

# Epigenetics in Aquaculture

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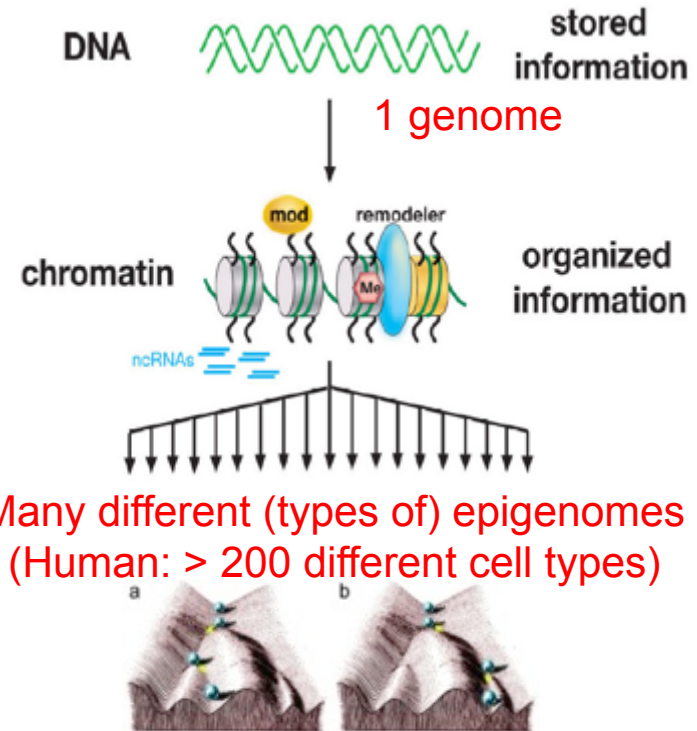
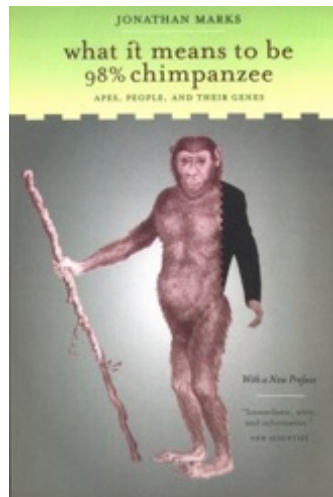
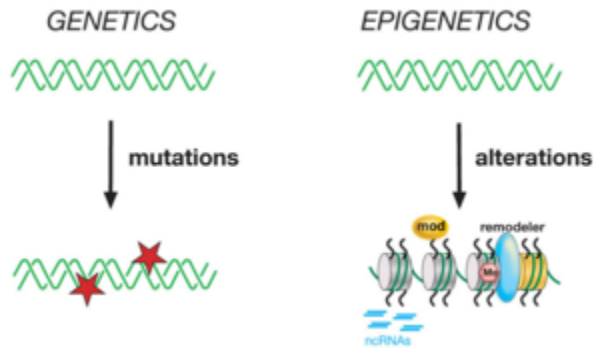
Diversify meeting. Palau Macaya, Barcelona, 17–19 January 2017



F. Piferrer, D. Mylonas, J.F. Asturiano, F. Prat

7<sup>TH</sup> International Symposium on Reproductive Physiology of Fish. Mie, Japan, 18–23 May, 2003

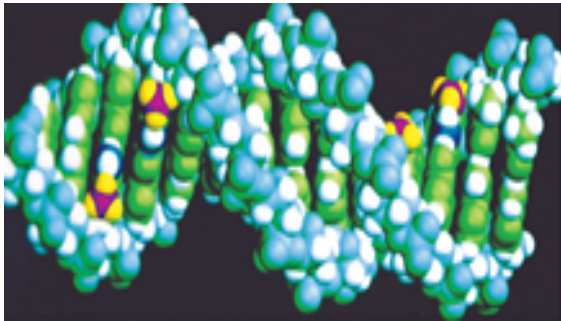
# Epigenetics



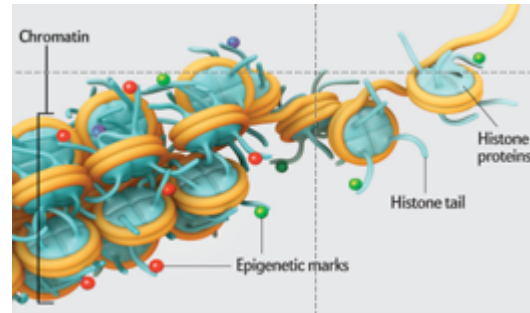
“The study of **phenomena and mechanisms** that cause **chromosome-bound, mitotically and/or meiotically heritable** changes to gene expression or phenotype that are **not dependent** on changes to DNA sequence”

# Main Epigenetic Mechanisms

## DNA methylation



## Histone modifications



## Non-coding RNAs

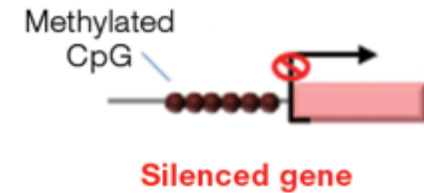
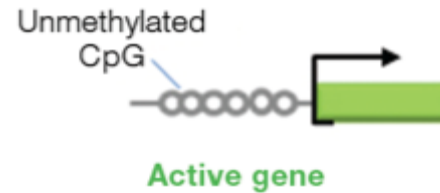
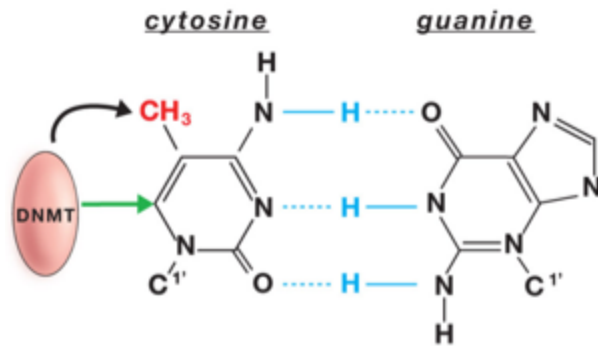
### lncRNAs

