SMAll RuminanTs breeding for Efficiency and Resilience

WP3: Genetics of trade-offs and synergies between resilience and efficiency related traits

Major achievements

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Objectives of the WP

The challenge for livestock breeding is to improve the resilience traits simultaneous with feed efficiency and other traits important for a sustainable livestock sector. Simultaneous breeding for multiple traits can fall foul of trade-offs between traits. The WP objectives are to:

- To identify trade-offs & synergies under genetic control (Task3.1)
- To better understand the biological mechanisms underlying those trade-offs & synergies and how they affect resilience and efficiency (Task3.2)
- To develop prediction models to manage trade-offs and optimize resilience and efficiency in challenging conditions (Task3.3)

Task 3.1. Identify trade-offs under genetic control

- Systematic review on host genetic component traits underlying herd disease resilience, and the influence of trade-offs on it (UEDIN) :
  - Published here : Doeschl-Wilson et al. "Livestock disease resilience: From individual to herd level" Animal, Dec Vol. 15 . Suppl 1, 2021
  - Potential trade-offs between **individual resilience** and **herd resilience**

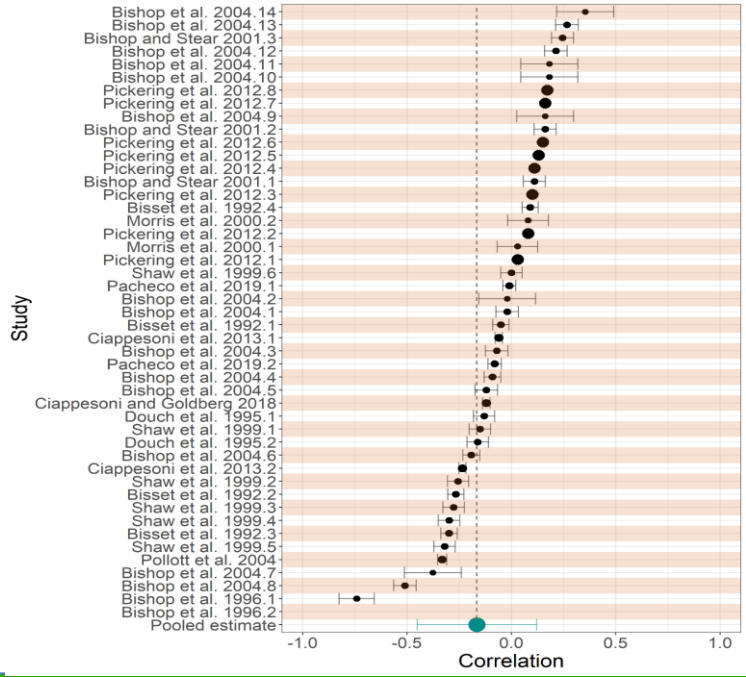
- Meta-analysis of genetic parameters (SRUC, INRAE, UEDIN)
  - 2,151 estimates of heritability and genetic correlation for 81 sheep and 14 goat breeds collated from 12 SMARTER partners AGRIS and public data.
  - Results were published here : Mucha et al. « Animal Board Invited Review: Meta-analysis of genetic parameters for resilience » Animal, Vol16, issue3, 2022

- Genetic analyses for pleiotropic QTLs and potential underlying genes and pathways associated with efficiency, resilience and reproduction related traits (INRAE, UNILEON, INIA_UY)

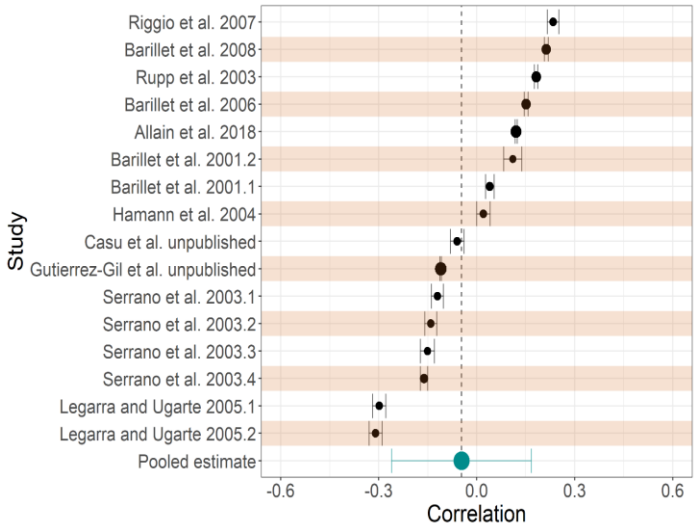
Limited evidence of genetic antagonisms found between resilience and efficiency for dairy goats (SCS with fat content) and dairy sheep (SCS with protein content), and not for meat sheep. => Selection for both R&E is feasible. Even though the pooled estimates were non significant, antagonisms may exist but only in specific populations and environments (Figures a & b)

