Influence of Epigenetic Variation on Marine Invertebrate Physiology

Steven Roberts
Associate Professor
University of Washington
School of Aquatic and Fishery Sciences
robertslab.info
@sr320

Background

Physiology

How fundamental processes work in aquatic species

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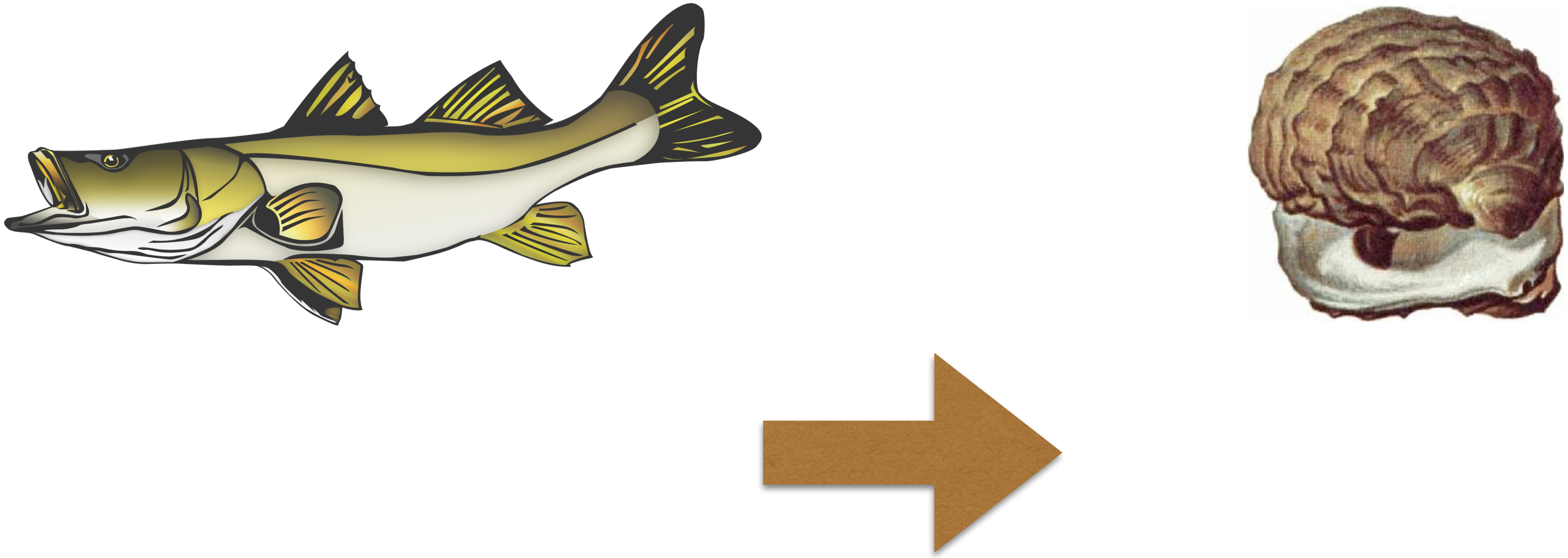

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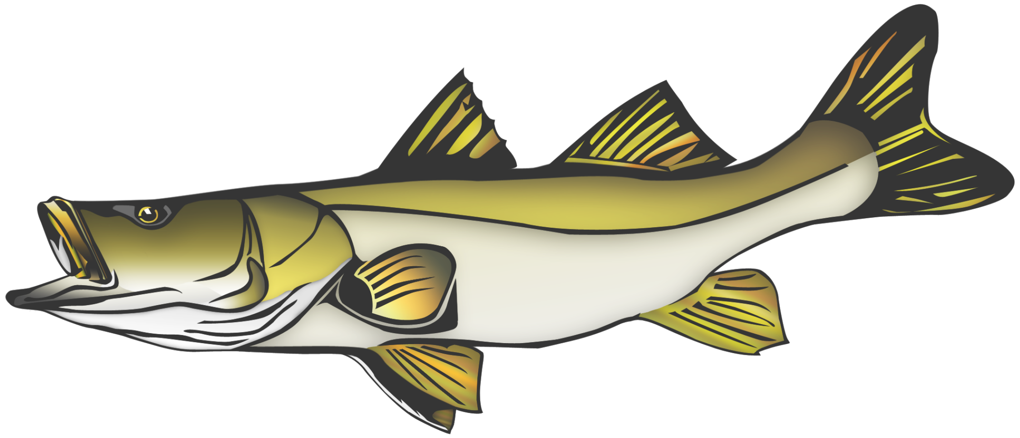

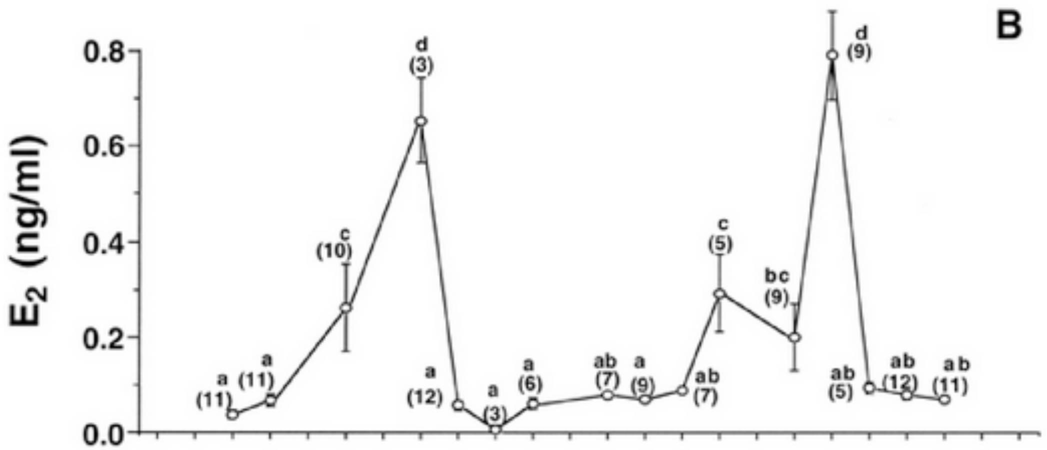

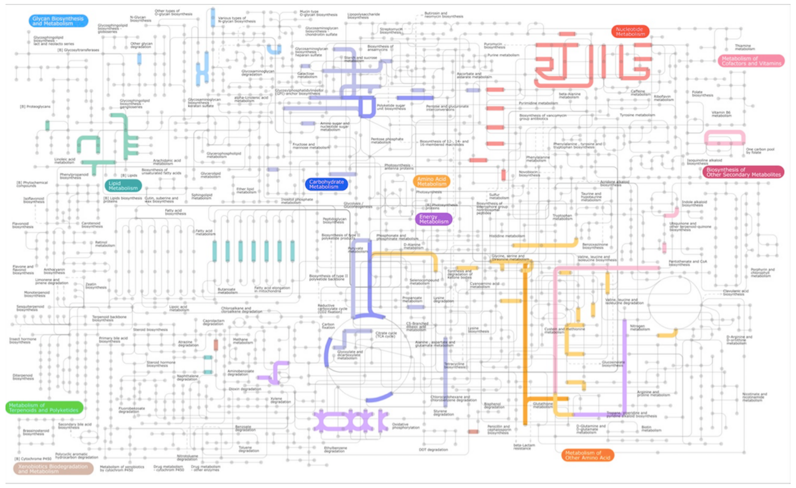

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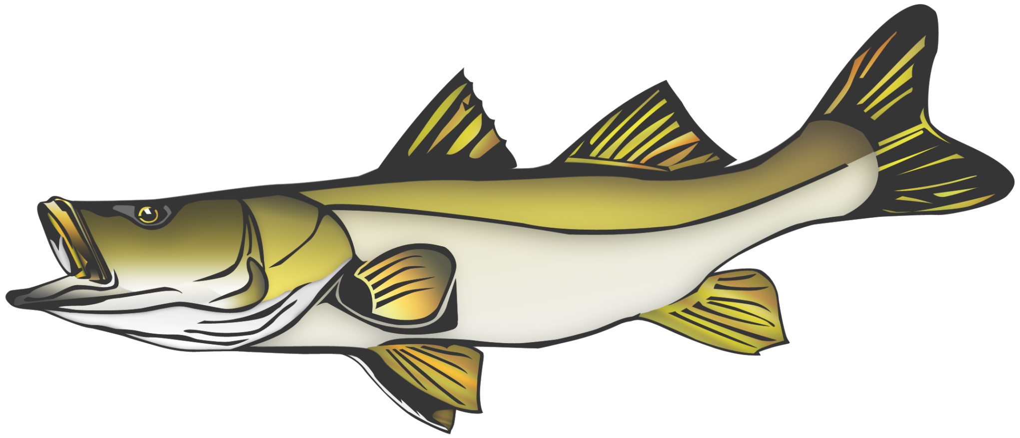
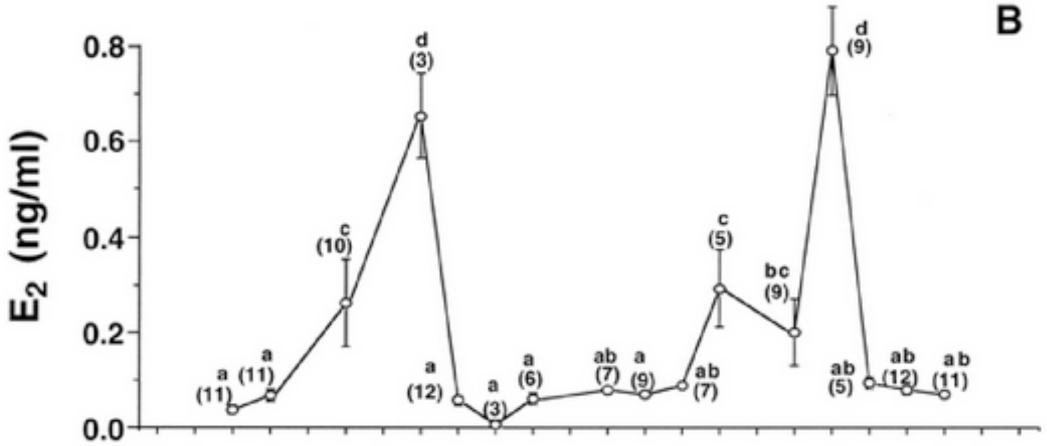
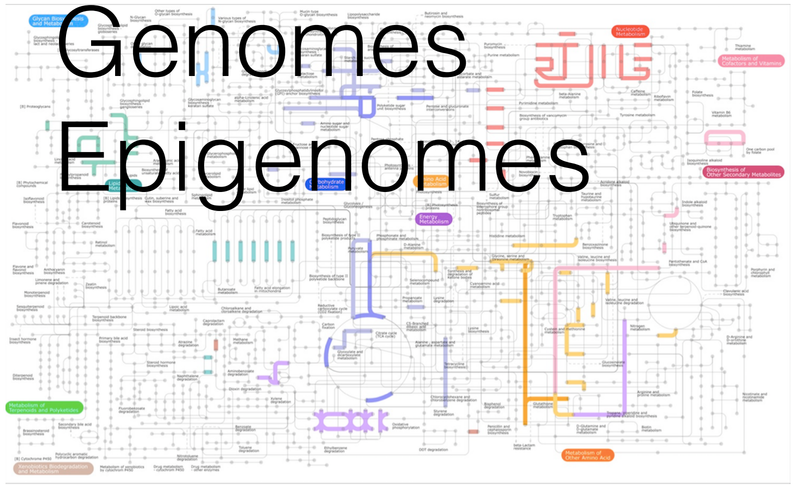


Hormones
Proteins



Transcriptomes
Proteomes
Genomes
Epigenomes



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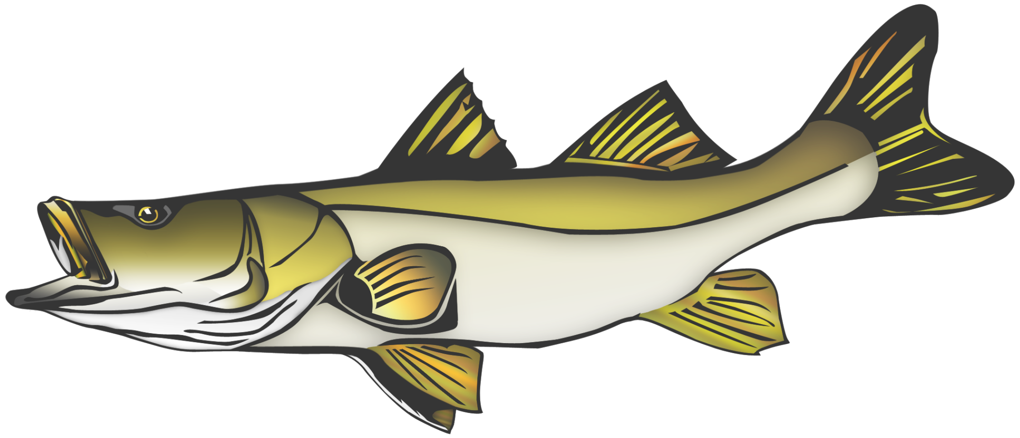

