\left(P_{t-1,j} - P_{t-1,i}\right)$$

$$b_{ij} = \bar{b} + A_{D,i} + A_{I,j}$$

- **Variability -** Records grouped by family
- **Trait level –** Individual records

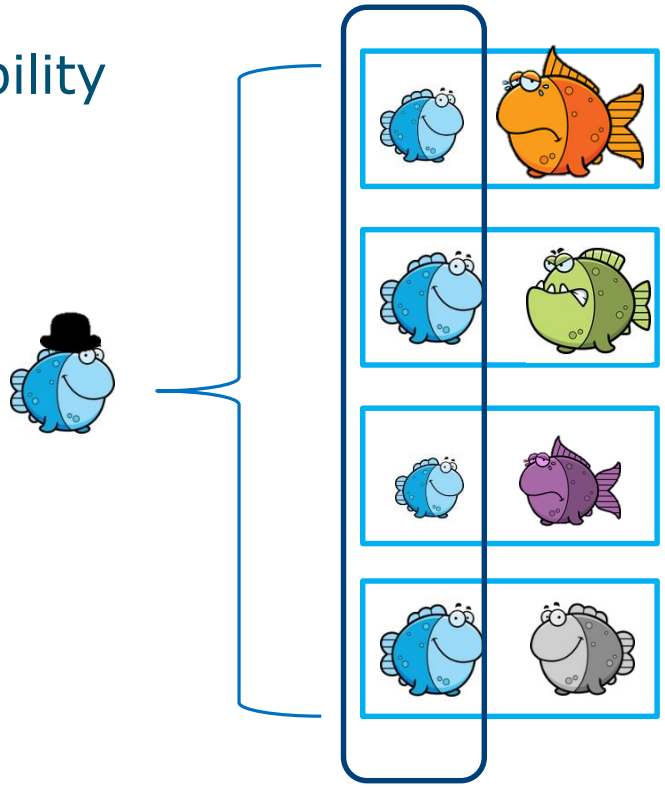


Statistical models - variability

- Direct sire model for inherited variability

$$y_{v,D} = \mu + Z_{D_s} s_D + e$$

s_D - direct genetic effects of sires



Statistical models - variability

- Direct sire model for inherited variability

$$y_{v,D} = \mu + Z_{D_s} s_D + e$$

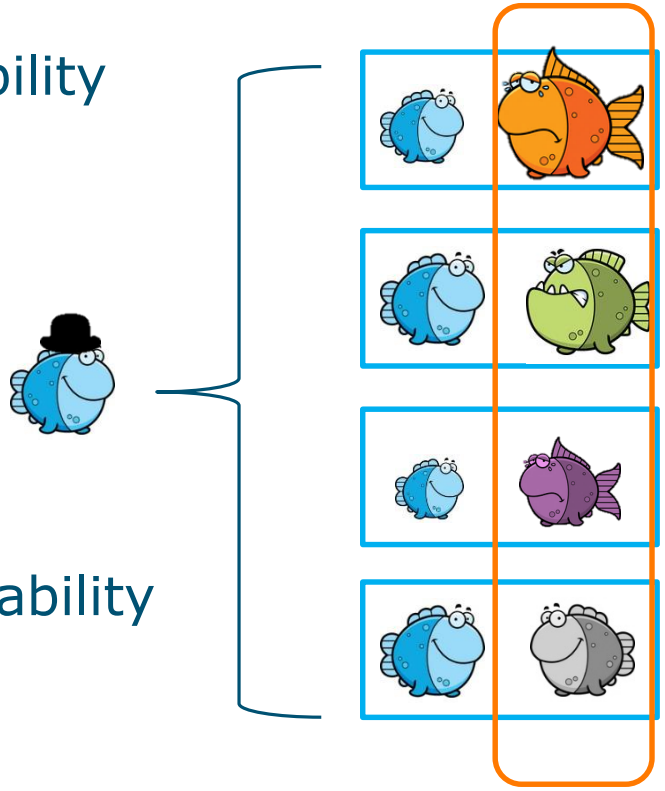
s_D - direct genetic effects of sires

- Indirect sire model for inherited variability

$$y_{v,I} = \mu + Z_{I_s} s_I + e$$

s_I - indirect genetic effects of sires