### sncRNA

siRNA (20-25 nt)

miRNA (21-22 nt)

piRNA (29-30 nt)

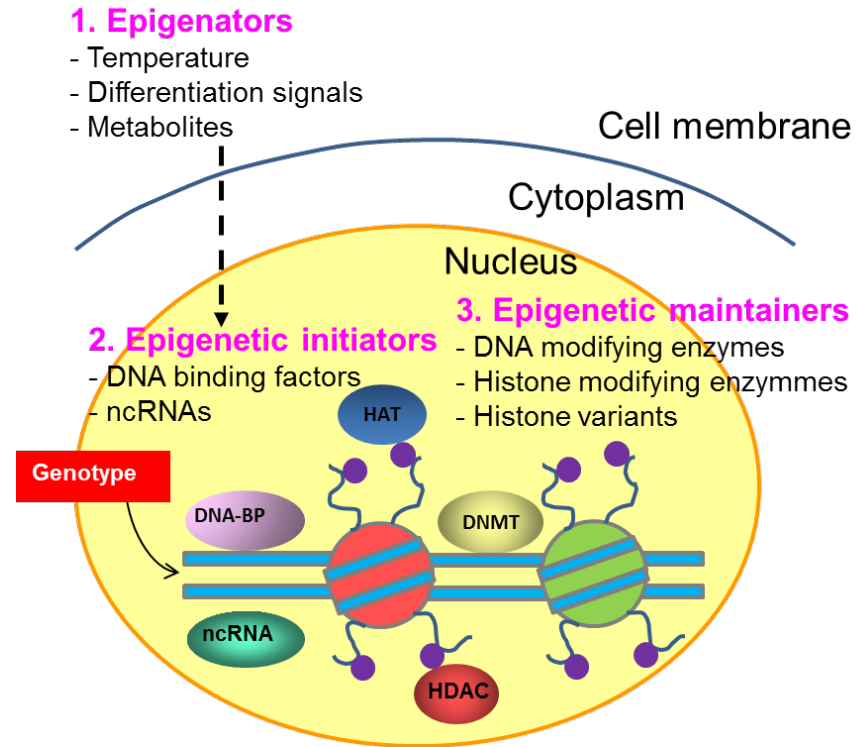
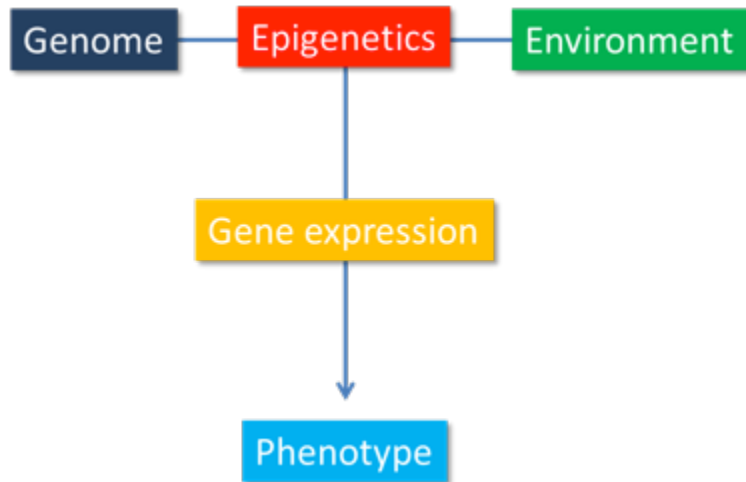


**Dogma: DNA methylation in the promoter represses gene transcription**



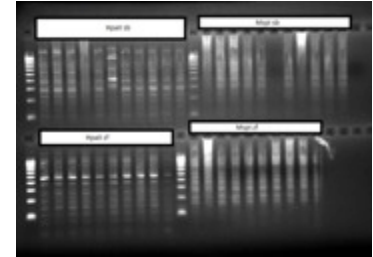
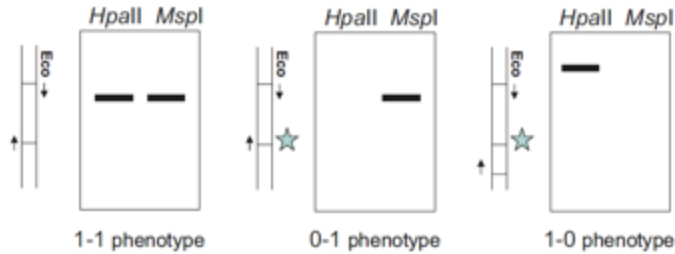
# Establishment of Epigenetic Marks

Genotype + Environment = Phenotype



Piferrer (2013). *Dev. Dyn.* 242: 360–370

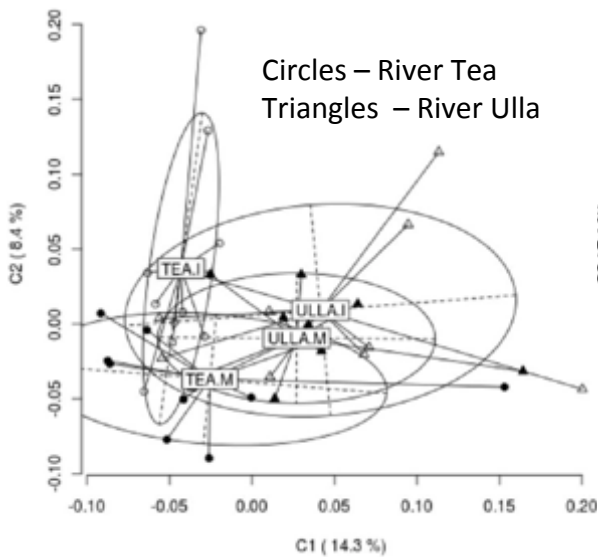
# Epigenetics can explain the phenotypic variance that cannot be explained by genetic variance alone