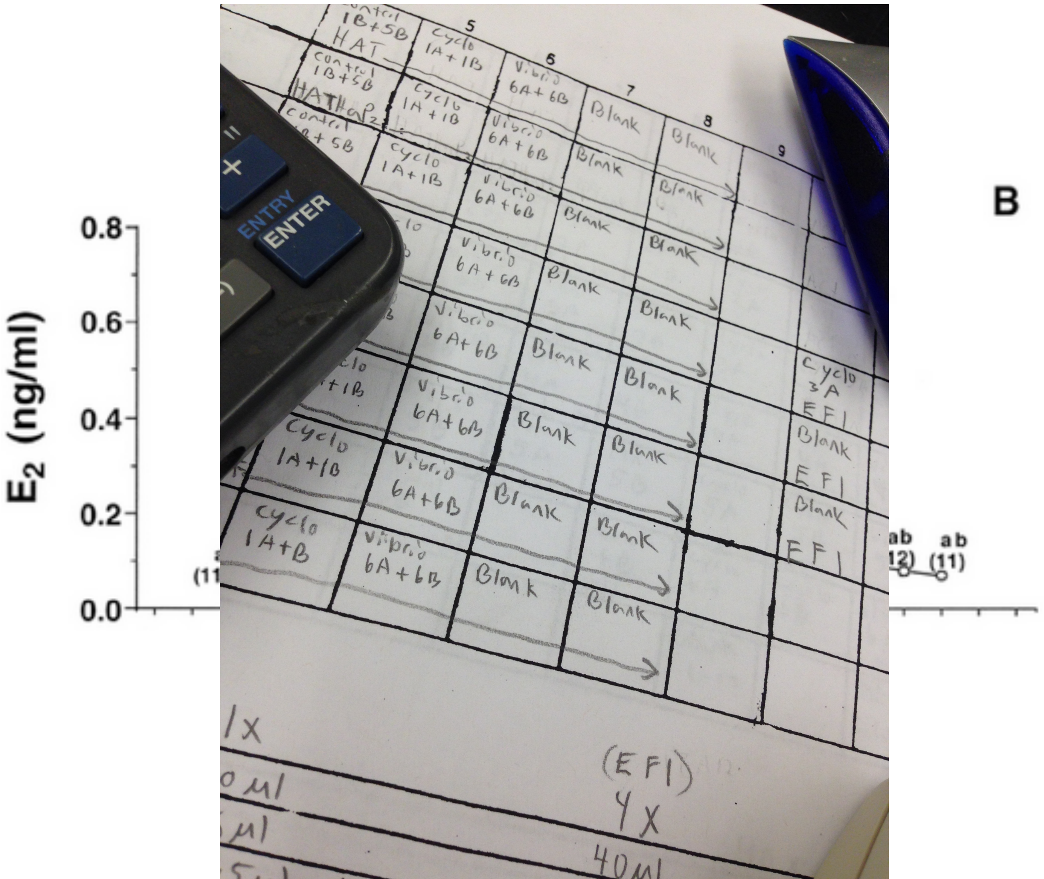

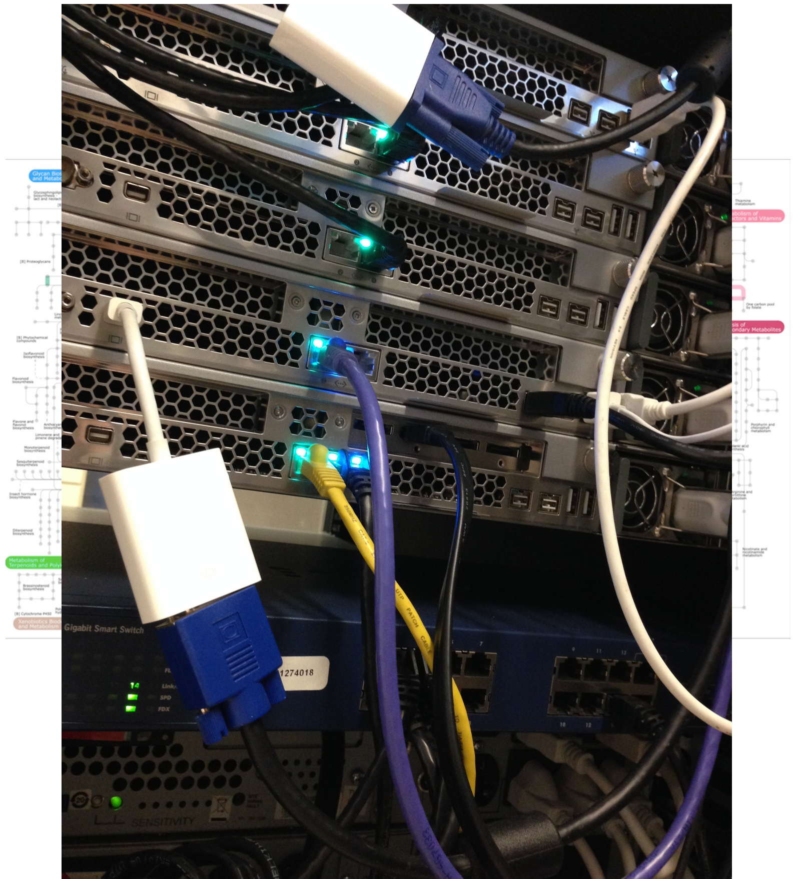

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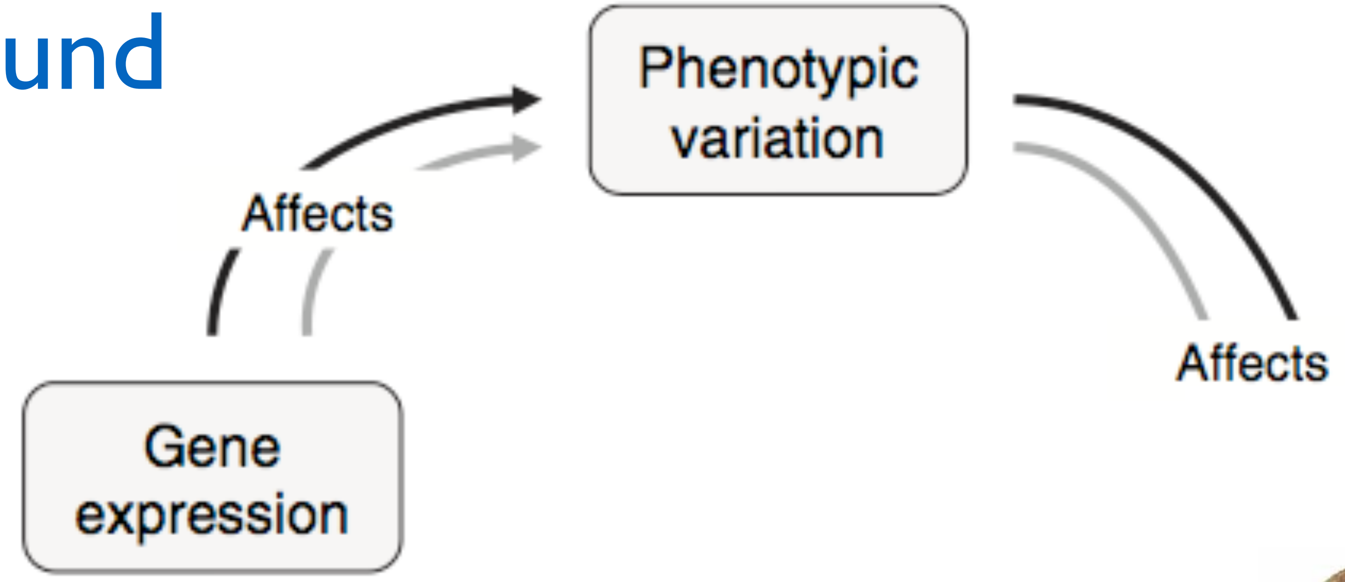


Gene expression

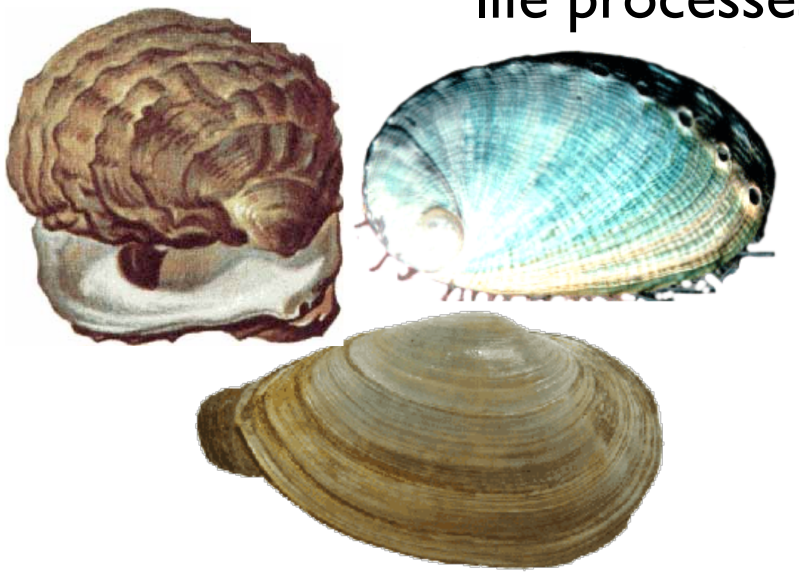
Affects

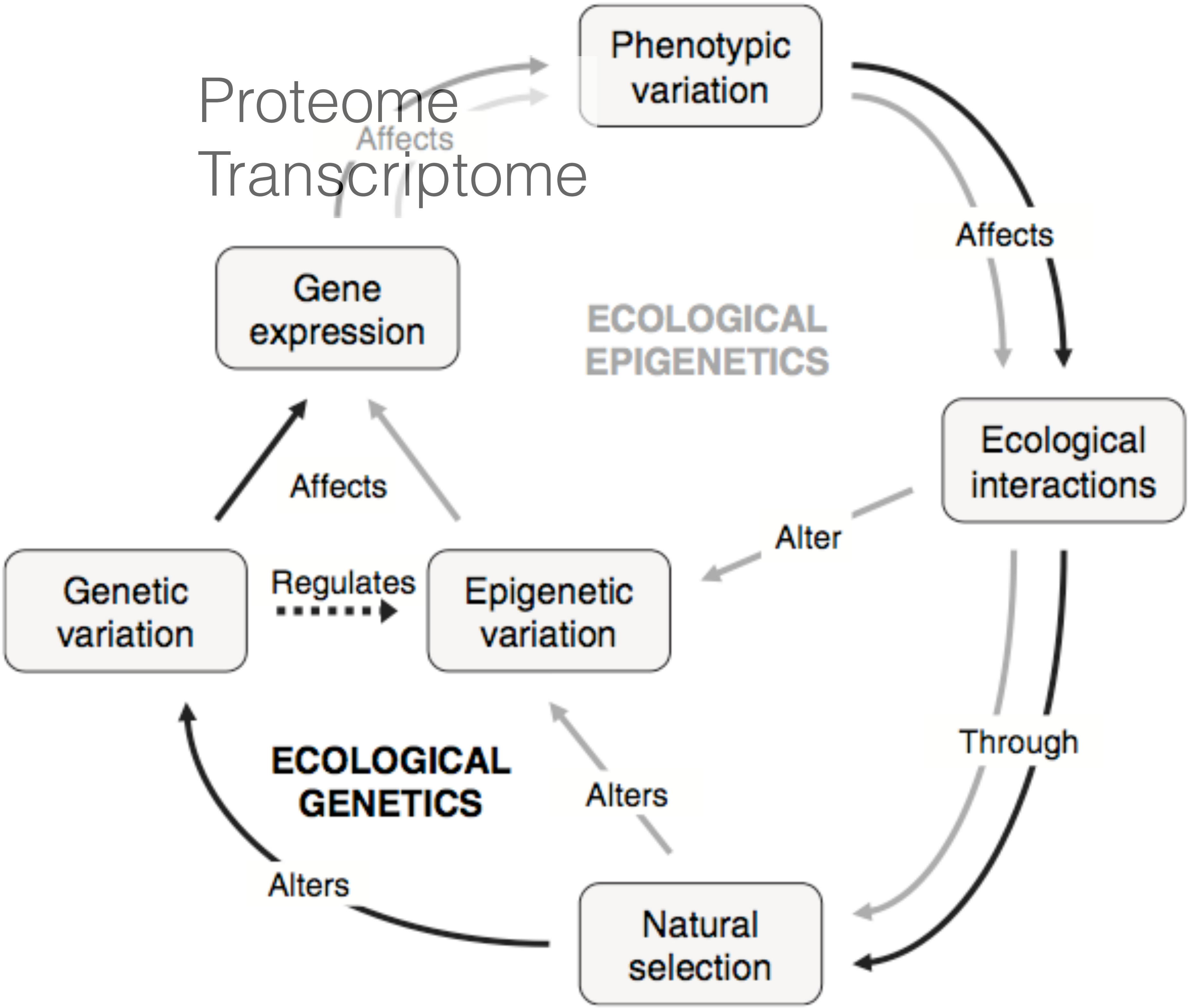
Phenotypic variation

Affects

“important traits”

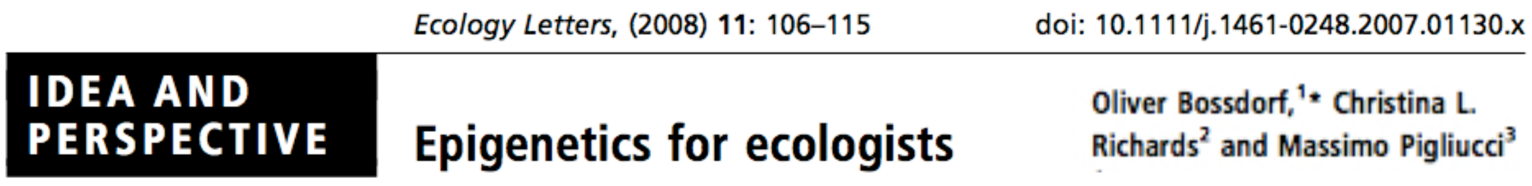
“life processes”





Proteome
Transcriptome

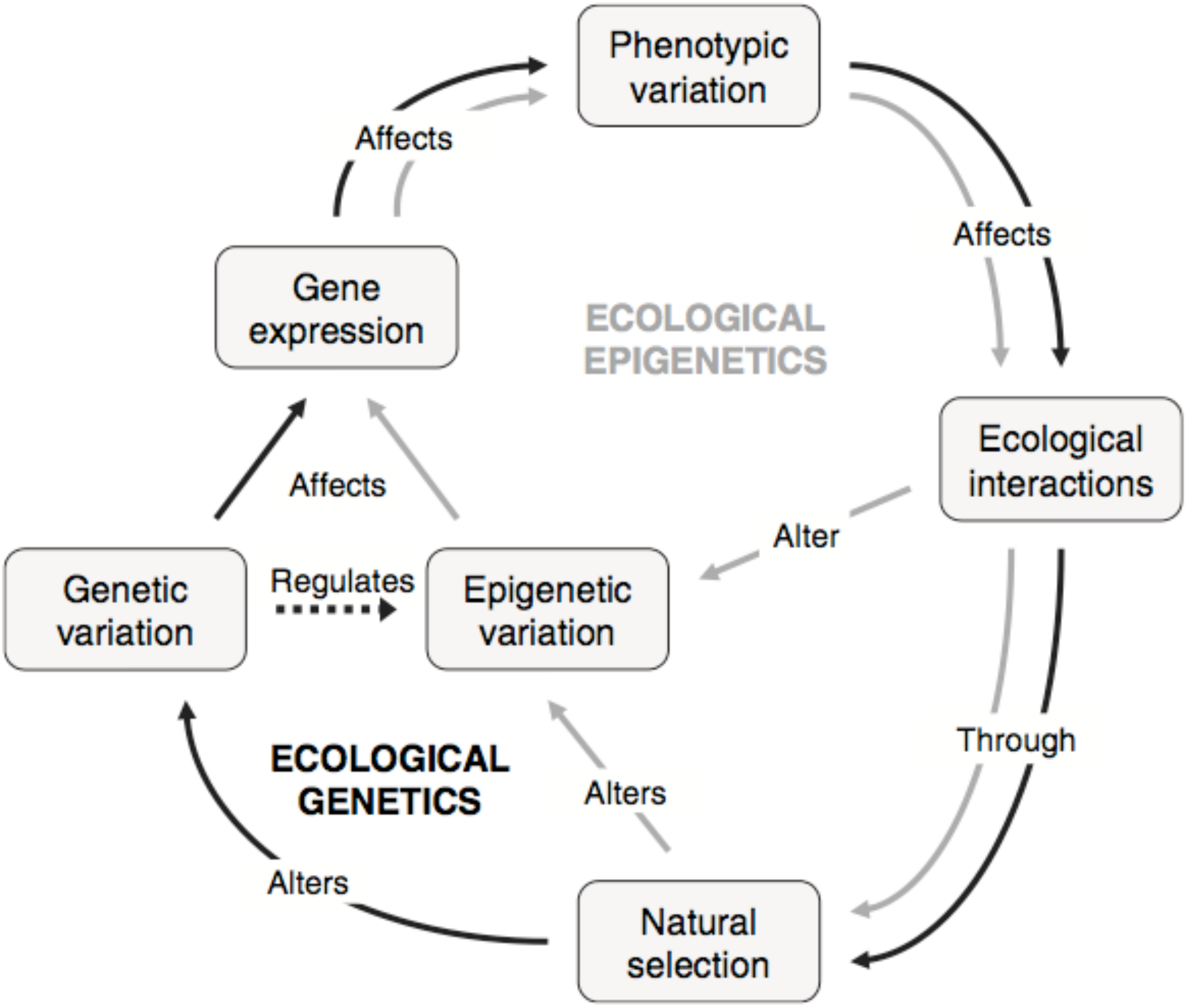
modified from


Ecology Letters, (2008) **11**: 106–115 doi: 10.1111/j.1461-0248.2007.01130.x

IDEA AND PERSPECTIVE

Epigenetics for ecologists

Oliver Bossdorf,[1]* Christina L. Richards[2] and Massimo Pigliucci[3]