Forest plots showing genetic correlation estimates between:

(a) Body Weight and FEC (parasitism) in meat sheep



(b) Milk yield and SCS (mastitis) in dairy sheep

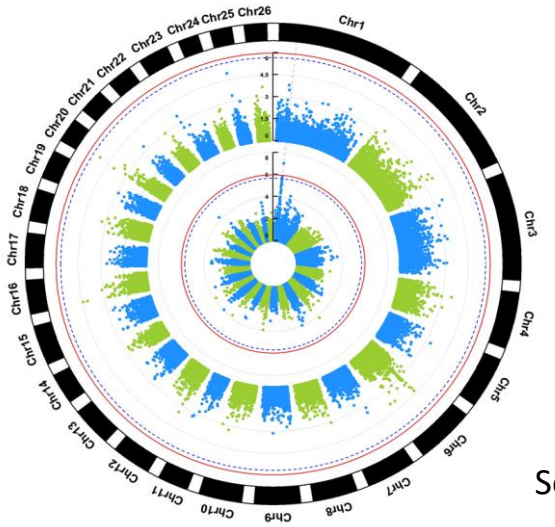


Mucha et al. (2021) Animal

Task 3.1. Identify trade-offs under genetic control

- **pleiotropic QTLs and potential underlying genes and pathways associated with efficiency, resilience and reproduction related traits**

- 7 GWAS datasets collated (or newly generated) (UNILEON, INIA-UY, Capgenes, INRAE) from 8 breeds (Romane, Lacaune, Saanen, Alpine, Churra, Corriedale, Merino, Texel) with > 15000 genotypes
- Pleiotropy identified by Clip Test (David et al., 2023)



- GWAS Pleiotropic QTLs identified (CNR, INRAE) :
  - ✓ Lacaune : CHI3 for mastitis- milk production
  - ✓ Saanen: CHI19 for mastitis-longevity-production
  - ✓ **Romane: OAR1 for Body Condition Score and Body weight**

Source: Johanna Ramirez-Diaz (CNER), 2023

Task 3.2. Create experimental data to study trade-offs

- Five data sets were created in genetically selected sheep and goat which will undergo both nutritional and infection challenges

	Breed Species (Partner)	Genetic group	Challenge	Status
	ASSAF **Dairy sheep** (UNILEON) N=60	Milk production	Nutritional : growing period (N=60) Infectious: LPS* in L1 (N=24)	**Complete**
	ALPINE **Dairy goat** (INRAE) N= 98	Longevity	Nutritional: 2 days on hay in L1 (N=98) Infectious = LPS* (N=87)	**Complete**
	ROMANE **Meat sheep** (INRAE) N=48	Parasite resistance	Infectious: parasite *H. contortus* Nutritional: low/high protein around lambing	**Complete**
	ROMANE **Meat sheep** (INRAE) N=60	Feed efficiency	Infectious: parasite *H. contortus*	**Complete**
	CORRIEDALE **Meat sheep** (INIA-UY) N = 67	Parasite resistance	Nutritional: None (feed intake records) Infectious: parasite *H. contortus*	**Complete**

***LPS**: challenge with lipopolysaccharide mimicking an inflammatory disease such as mastitis

Task 3.2. Create experimental data to study trade-offs

❑ Results in **ROMANE meat sheep (INRAE)** genetically selected for parasite resistance