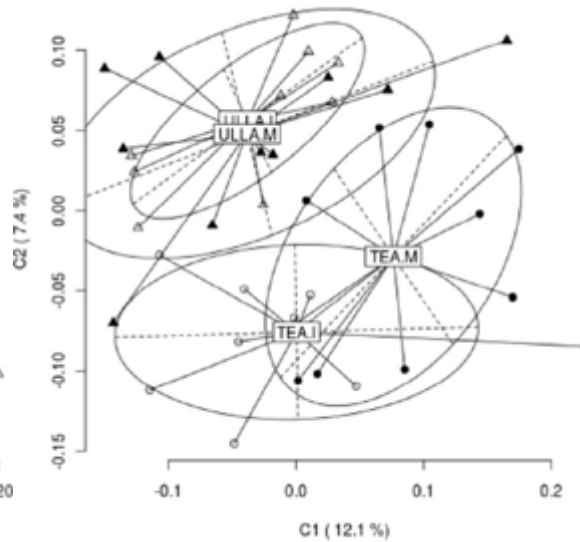
Genetic. AFLP: *EcoRI* + *MseI*

Epigenetic. MS-AFLP: *EcoRI* + *HpaII* or *MspI*

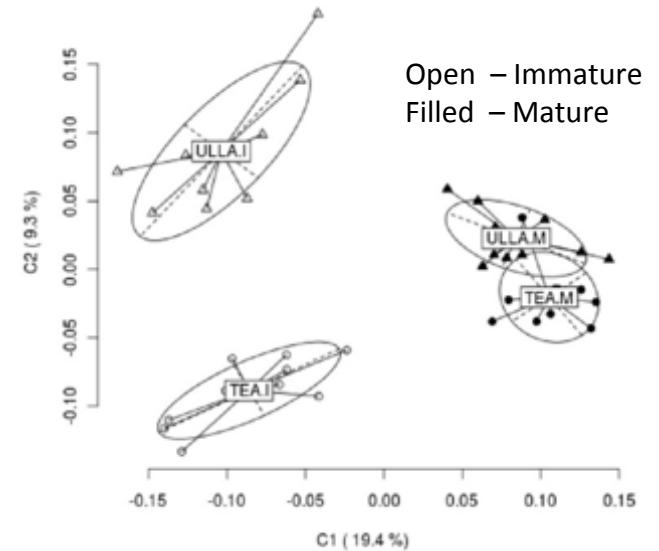
Genetic (AFLP)



Epigenetic, liver (MS-AFLP)

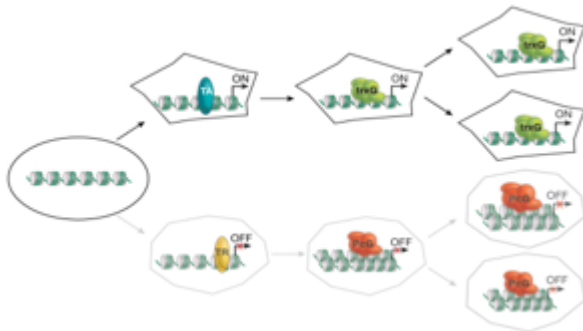


Epigenetic, gonads (MS-AFLP)

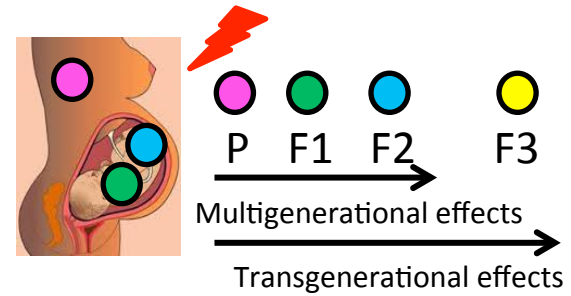


# Epigenetic Inheritance

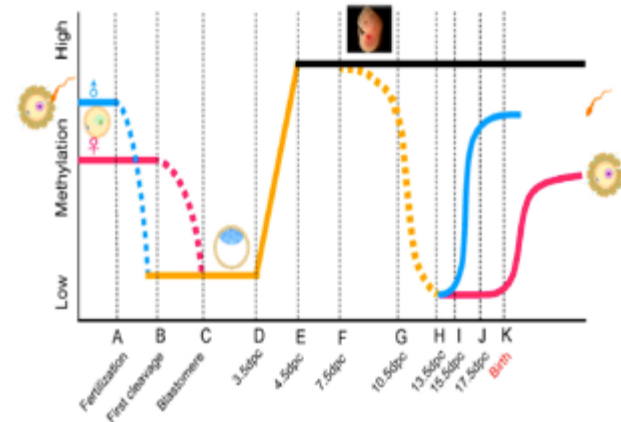
Cell-cell transfer (mitosis)