Phenotypic variation

Affects

Ecological interactions

Through

Natural selection

Alters

Genetic variation

Affects

Gene expression

Affects

Regulates

Epigenetic variation

Alter

Alters

ECOLOGICAL EPIGENETICS

ECOLOGICAL GENETICS

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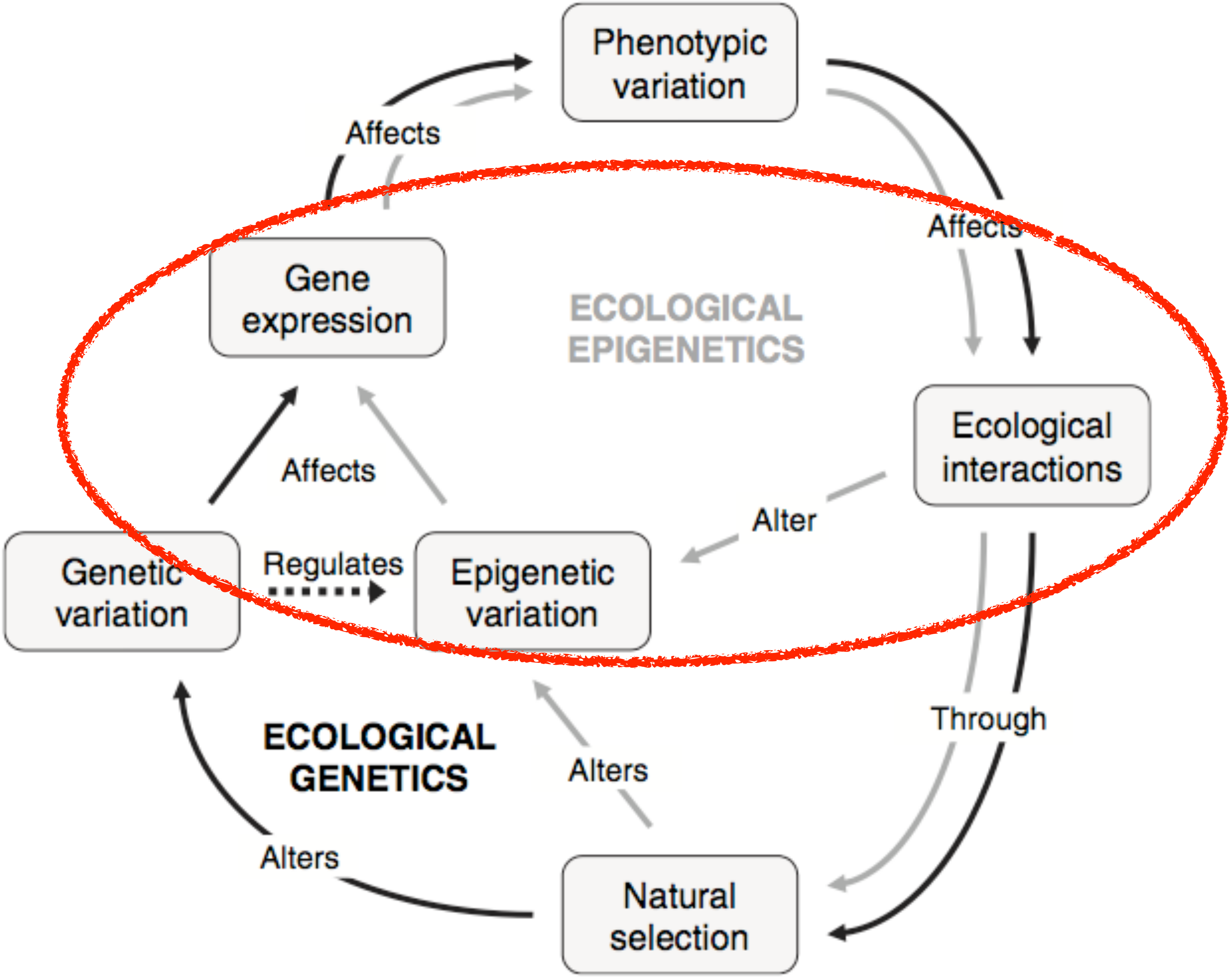

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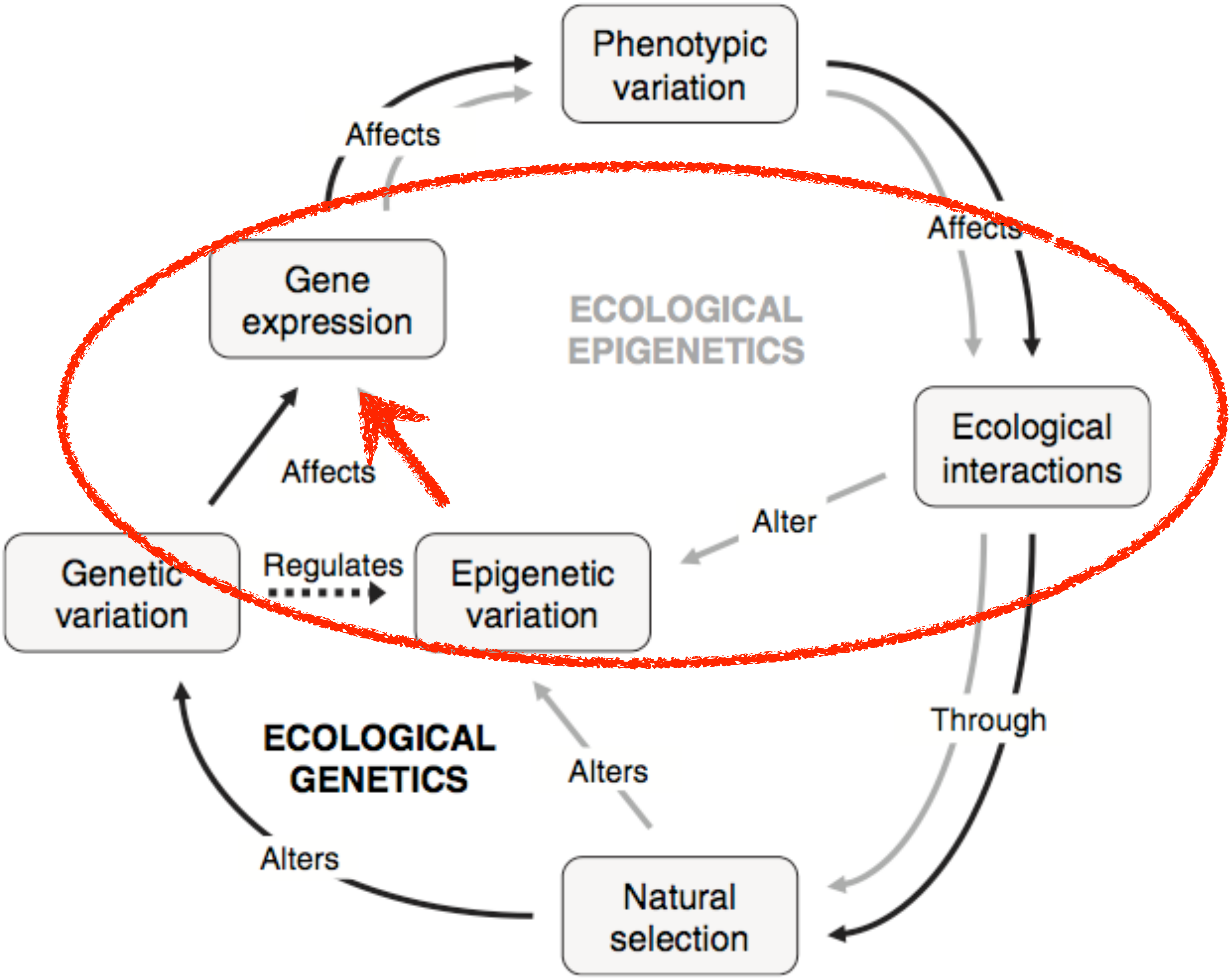

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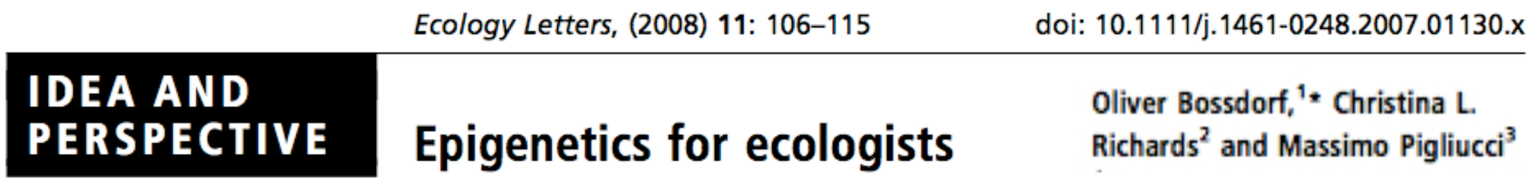
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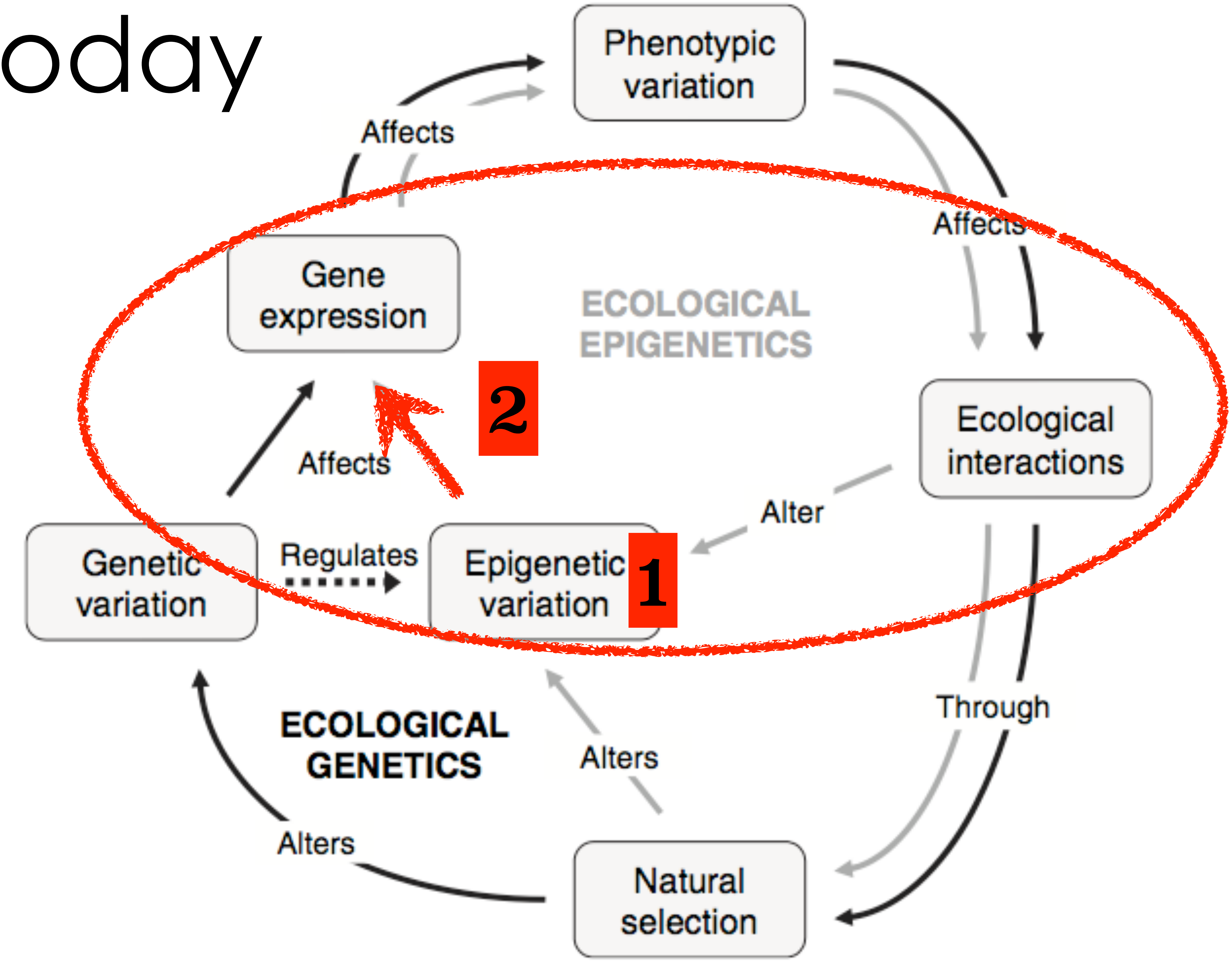

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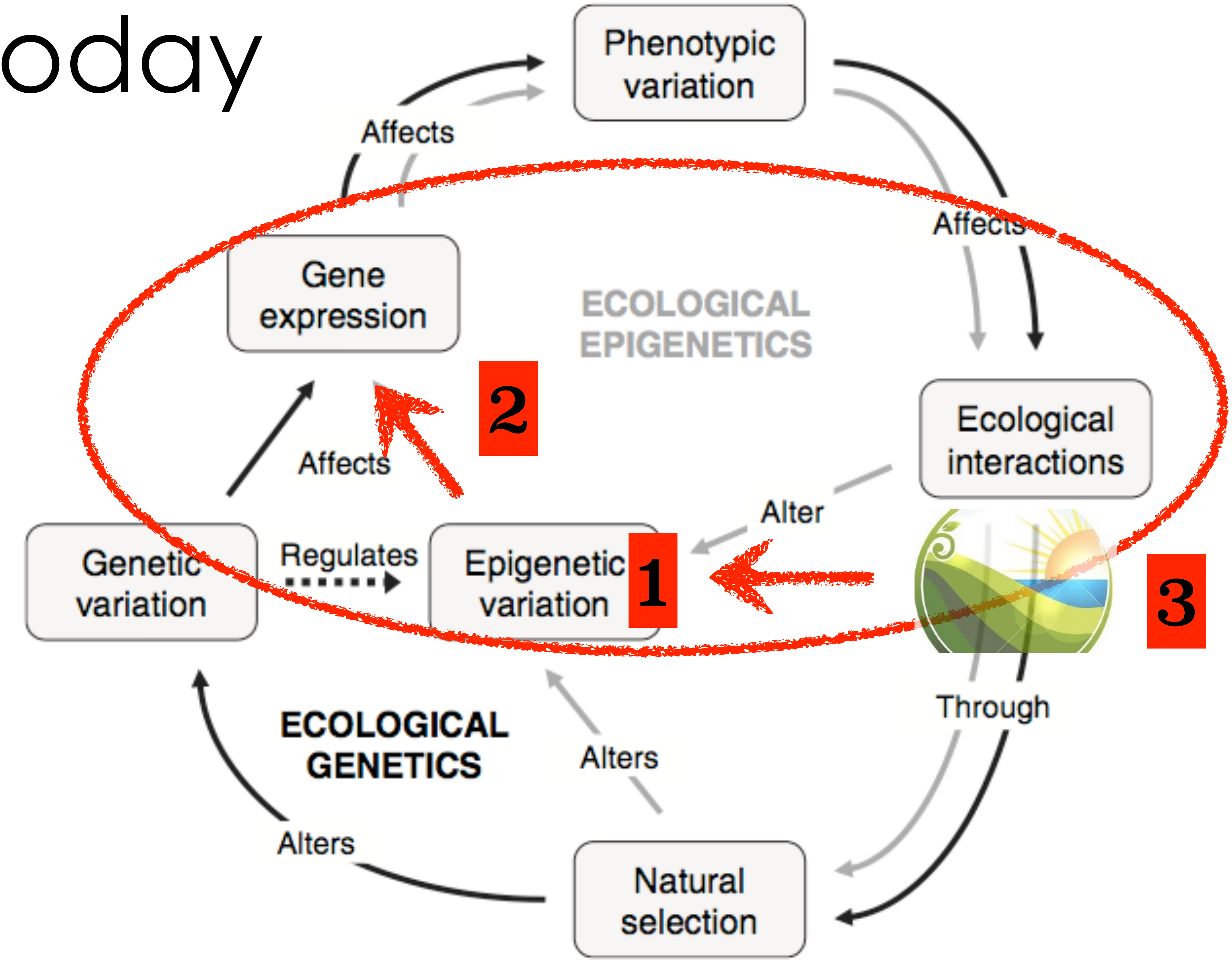