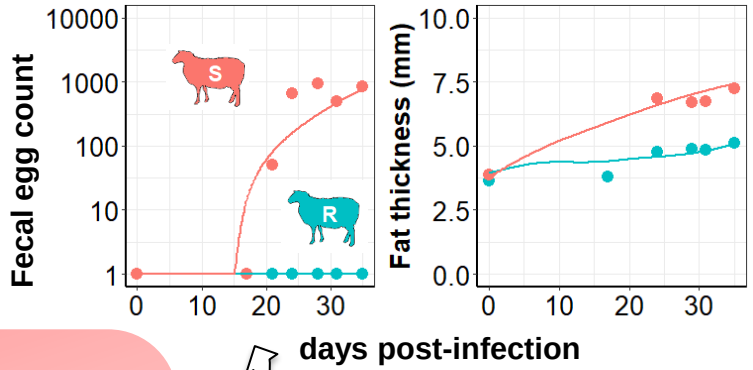
Selection for resistance to gastro-intestinal parasite in growing lambs effective

- most of the time in adult breeding ewes ✓
- at peripartum ✗

Around lambing, level of protein in the diet affects

- ewe growth ✓ (and lamb growth ✓)
- ewe resistance to parasite ✗

Response to infection during growth



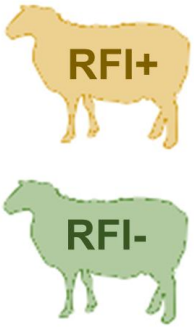
Trade-offs between resistance to parasite and production

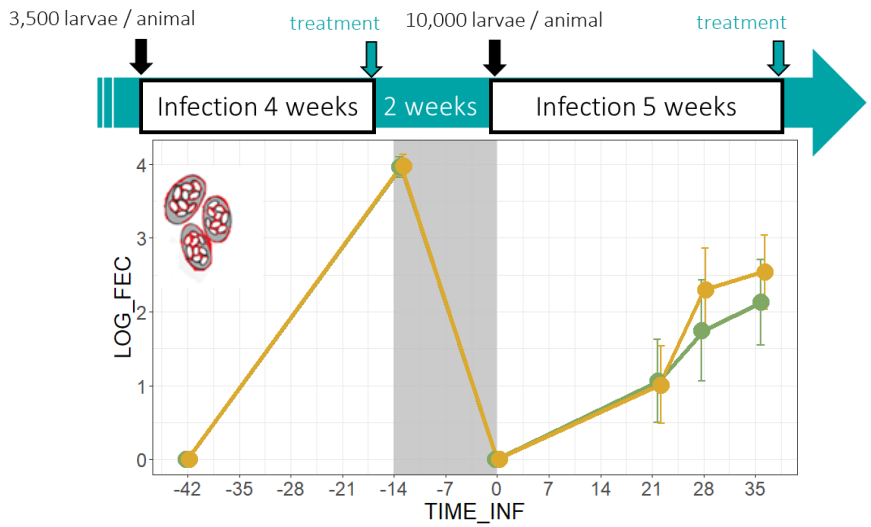
- during growth ✓ (reduced fat deposition)
- during reproduction ✗ (except around 1st lambing where a cost of host genetic resistance on body weight has been detected)

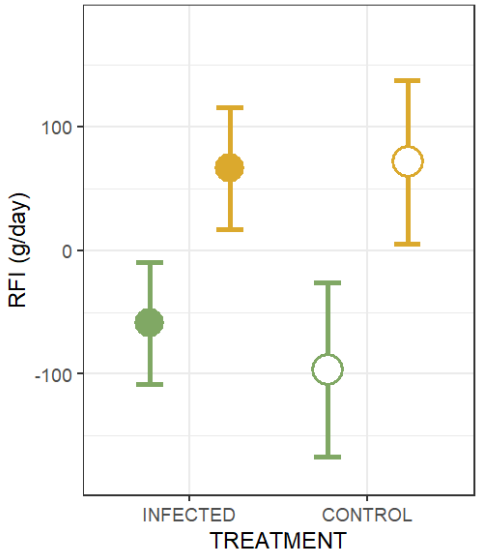
Douhard et al. "The cost of host genetic resistance on body condition: Evidence from divergently selected sheep" Evol. App. 15:9, 2022

Task 3.2. Create experimental data to study trade-offs

- Results in **ROMANE meat sheep (INRAE)** genetically selected for feed efficiency







No line difference in FEC during growth

No effect of infectious challenge on residual feed intake (RFI)