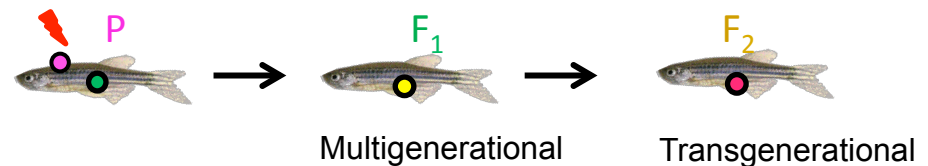
Organism-organism transfer (meiosis)  
Multi- vs. transgenerational effects



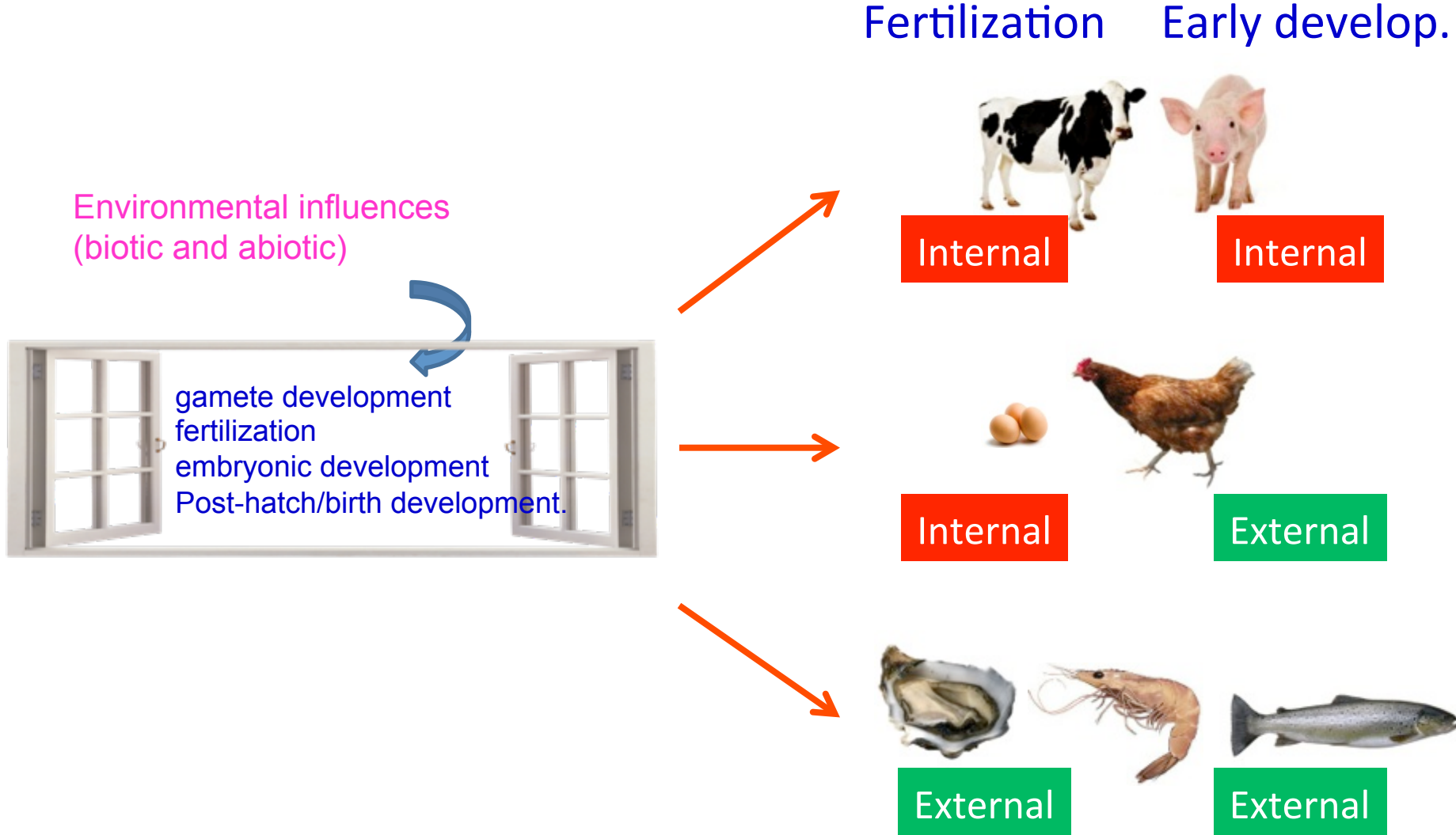
Anway et al 2005. *Science* 308, 1466–1469