Phenotypic variation

Affects

Gene expression

ECOLOGICAL EPIGENETICS

Affects

Ecological interactions

Affects

2

Alter

Genetic variation

Regulates

Epigenetic variation

1

3

Through

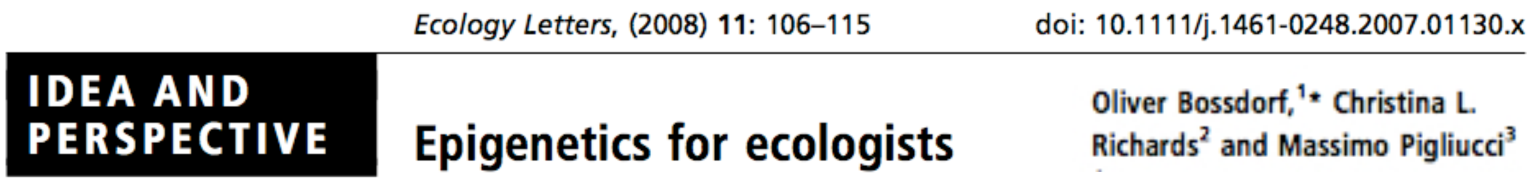
ECOLOGICAL GENETICS

Alters

Alters

Natural selection

modified from



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IDEA AND PERSPECTIVE

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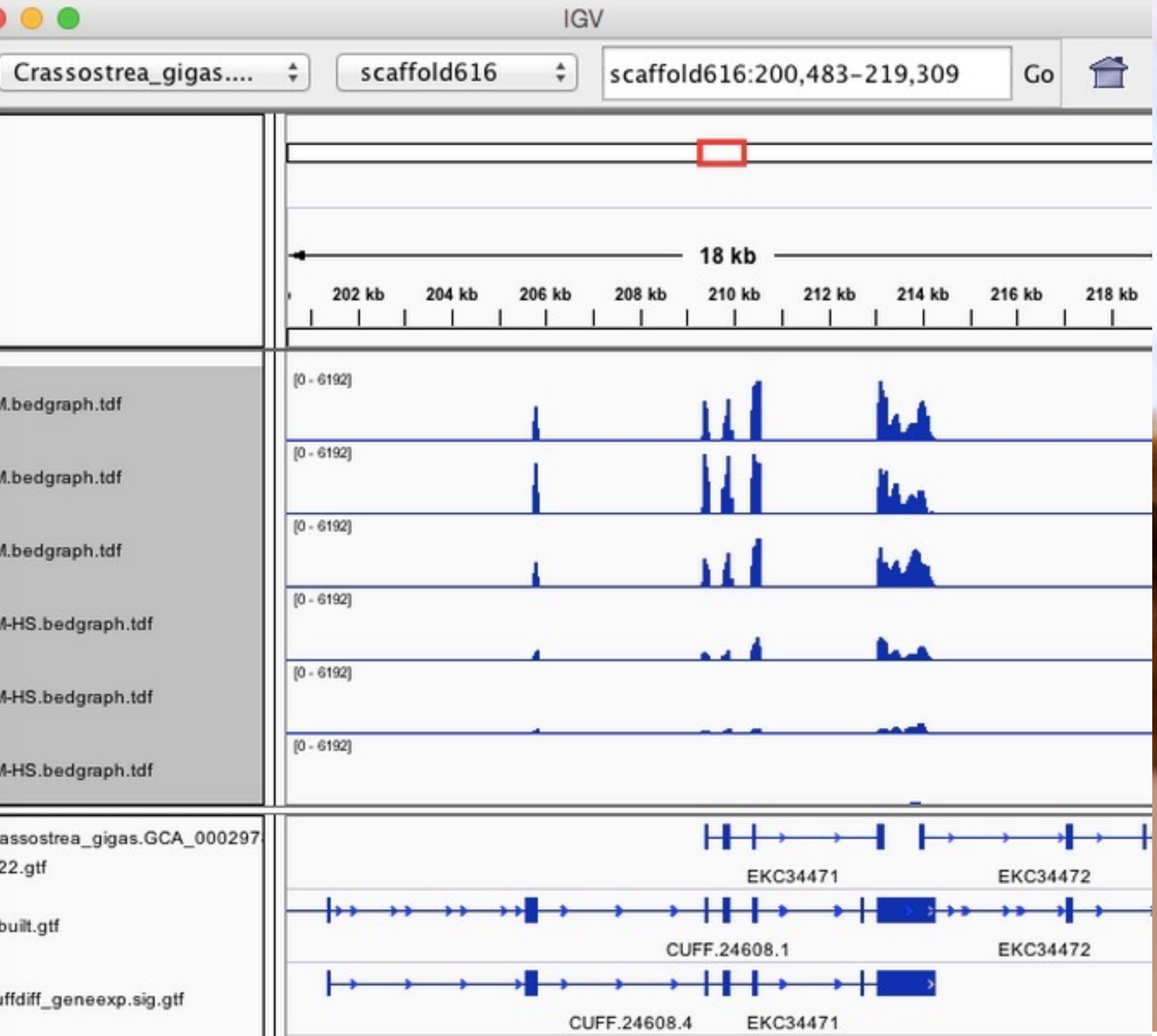
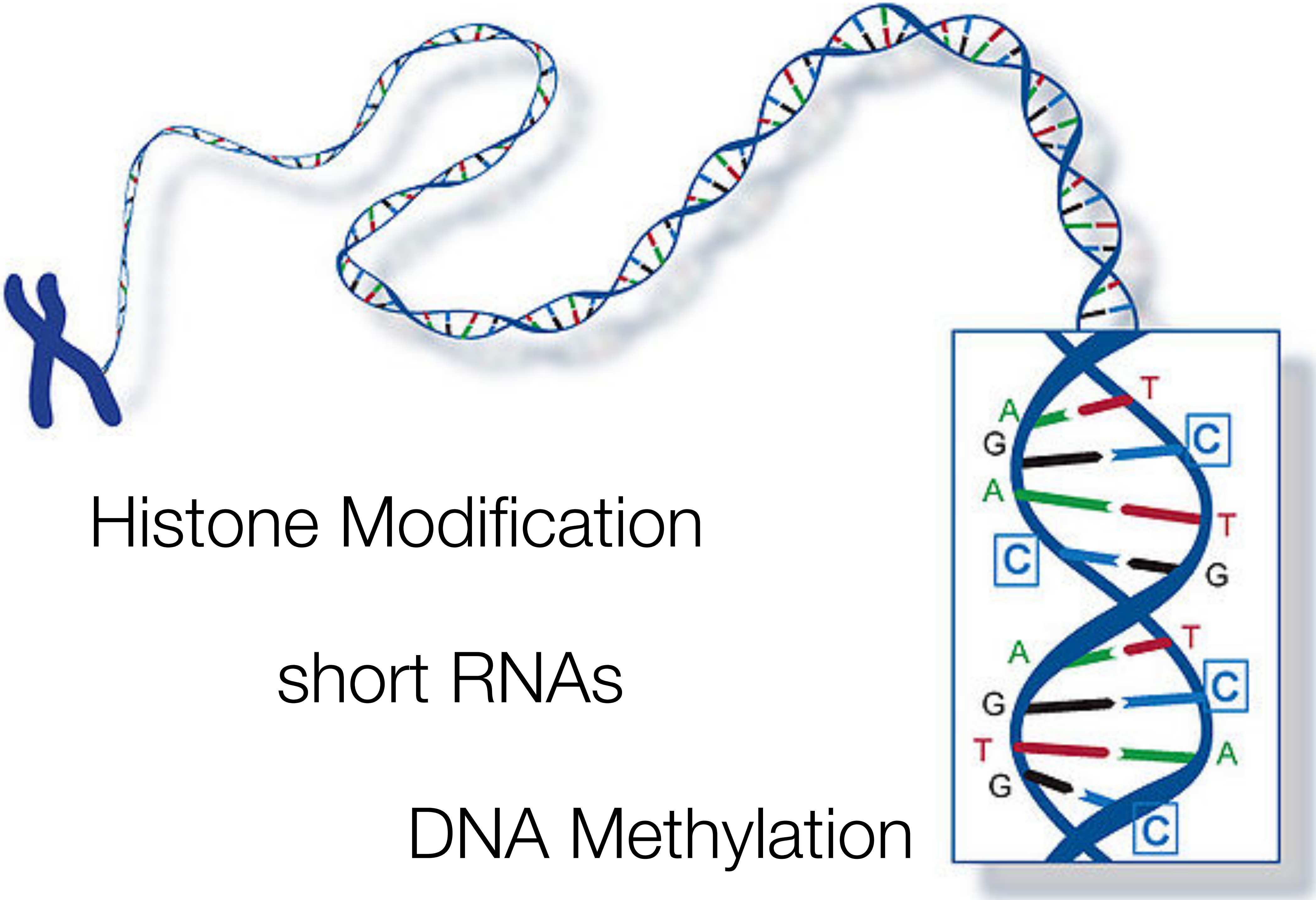
Genome Resources



scaffold616:200,483-219,309

Epigenetics



Histone Modification

short RNAs

DNA Methylation

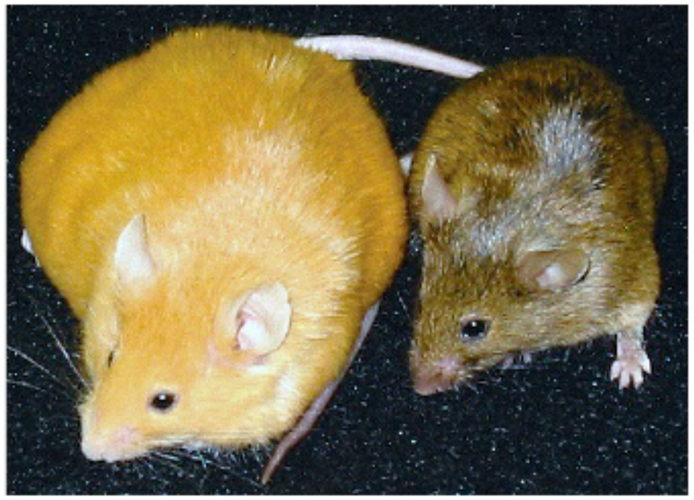
Epigenetics

Photo credit: Flickr, Creative Commons, he-boden

Epigenetics

Learn.Genetics
GENETIC SCIENCE LEARNING CENTER

These Two Mice are Genetically Identical and the Same Age



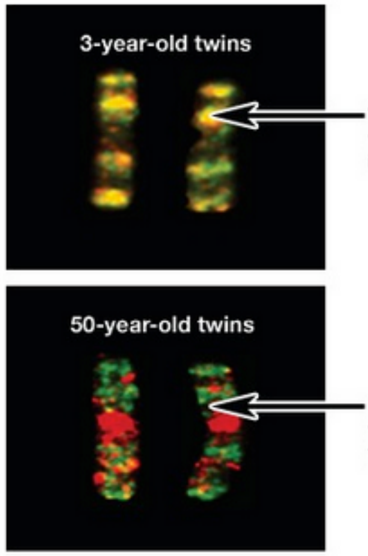
While pregnant, both of their mothers were fed Bisphenol A (BPA) but DIFFERENT DIETS:

The mother of this mouse received a **normal mouse diet**

The mother of this mouse received a diet **supplemented** with choline, folic acid, betaine and vitamin B12

Nature AND Nurture

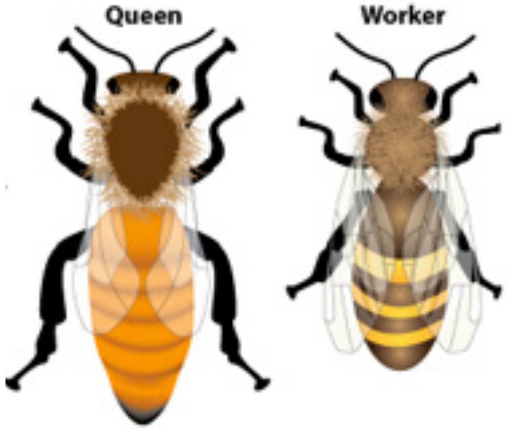
Chromosome 3 Pairs
3-year old twins vs. 50-year-old twins

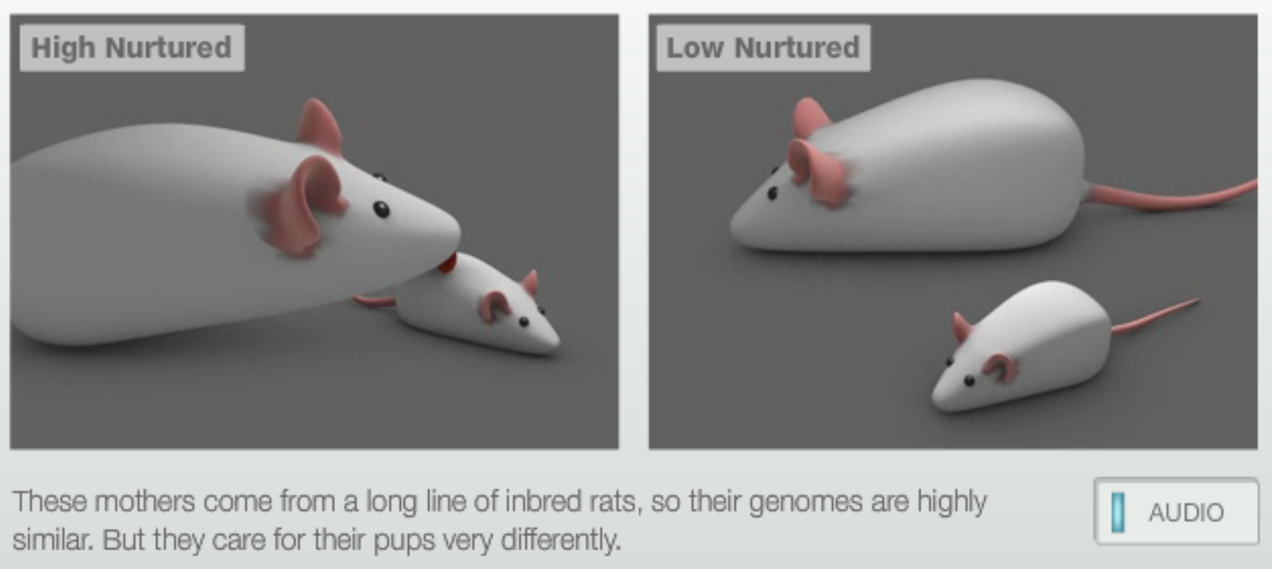


Yellow shows where the twins have epigenetic tags in the same place.