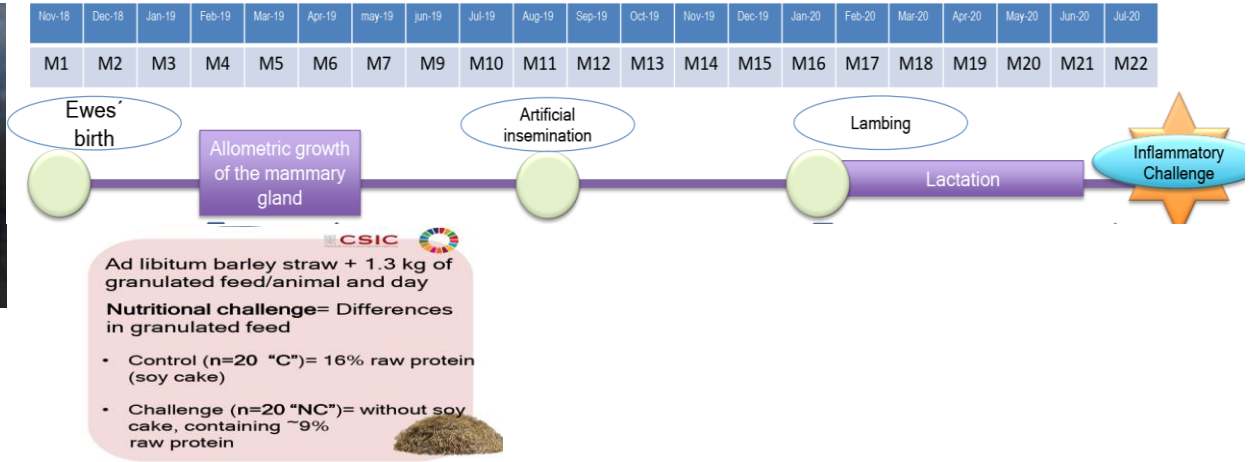
Trade-off between feed efficiency and parasite resistance

- during growth ✗
- during reproduction **?** (data analysis in progress)

Douhard et al. "Feed efficiency and resource allocation trade-offs: theory, evidence and prospects" Proceedings of 12th WCGALP

Task 3.2. Create experimental data to study trade-offs

- Results in **ASSAF Dairy sheep (UNILEON)** in genetically selected for milk production



Evidence for an effect of DIET and genetic LINE on the outcome of the inflammatory challenge with LPS (Cytokine/chemokine ratio traits) :

DIET significant for several plasma markers: IL-10, IL36RA and VEGF-A.

LINE significant for a number of markers : IL-8.

=> Analysis of mechanisms that underlie the trade-offs are in progress

Results in **ASSAF Dairy sheep (UNILEON)**

https://doi.org/10.1016/j.rvsc.2023.04.006

Influence of a temporary restriction of dietary protein in prepubertal ewe lambs on first lactation milk traits and response to a mammary gland inflammatory challenge

Rocío Pelayo [a], Héctor Marina [a], Aroa Suárez-Vega [a], Gonzalo Hervás [b], Cristina Esteban-Blanco [a], Blandine Gausseres [c], Gilles Foucras [c], Juan J. Arranz [a], Beatriz Gutiérrez-Gil [a,*]