Yan (2014). *Mol. Cell. Endocrinol.* 398: 24–30



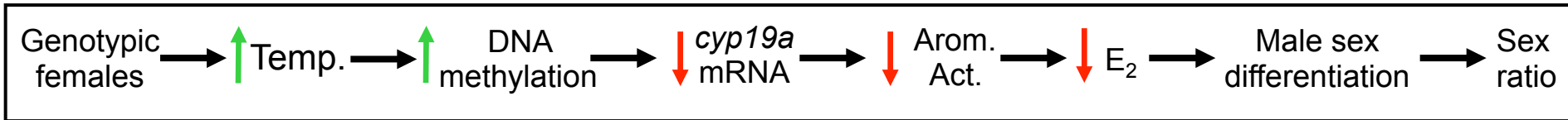
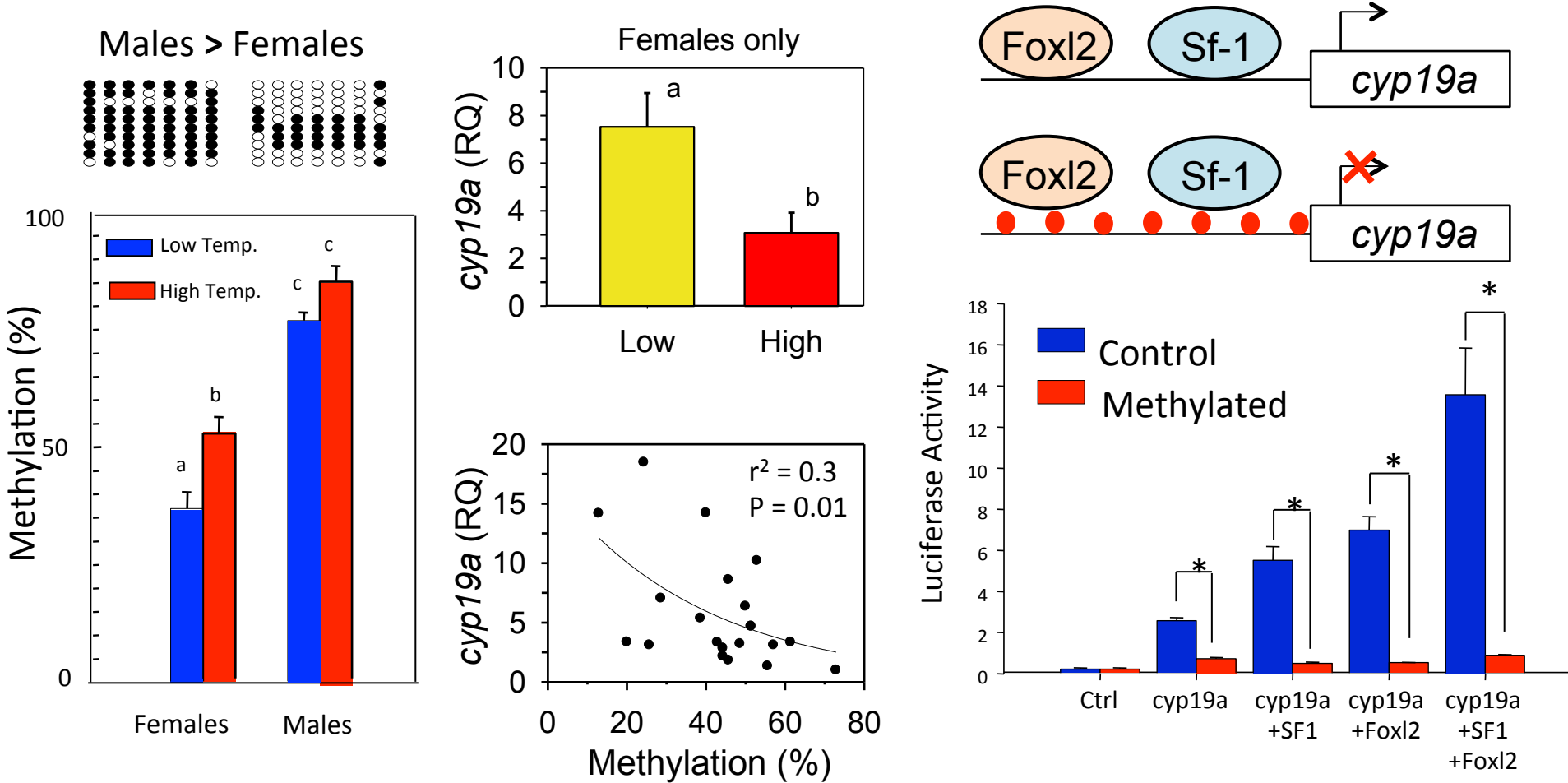
# Epigenetics and Animal Production



Growth, Product quality, Health, Welfare, Reproduction



# An Epigenetic Switch linking temperature and *cyp19a* expression



environment → DNA methylation → gene expression → phenotype



# Nutritional programming

What happens to you during early life has long-lasting consequences



OK



+ Butyrate

not OK



OK

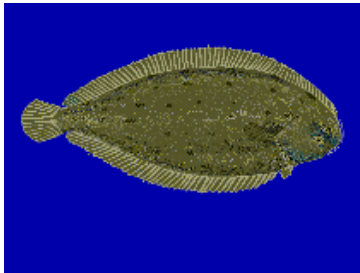
 Fish-based

 Plant-based

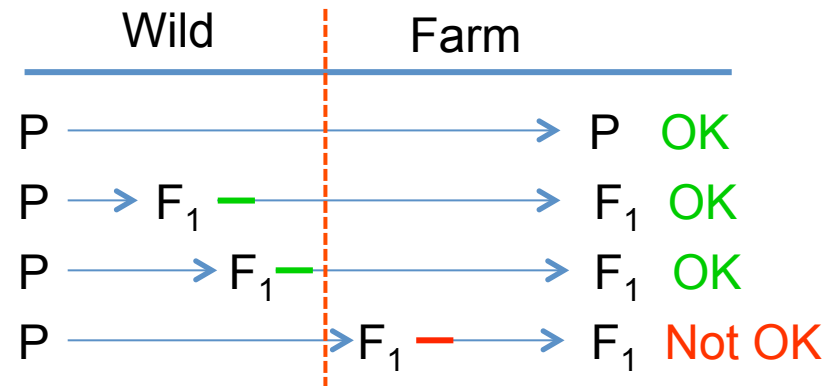


TIMING IS EVERYTHING

## Problems with F1 Senegalese Sole Born in Captivity



*Solea senegalensis*



Genotype x Environment = Phenotype

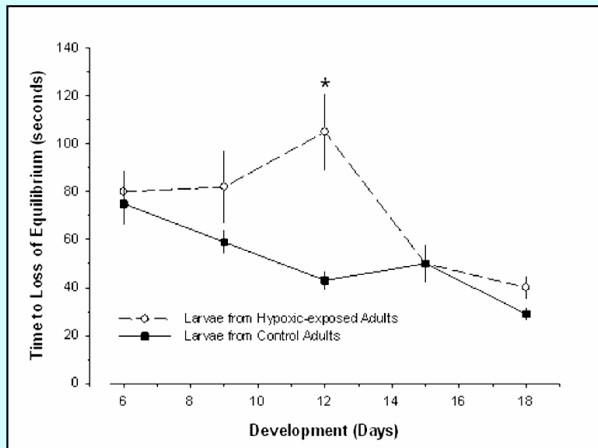
Genotype x Environment x Timing = Phenotype