Red and green show where the twins have epigenetic tags in different places.

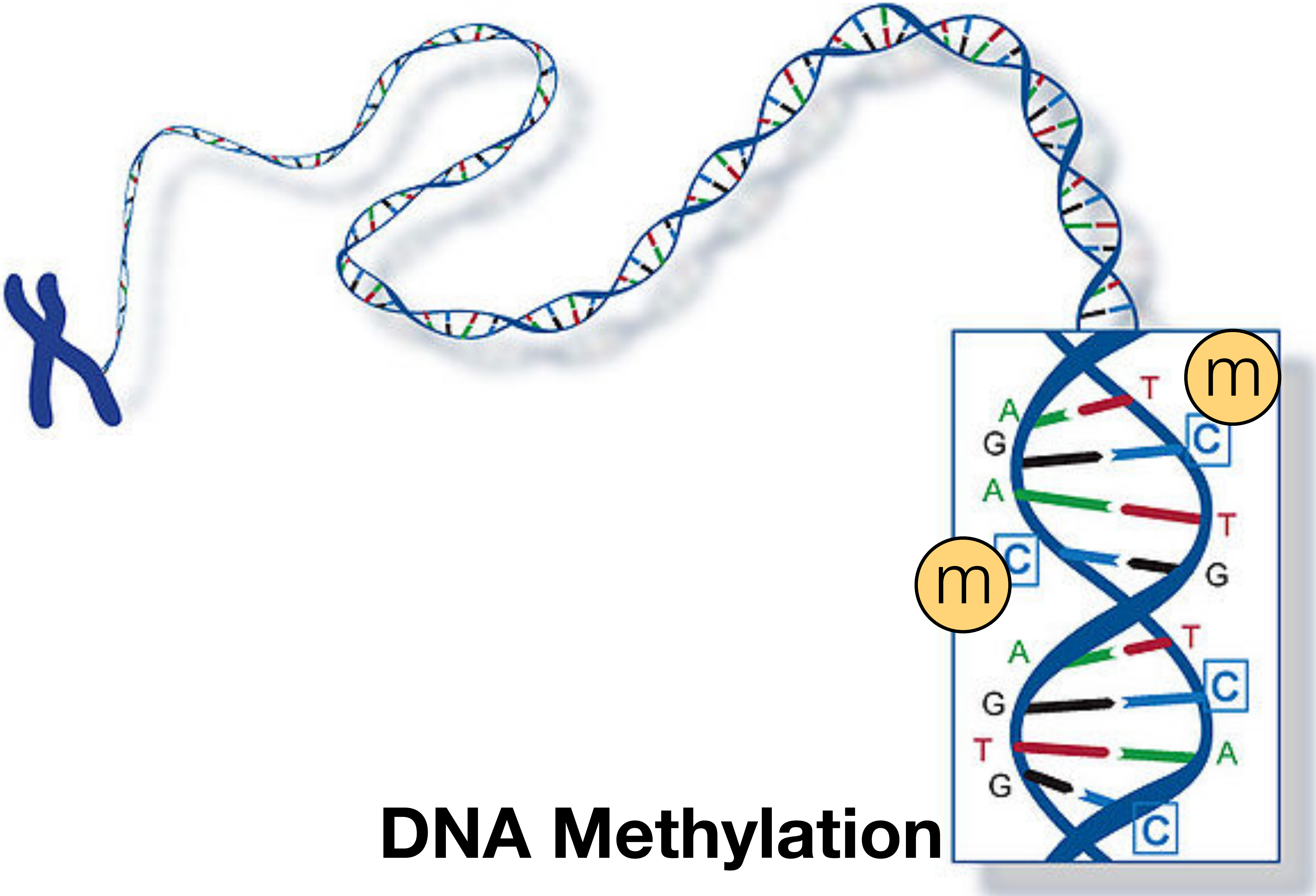
Queen Bee Larvae: Queens are raised in specially constructed cells called "queen cups," which are filled with royal jelly.





These mothers come from a long line of inbred rats, so their genomes are highly similar. But they care for their pups very differently.

http://learn.genetics.utah.edu



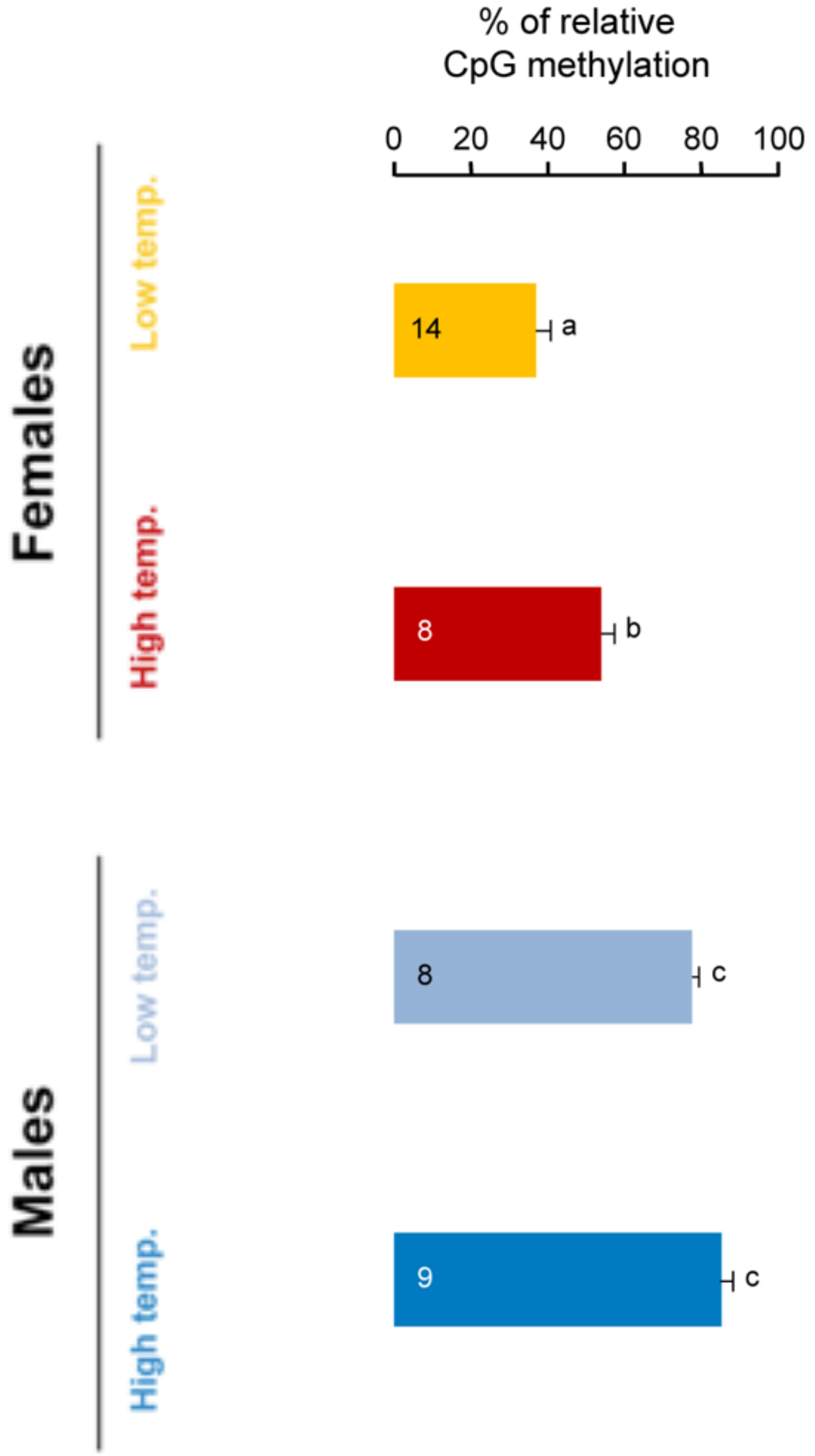
DNA Methylation

Mechanism?

PLOS | GENETICS

DNA Methylation of the Gonadal Aromatase (*cyp19a*) Promoter Is Involved in Temperature-Dependent Sex Ratio Shifts in the European Sea Bass

Laia Navarro-Martín, Jordi Viñas, Laia Ribas, Noelia Díaz, Arantxa Gutiérrez, Luciano Di Croce, Francesc Piferrer ✉



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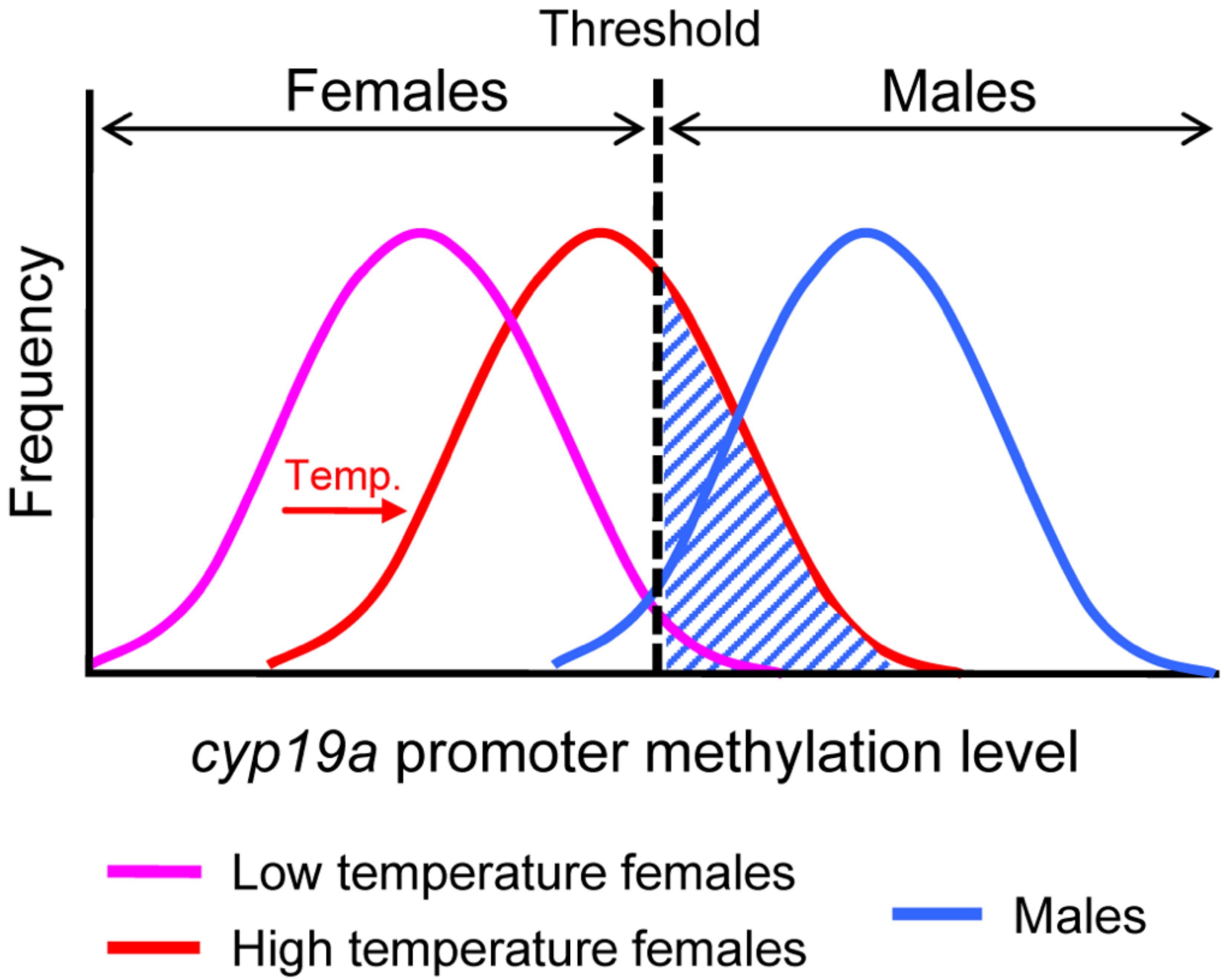

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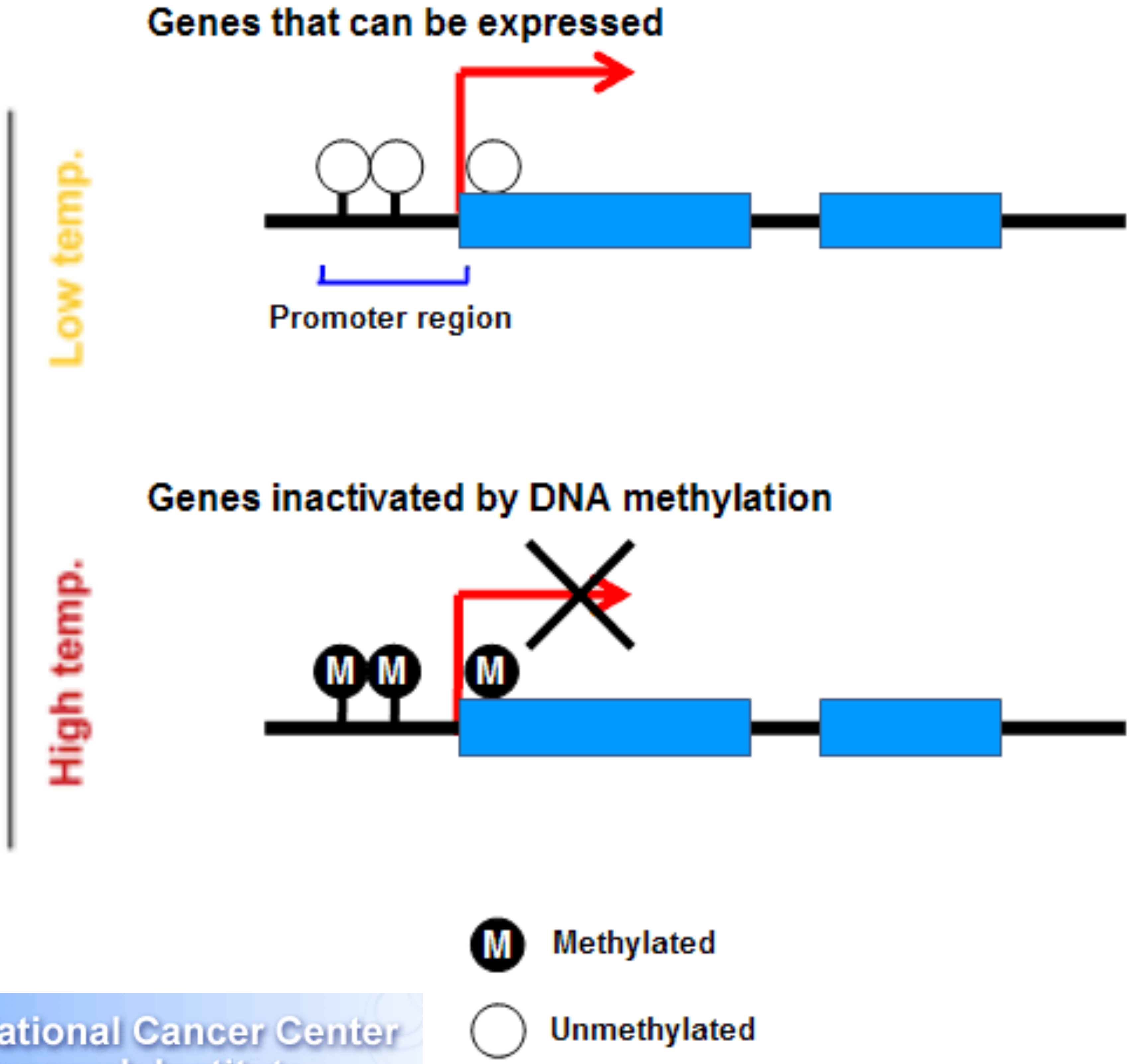