$y_{v,D}$ and $y_{v,I}$ - log transformed



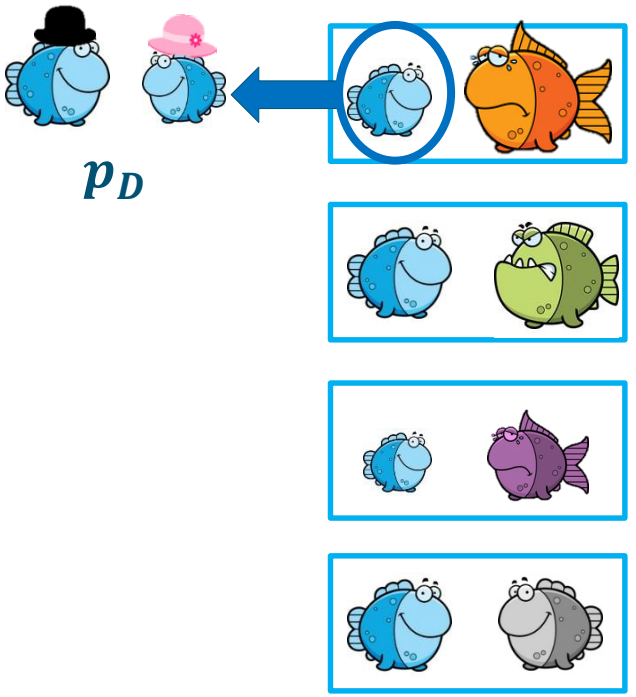
$y_{v,I}$

Statistical models – trait level

- Direct sire-dam model for the trait

$$y_{t,D} = \mu + Z_{D_p} p_D + e$$

Individual observations

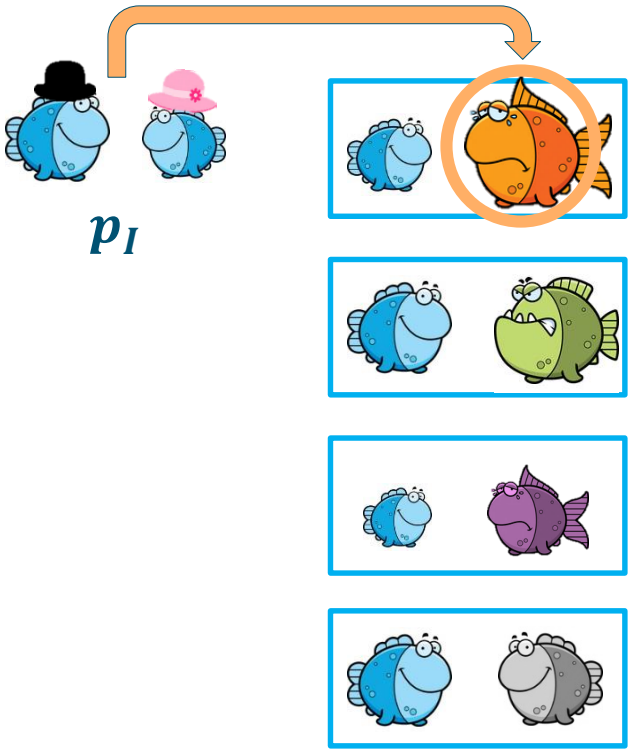


Statistical models – trait level

- Direct sire-dam model for the trait

  $y_{t,D} = \mu + Z_{D_p} p_D + e$

  Individual observations



- Indirect sire-dam model for the trait

  $y_{t,I} = \mu + Z_{I_p} p_I + e$

Correlations

Model	Estimated genetic effects	Simulated breeding values		
		A_{GR}	A_D	A_I
Variability				
Direct sire model	s_D			
Indirect sire model	s_I			
Trait			r	
Direct sire and dam model	p_D			
Indirect sire and dam model	p_I			