# Epigenetics and Aquaculture



## - Hypoxic tolerance

Larval zebrafish (*Danio rerio*) exposed to acute, severe hypoxia (3-5% O<sub>2</sub>)



## - Effects of diet during early development

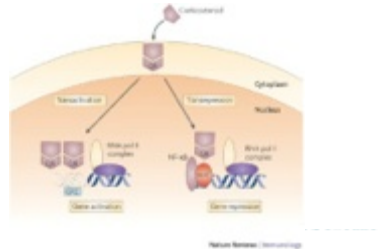
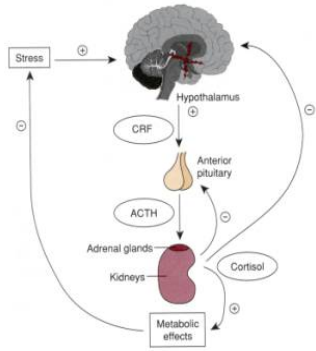
Agouti mice born from mothers fed diets with different amounts of methyl donors



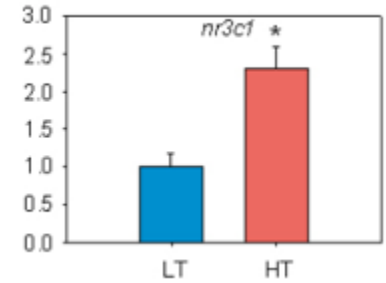
Malpigmentation in turbot farming is a big problem and is influenced by diet. The underlying cause is not known



# Epigenetics and Stress



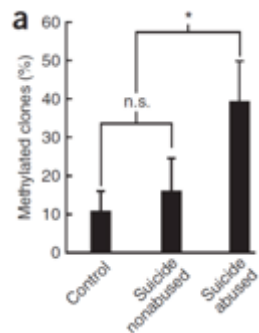
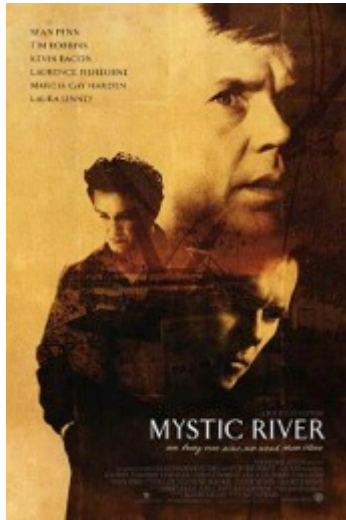
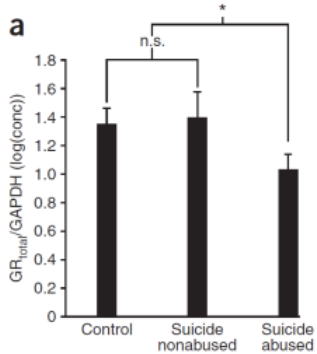
## Sea bass Thermal stress



Díaz & Piferrer (2015). *BMC Genomics*

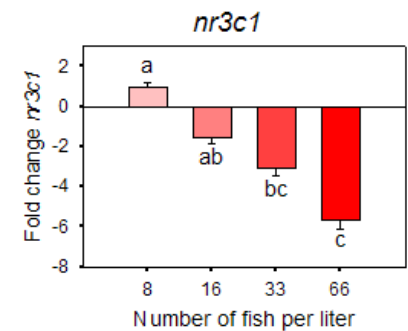
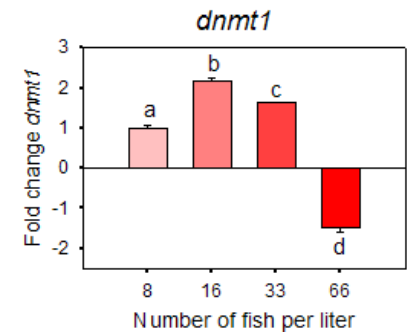
## Epigenetic regulation of the glucocorticoid receptor in human brain associates with childhood abuse

Patrick O McGowan<sup>1,2</sup>, Aya Sasaki<sup>1,2</sup>, Ana C D'Alessio<sup>3</sup>, Sergiy Dymov<sup>3</sup>, Benoit Labonté<sup>1,4</sup>, Moshé Szyf<sup>2,3</sup>, Gustavo Turecki<sup>1,4</sup> & Michael J Meaney<sup>1,2,5</sup>



McGowan et al. 2009. *Nature Neurosci.* 12, 342–348

## Zebrafish Confinement stress



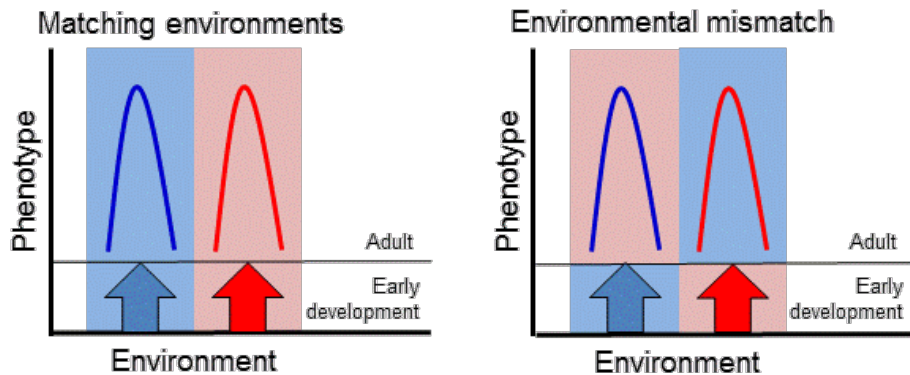
Valdivieso et al. (Unpubl. Obs.)