Genes that can be expressed

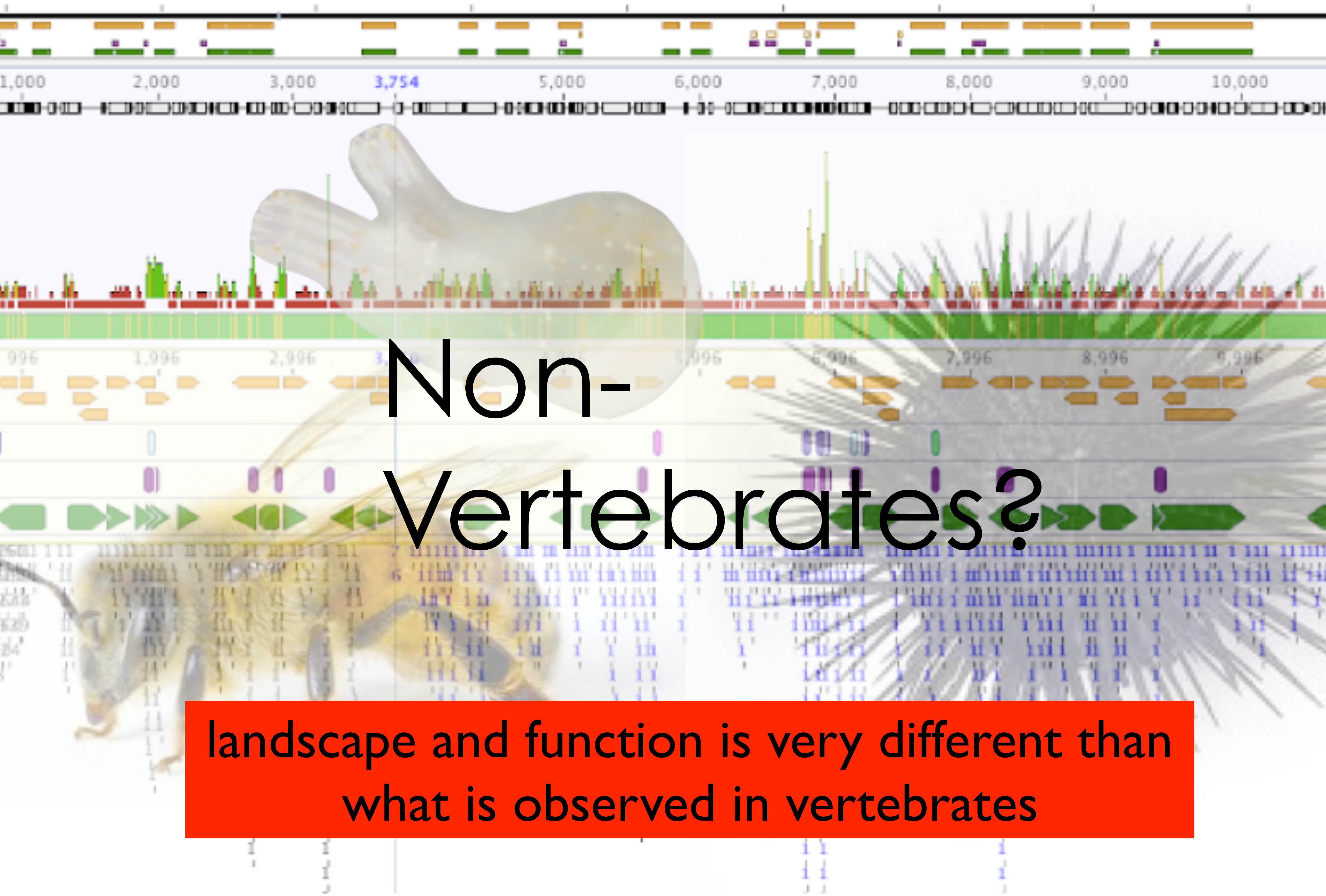
Promoter region

Genes inactivated by DNA methylation

M Methylated

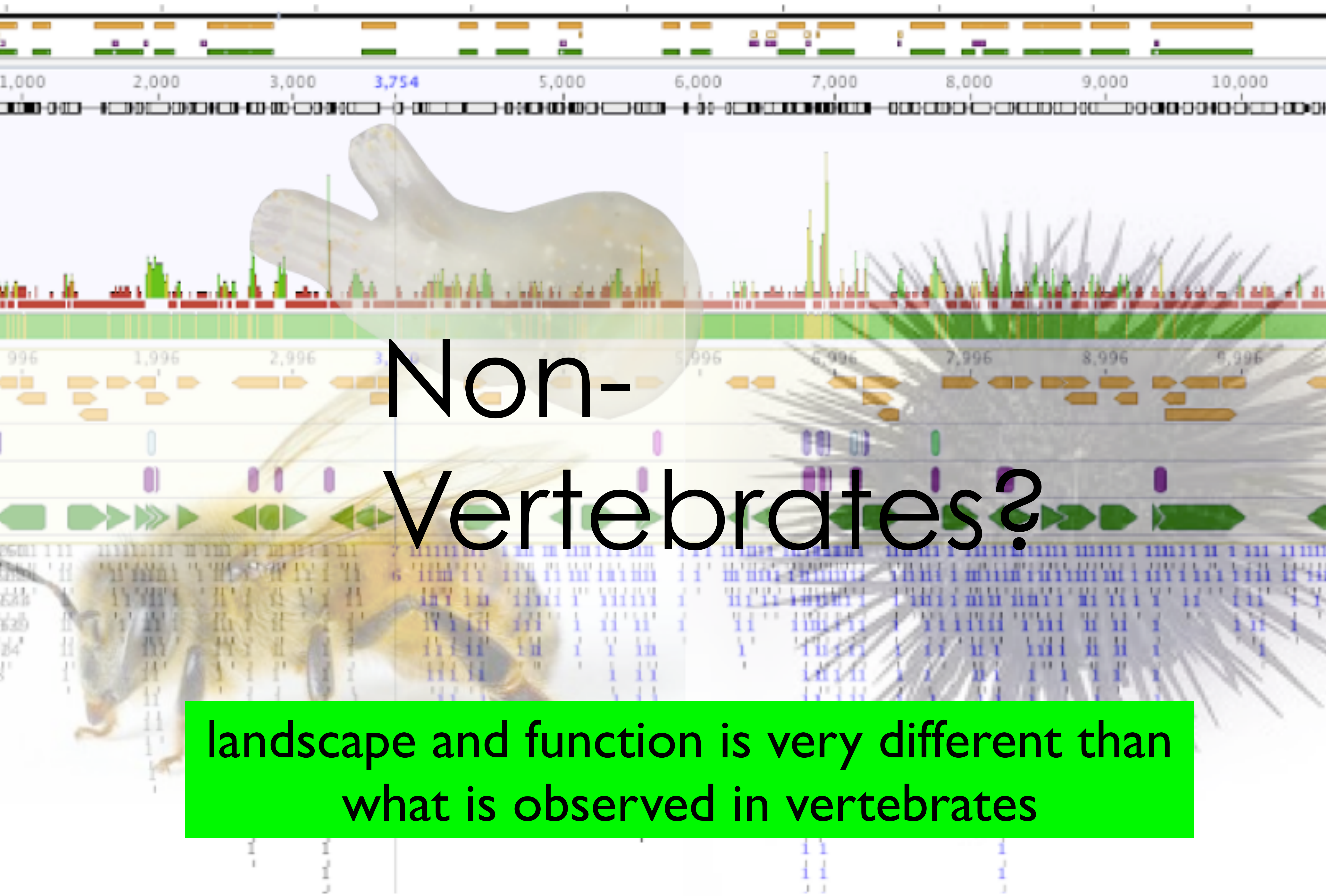
○ Unmethylated

Non-Vertebrates?



Non-Vertebrates?

landscape and function is very different than what is observed in vertebrates



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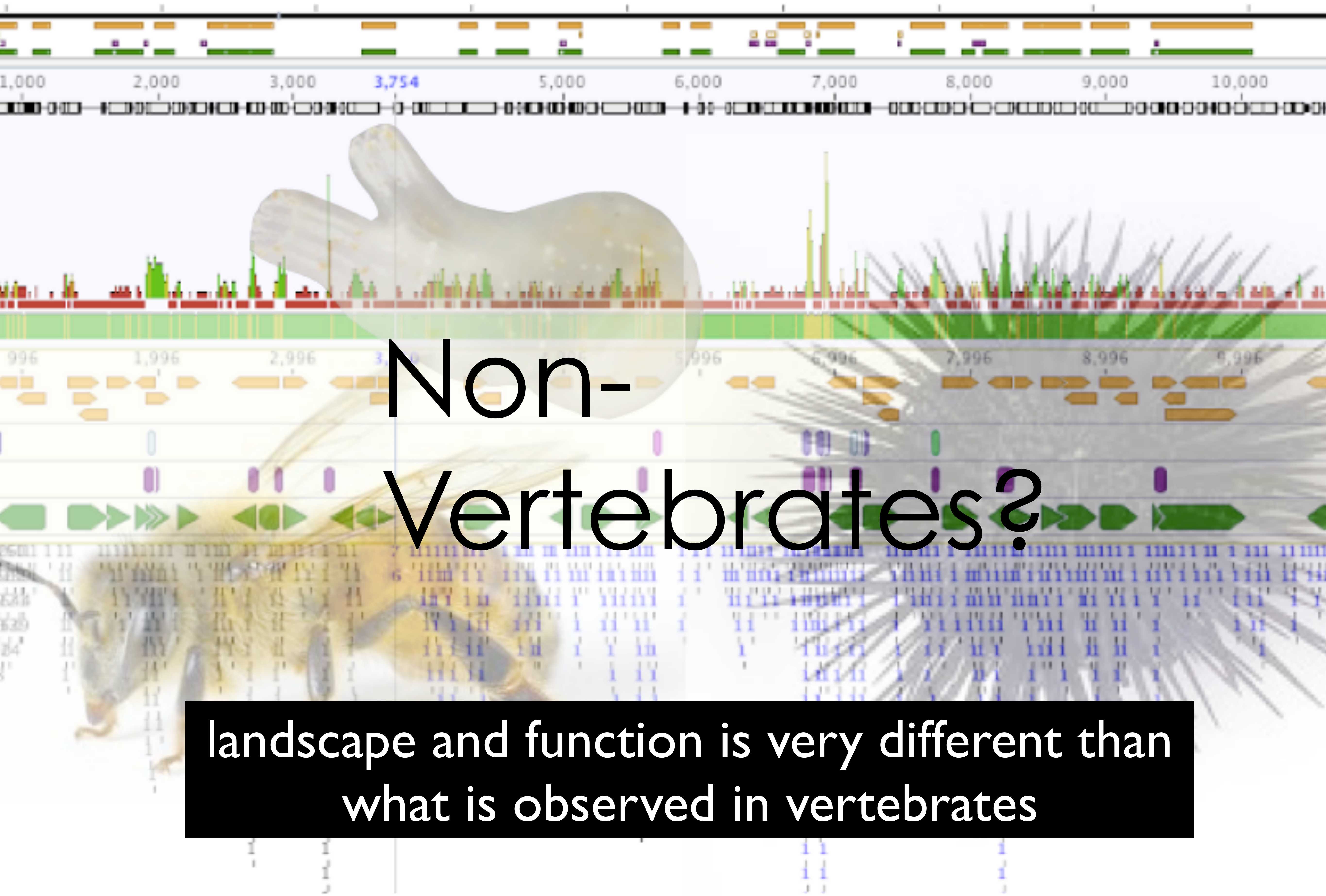
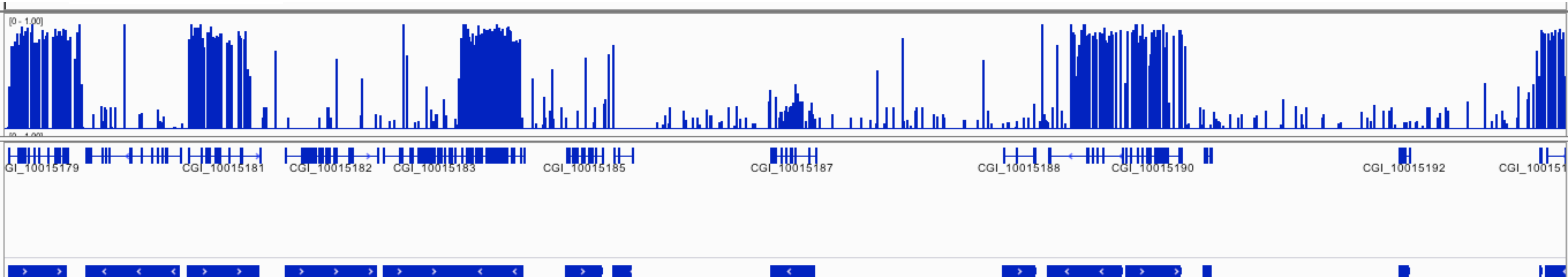


landscape and function is very different than what is observed in vertebrates

Absent in
several
model
organisms

Oysters?