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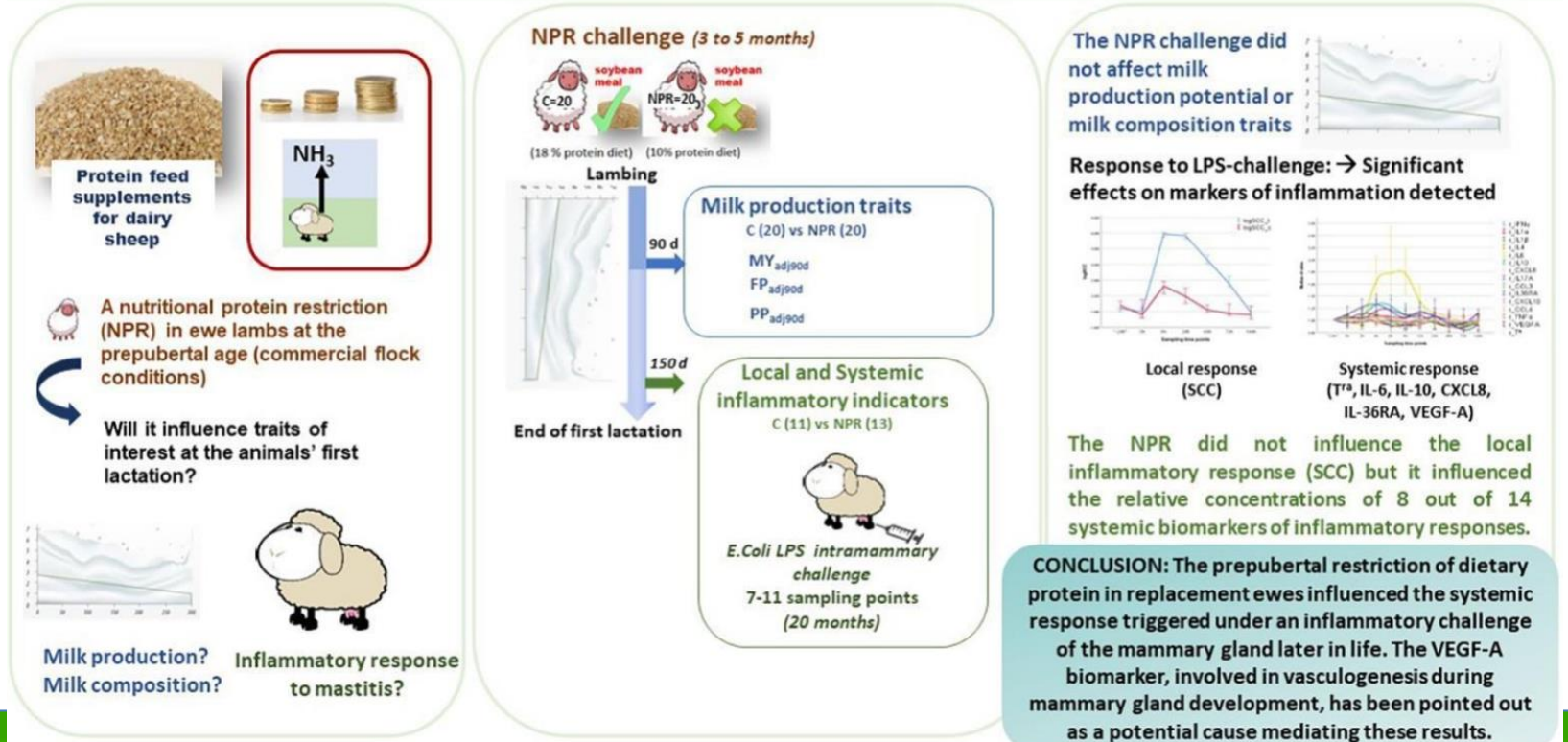
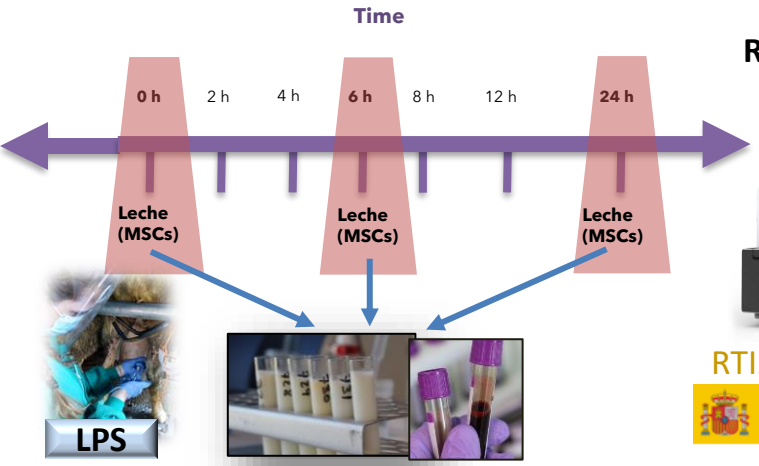
Influence of dietary protein restriction in prepubertal ewe lambs on first lactation milk traits and response to a mammary gland inflammatory challenge