# Altered sex ratios in response to climate change – Who will fall into the (epigenetic) trap? (Comment on DOI 10.1002/bies.201600058)

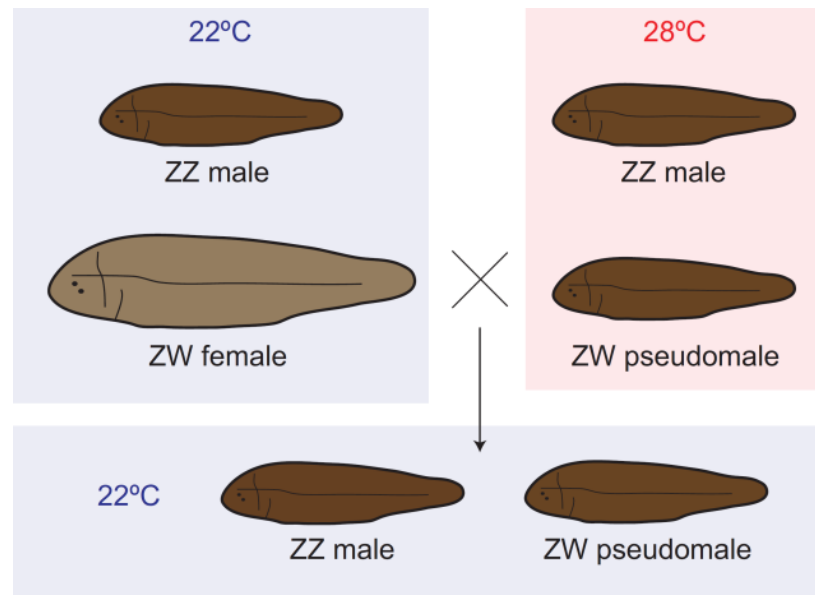
Francesc Piferrer

Bioessays (2016) 38: 939, 2016

Idea to watch



**Epigenetic trap:** any epigenetic change that arises in response to novel environmental cues that produce maladaptive phenotypes

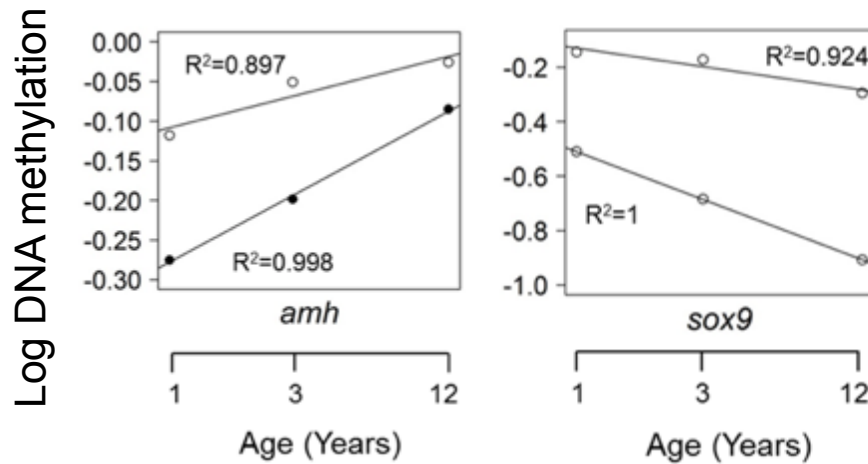


Shao et al. (2014). *Genom. Res.*

Perhaps **Bad** in nature, perhaps **good** in culture

# New Developments

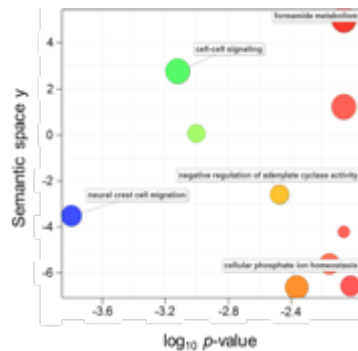
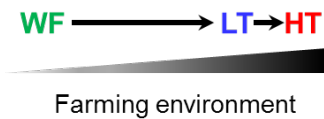
## Piscine epigenetic clock