Epigenetic variation 1

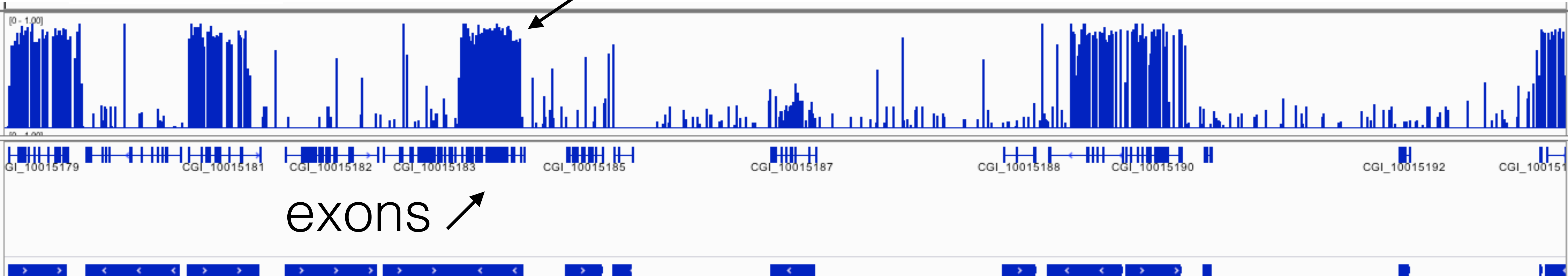


mosaic

associated with gene bodies

Epigenetic variation 1

DNA methylation level (0-100%) @ cytosines



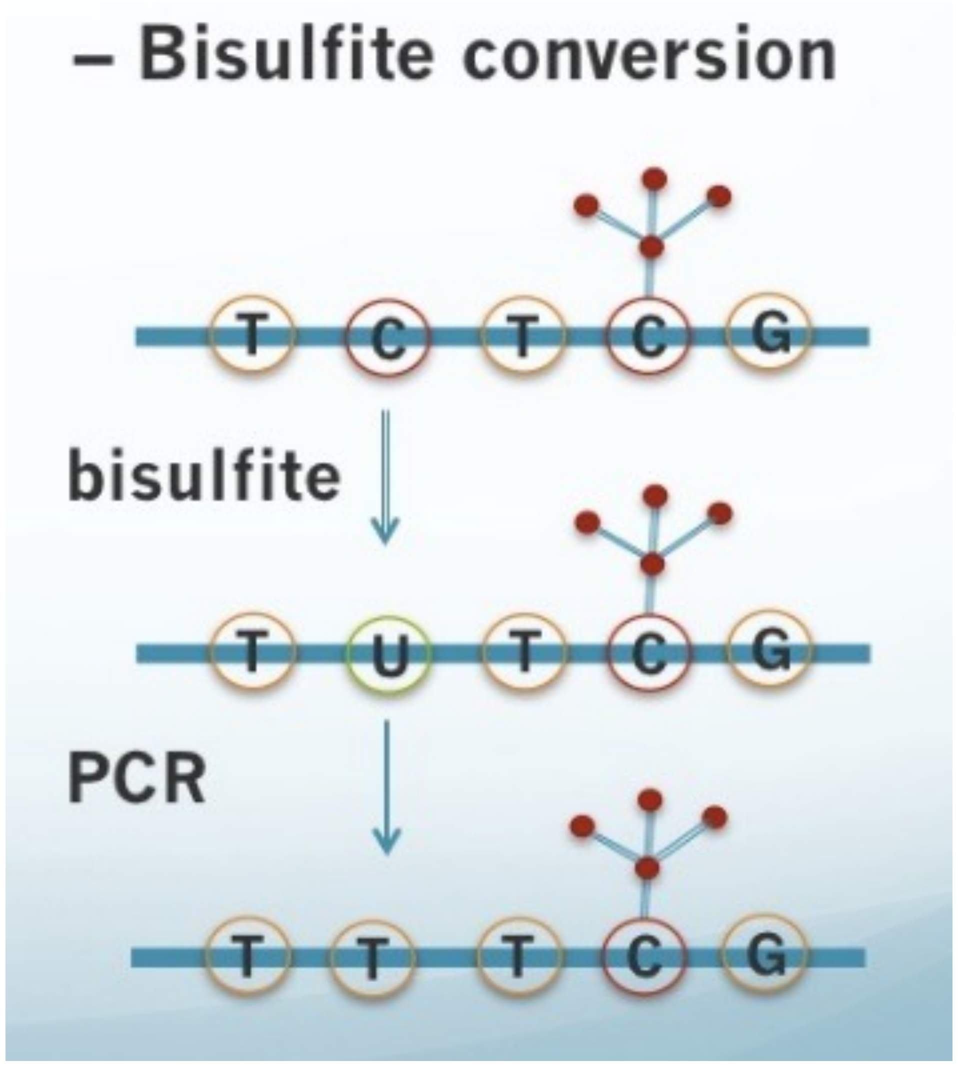
exons

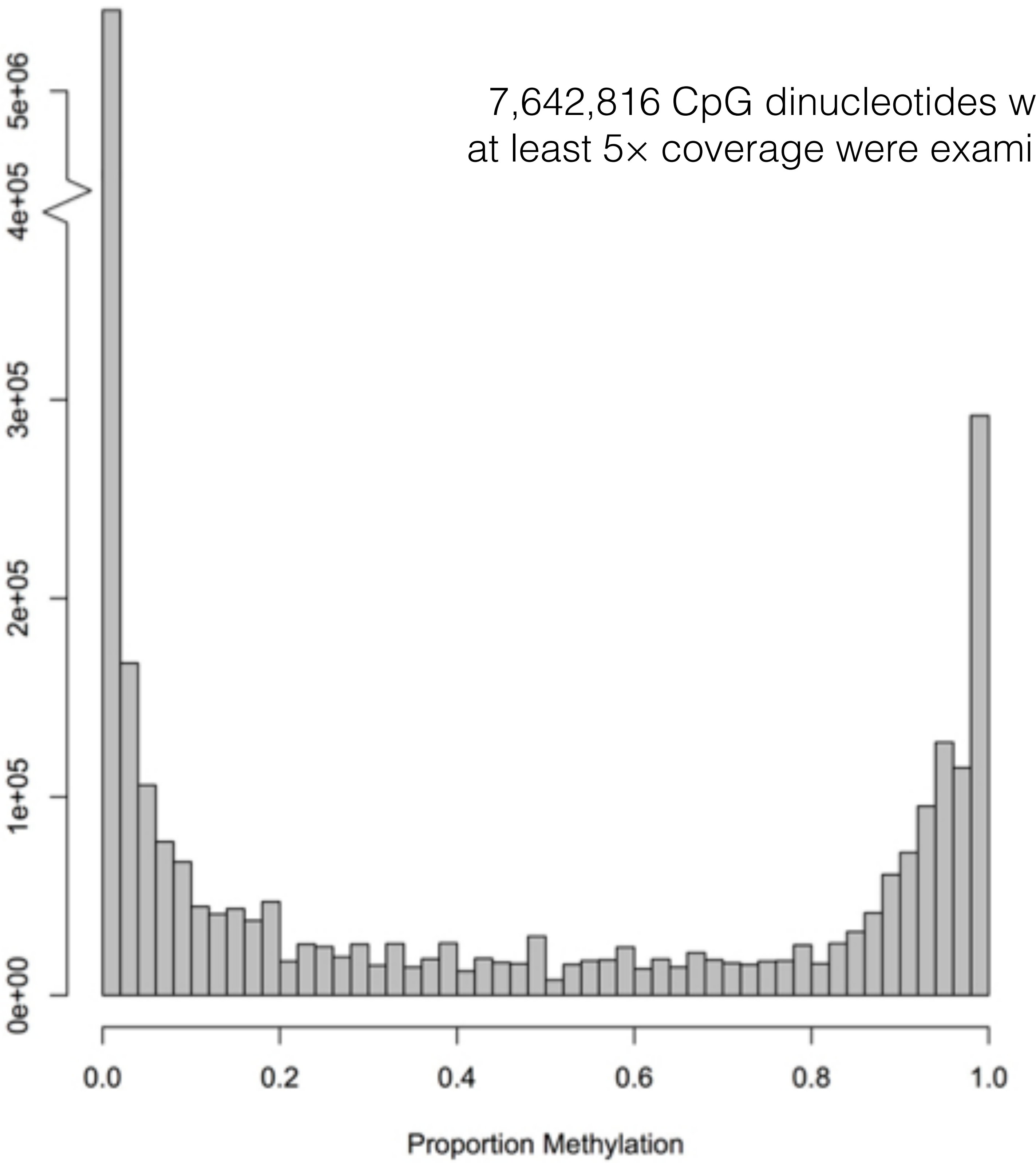
gene

mosaic

associated with gene bodies

Epigenetic variation **1**





7,642,816 CpG dinucleotides with
at least 5× coverage were examined


frontiers in
PHYSIOLOGY

ORIGINAL RESEARCH ARTICLE
published: 17 June 2014
doi: 10.3389/fphys.2014.00224

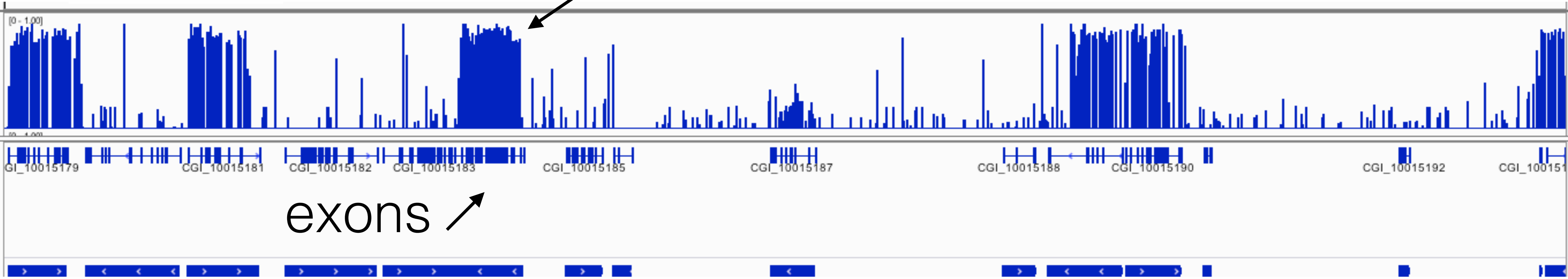
Genome-wide profiling of DNA methylation and gene expression in *Crassostrea gigas* male gametes

Claire E. Olson and Steven B. Roberts*

School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA

Epigenetic variation 1

DNA methylation level (0-100%) @ cytosines



exons

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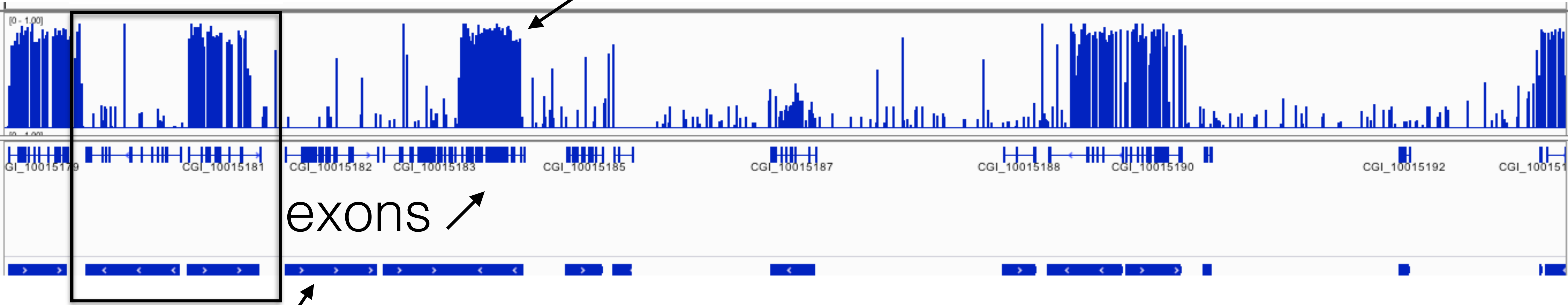


exons

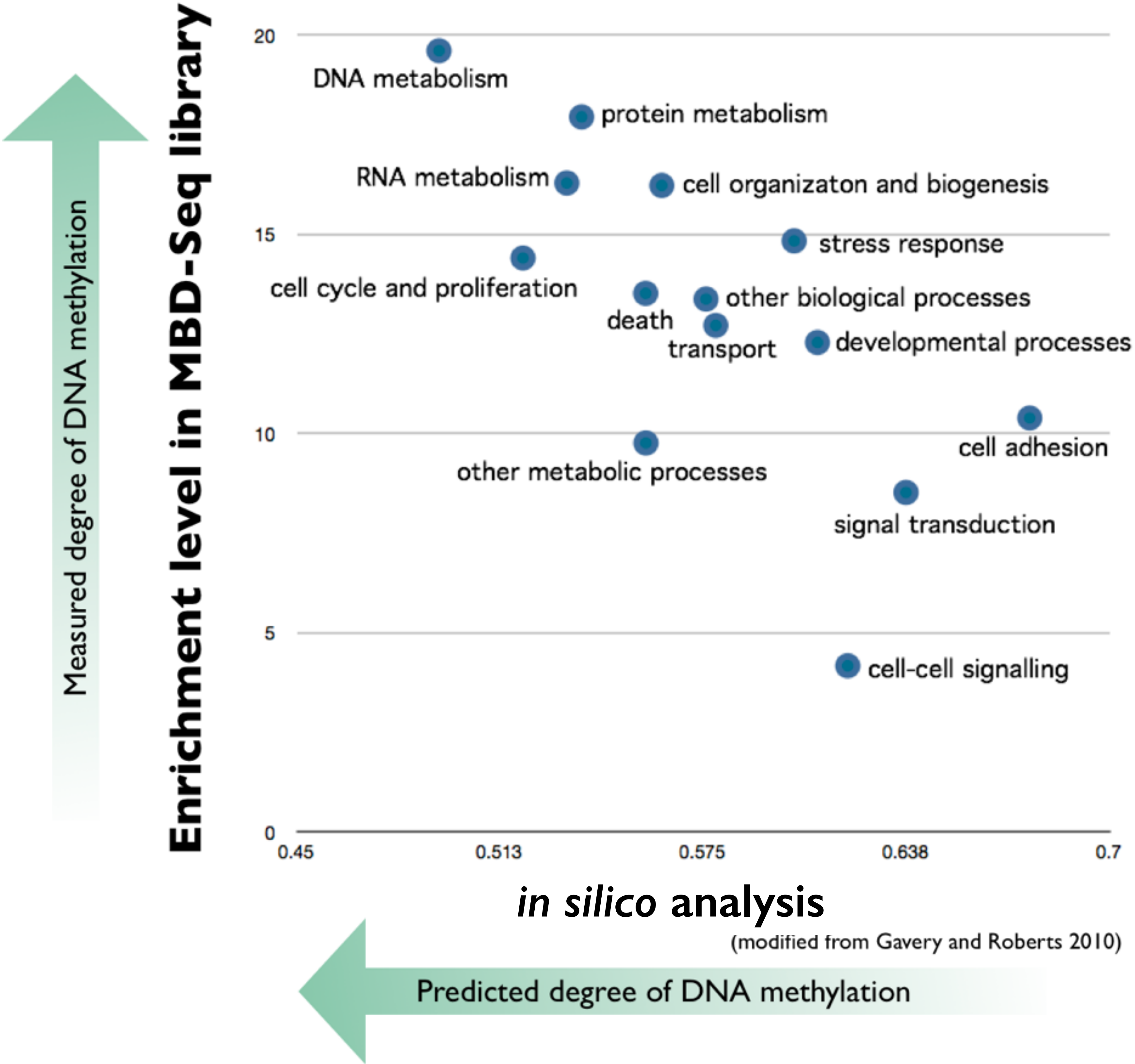
gene

mosaic

Why are only a subset of genes methylated?