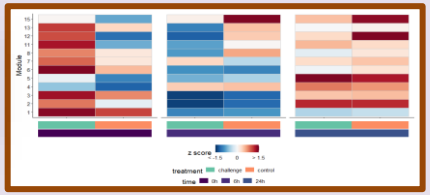
UNILEON: *RNA-Seq analyses of milk somatic cells and blood cells for inflammatory challenge*



RTI2018-093535-B-100
RNA-SeqRNA sequencing funded by a Spanish National Project

2. Studies underway...

RNA-Seq of Milk somatic cells (MSC) comparing Control and NC: Co-expression analysis (Simple Tidy GeneCoEx workflow)



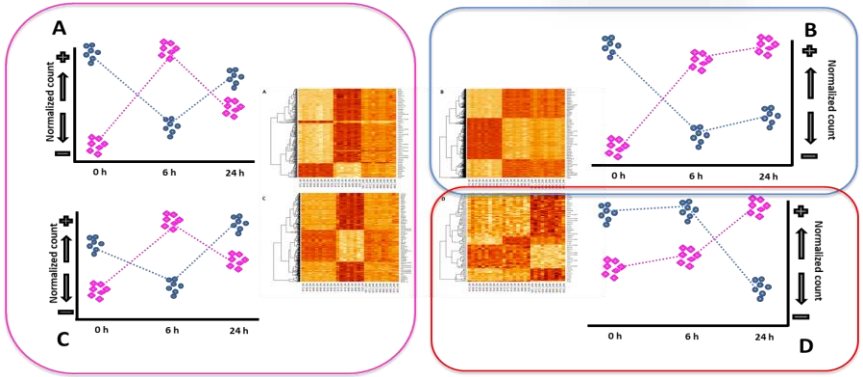
RNA-Seq of Blood samples comparing Control and NC: : dynamic study and C vs NC

1. RNA-Seq of Milk somatic cells (MSC) of Control animals (no protein restriction in prepubertal ages)

Dynamic milk transcriptome expression changes in response to *E. coli* LPS intramammary challenge:
Differentially expressed genes (DEGs): **13 NC vs 11 C**

Three groups of DEGs were defined:

- ***Acute inflammatory response DEGs* (A+C):** 521 genes with higher expression at 6h
- ***General inflammatory response DEGs* (B):** 1436 genes with higher expression at 6h and 24h
- ***Late inflammatory response DEGs* (D):** 67 genes with higher expression at 24h



Task 3.2. Create experimental data to study trade-offs

- Results in **CORRIEDALE sheep (INIA-UY)** genetically selected for parasite resistance

Analysis of feed conversion efficiency in Corriedale **lines** (Ferreira et al. 2021)

Trait	GIN line		
	Resistant	Susceptible	P
RFI	0.02 ± 0.018	–0.02 ± 0.016	0.116
FCR	9.0 ± 0.62	7.6 ± 0.75	0.161
DMI	0.97 ± 0.036	0.98 ± 0.044	0.969
ADG	123 ± 0.90	143 ± 0.11	0.168
Initial BW	27.1 ± 0.53	27.7 ± 0.64	0.483
Final BW	33.9 ± 0.46	34.7 ± 0.54	0.292

Corriedale lines did not show significant differences in residual feed intake (RFI), feed conversion ratio (FCR), dry matter intake (DMI), average daily gain (ADG) or body weight (BW), indicating that breeding parasite resistant animals in that population would not have undesirable effect on feed efficiency.

Task 3.3: Develop prediction models to manage trade-offs and optimise resilience & efficiency in challenging conditions

Objective of the task: Develop mechanistic and statistical models to predict and manage trade-offs associated with infectious and nutritional challenges

1. **Marie Ithurbide** (INRAE, Toulouse): Toward genetic selection for resilience based on milk metabolites
2. **Nicolas Friggens** (INRAE, Mosar): Towards a resource allocation model for dairy goats building on SMARTER data
3. **Frederic Douhard** (INRAE, Toulouse): Modelling the energy cost of host resistance to gastrointestinal parasites in meat sheep
4. **Masoud Ghaderi-Zefreh** (Roslin Institute): Evaluation of novel resilience phenotypes based on longitudinal performance measures

Smarter

Thank you !