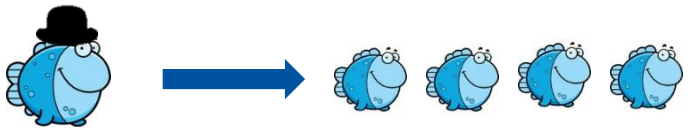
$$P_{t,i} - P_{t-1,i} = \mu_{GR} + A_{GR,i} + b_{ij}\left(P_{t-1,j} - P_{t-1,i}\right)$$

$$b_{ij} = \bar{b} + A_{D,i} + A_{I,j}$$

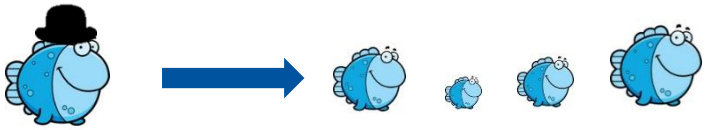
Results

Model	Estimated genetic effects	Simulated breeding values		
		A_{GR}	A_D	A_I
Variability				
Direct sire model	s_D	0.02	-0.96	0.04
Indirect sire model	s_I	0.07	-0.02	-0.91
Trait				
Direct sire and dam model	p_D	0.84	0.00	0.00
Indirect sire and dam model	p_I	-0.03	-0.01	0.01

Resistant to competition



Sensitive to competition



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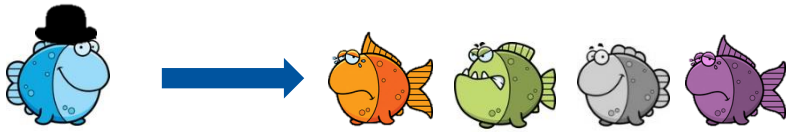
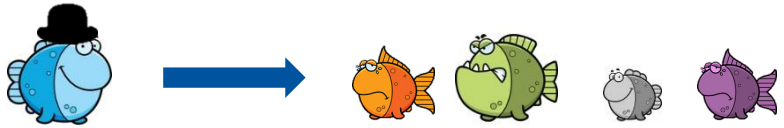
Cooperative



Competitive



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Conclusions

$$P_{t,i} - P_{t-1,i} = \mu_{GR} + A_{GR,i} + b_{ij}\left(P_{t-1,j} - P_{t-1,i}\right)$$

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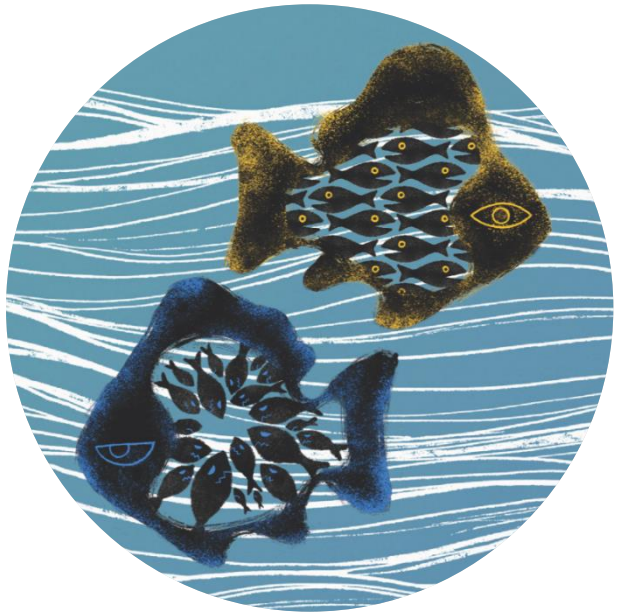

- Direct model of inherited variability captures genetic sensitivity to competition
- Indirect model of inherited variability captures genetic cooperativeness
- Models for trait levels were not able to capture genetic effects of competition

Thank you!

Standard errors

Model	Estimated genetic effects	Simulated breeding values		
		A_{GR}	A_D	A_I
Variability				
Direct sire model	s_D	0.02 (0.10)	-0.96 (0.01)	0.04 (0.12)
Indirect sire model	s_I	0.07 (0.07)	-0.02 (0.10)	-0.91 (0.06)
Trait				
Direct sire and dam model	p_D	0.84 (0.00)	0.00 (0.01)	0.00 (0.01)
Indirect sire and dam model	p_I	-0.03 (0.03)	-0.01 (0.04)	0.01 (0.03)