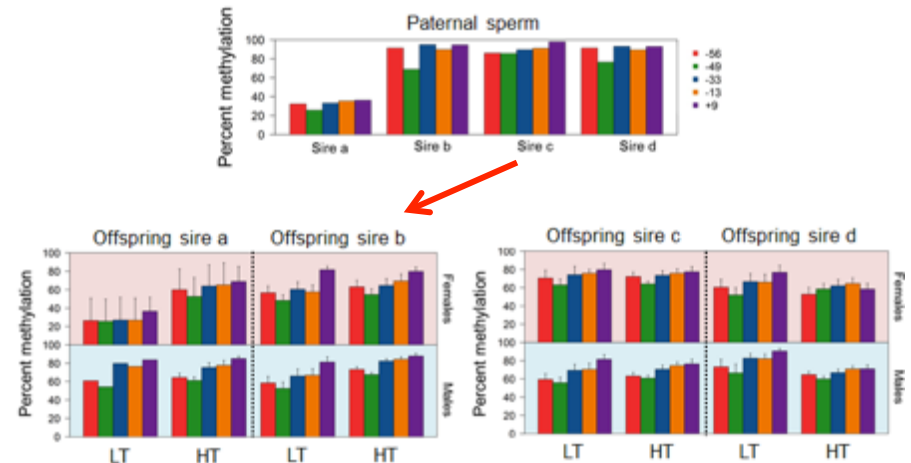
## Potential implications

Population studies  
Fisheries science

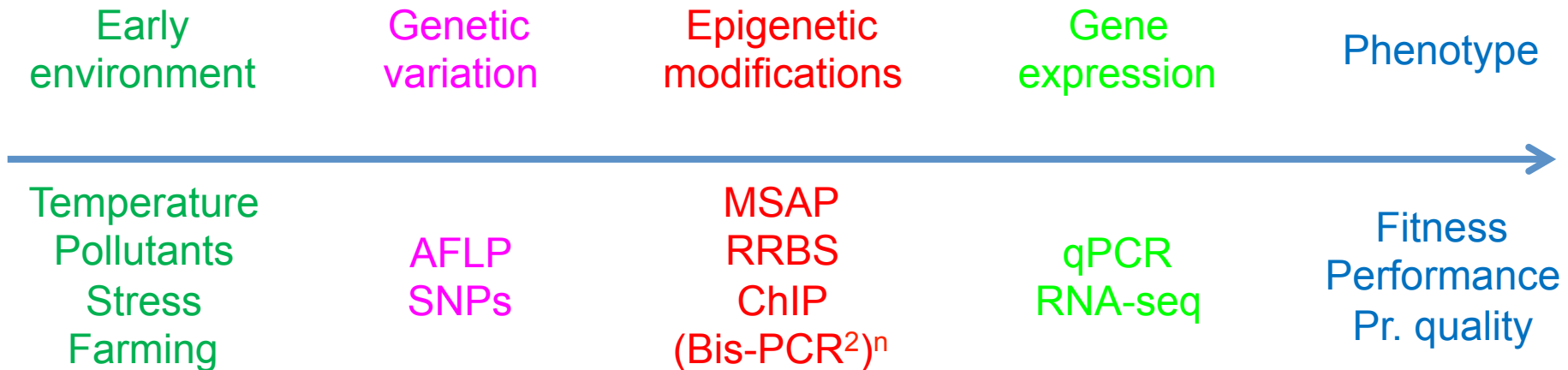
## Epigenetics of domestication



## Father-to-daughter transmission of epigenetic marks?



# Epigenetic Markers and Aquaculture



Diagnostic & Prognostic





# Summary/Take home messages

- Epigenetic mechanisms provide organisms with the ability to integrate genomic and environmental information to produce a given phenotype
- Epigenetics can explain the phenotypic variance that cannot be explained by genetic variance
- Transgenerational epigenetic inheritance is a type of non-Mendelian inheritance that involves retention vs. reprogramming of epigenetic marks and is dependent on DNA methylation.
- Timing is everything. Effects are stronger if the stimulus occurs during early development. Epigenetic modifications can be permanent and are involved in the process of domestication
- The effect of the environment can be passed down to the following generations even if the original stimulus is no longer present. This opens the possibility of epigenetic programming in animal husbandry, which is a non-pharmacological approach to production improvement



# Acknowledgments

## Group members

Dr. Francesc Piferrer

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Gemma Fuster, Technician

Núria Sanchez, Master Student



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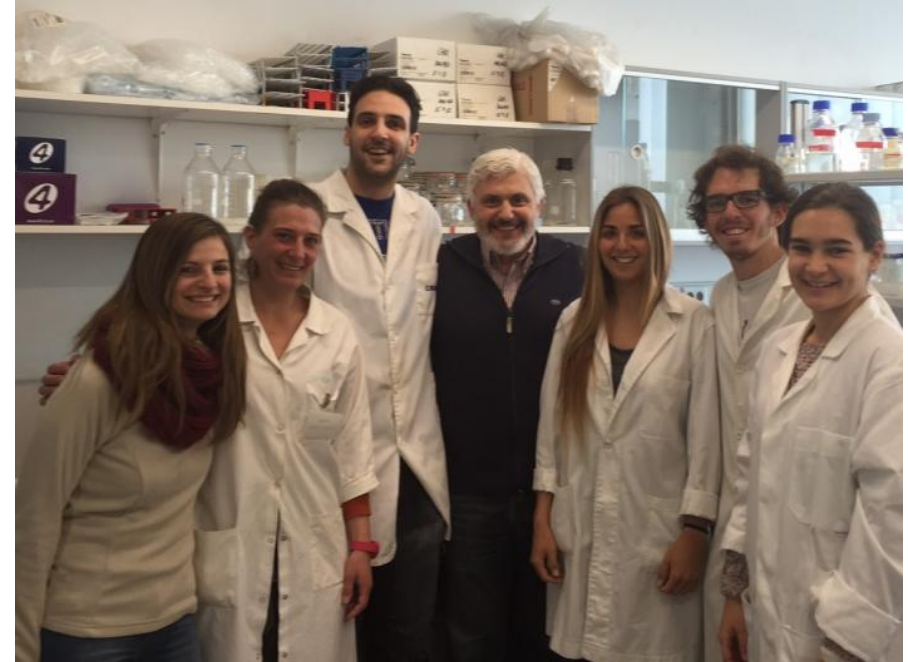
Marco Álvarez, Univ Andrés Bello, Chile

Laszlo Orban, Temasek LSL, Singapore

Luciano di Croce, CRG, Barcelona

Paloma Morán, Univ. Vigo

Marc Vandeputte, IFREMER, France



Project **Epifarm**