associated with gene bodies

Epigenetic variation 1

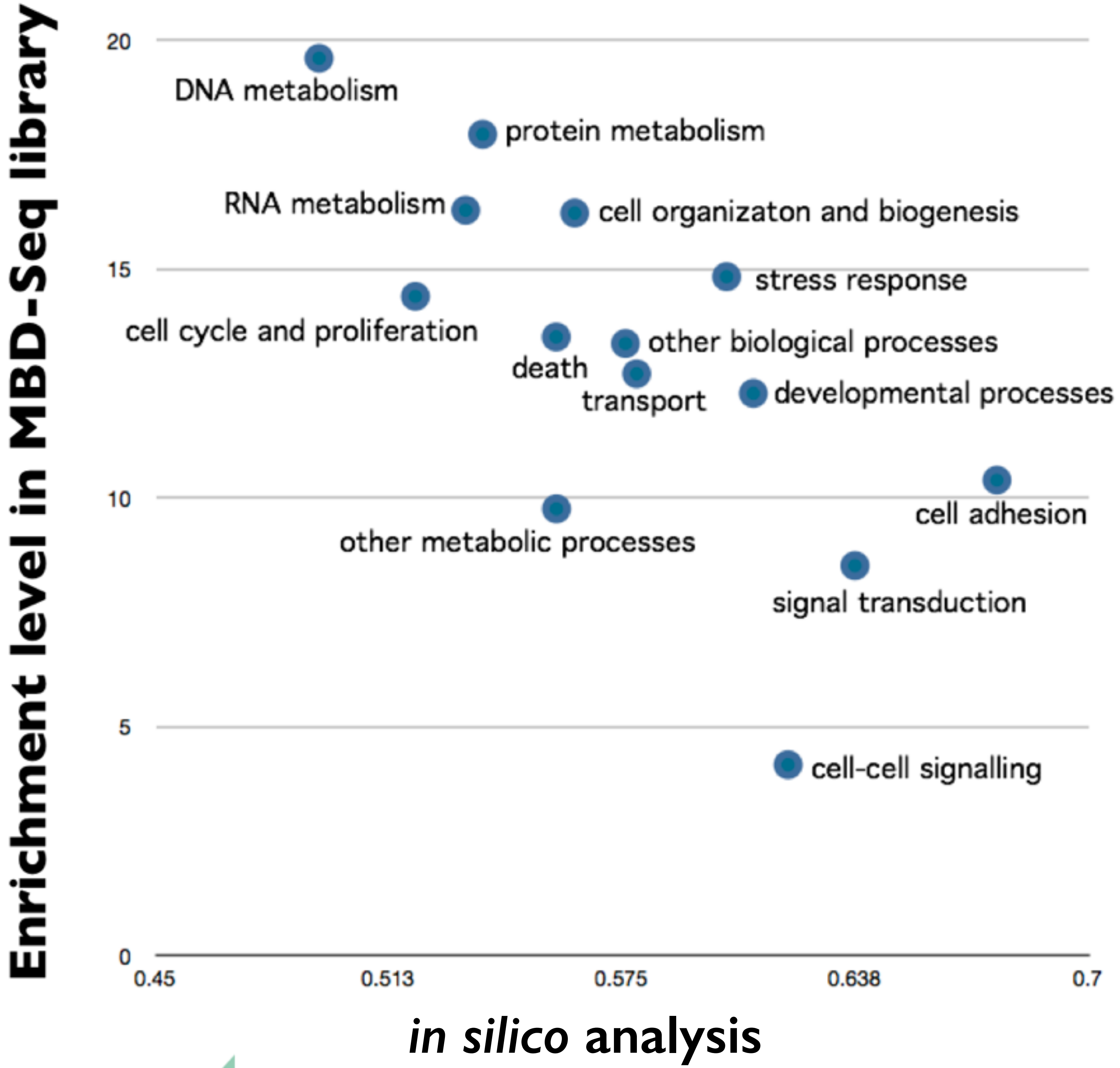


(modified from Gavery and Roberts 2010)

Roberts and Gavery 2012

Epigenetic variation 1

Measured degree of DNA methylation



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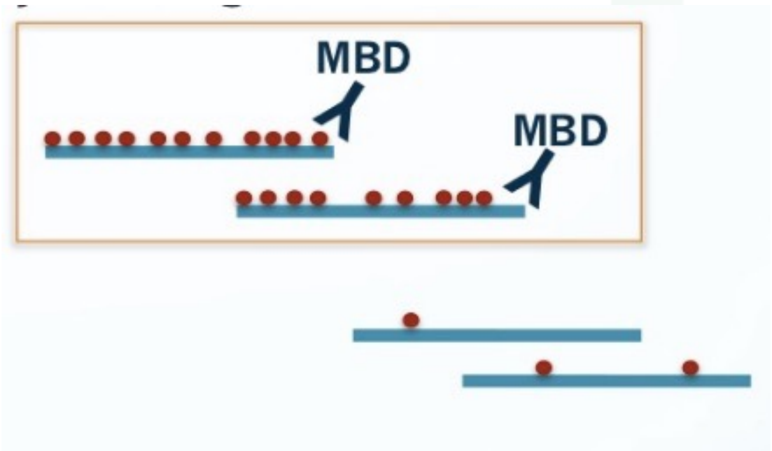
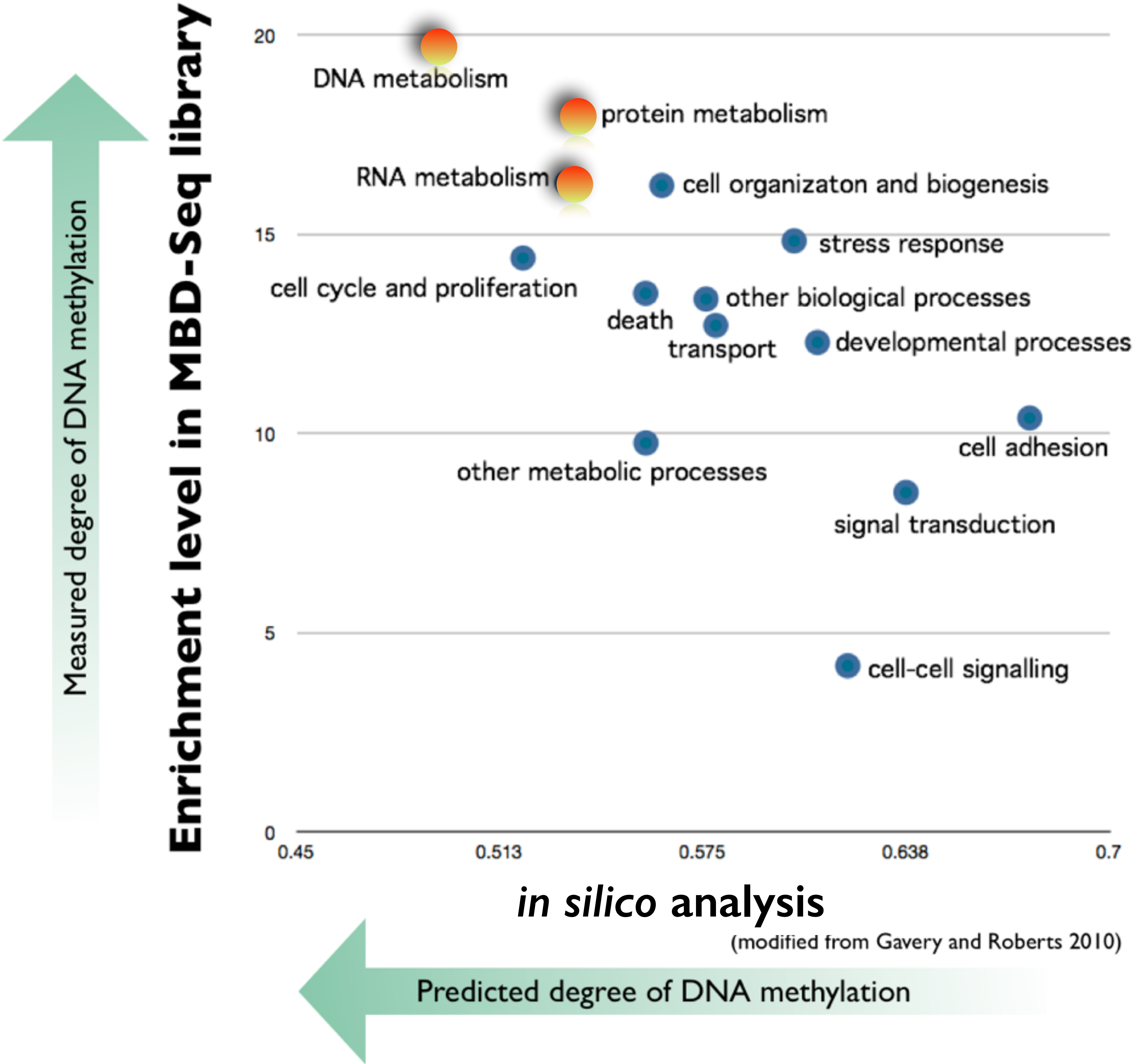
Predicted degree of DNA methylation



Roberts and Gavery 2012

Epigenetic
variation **1**



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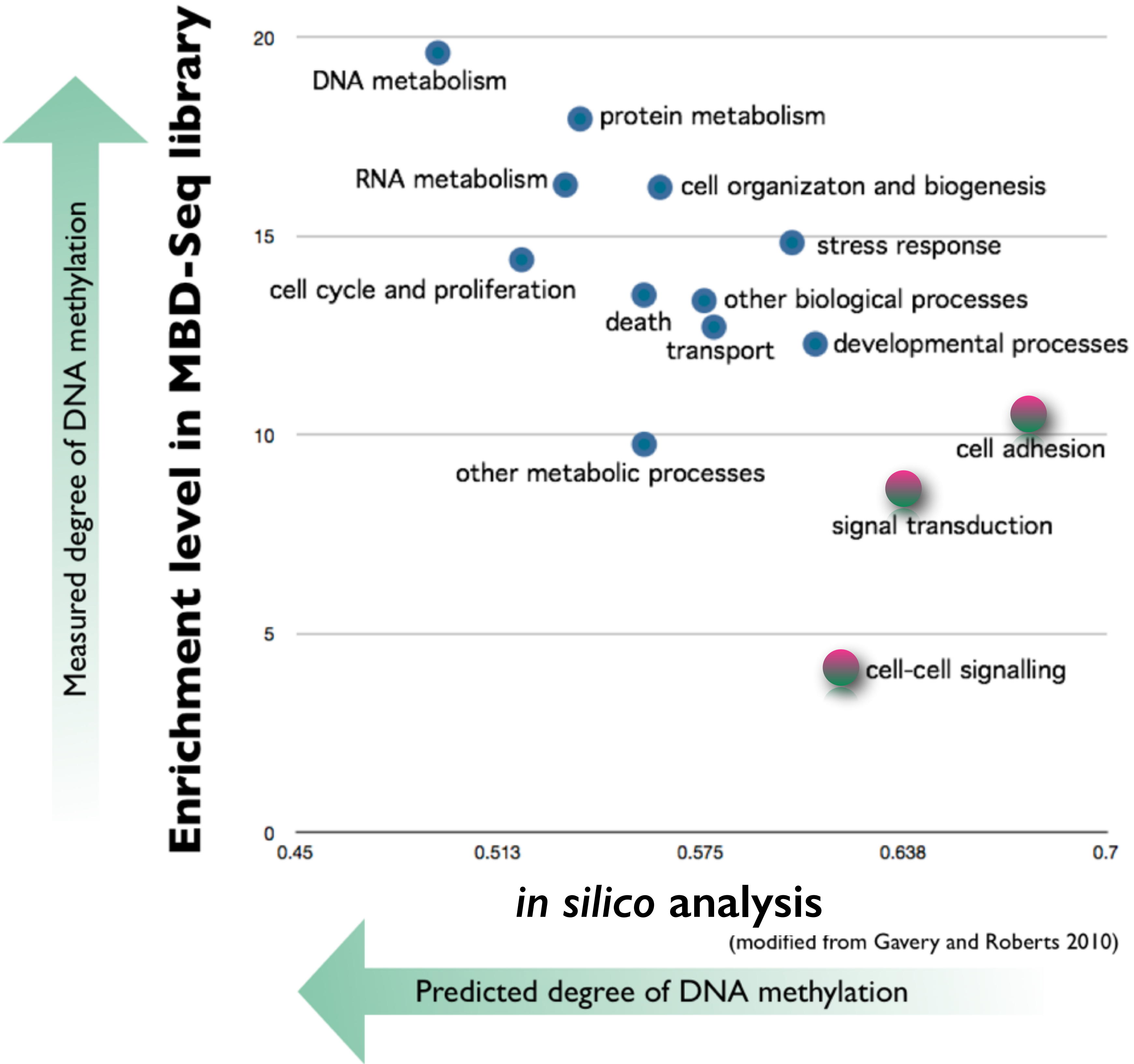

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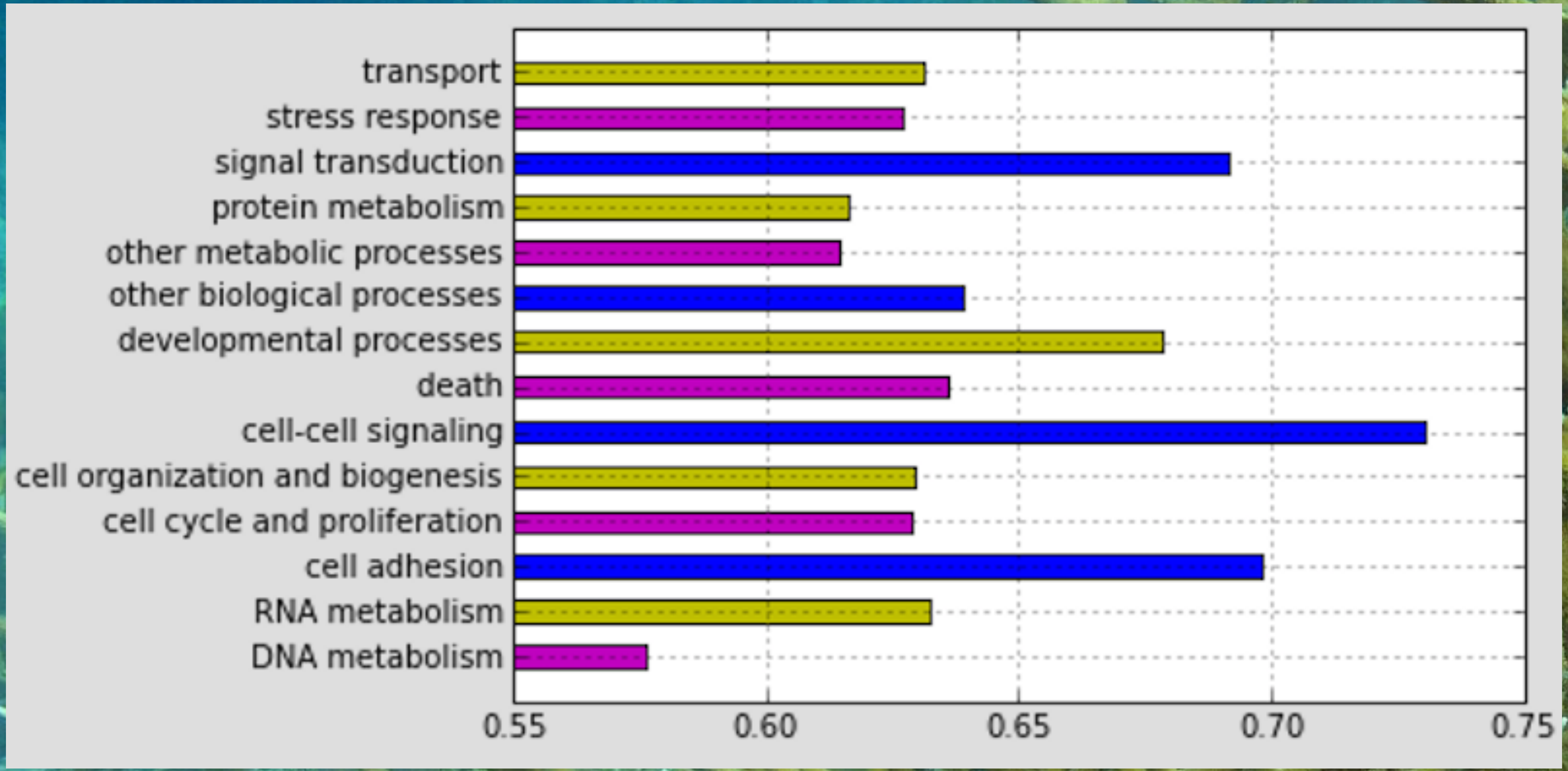
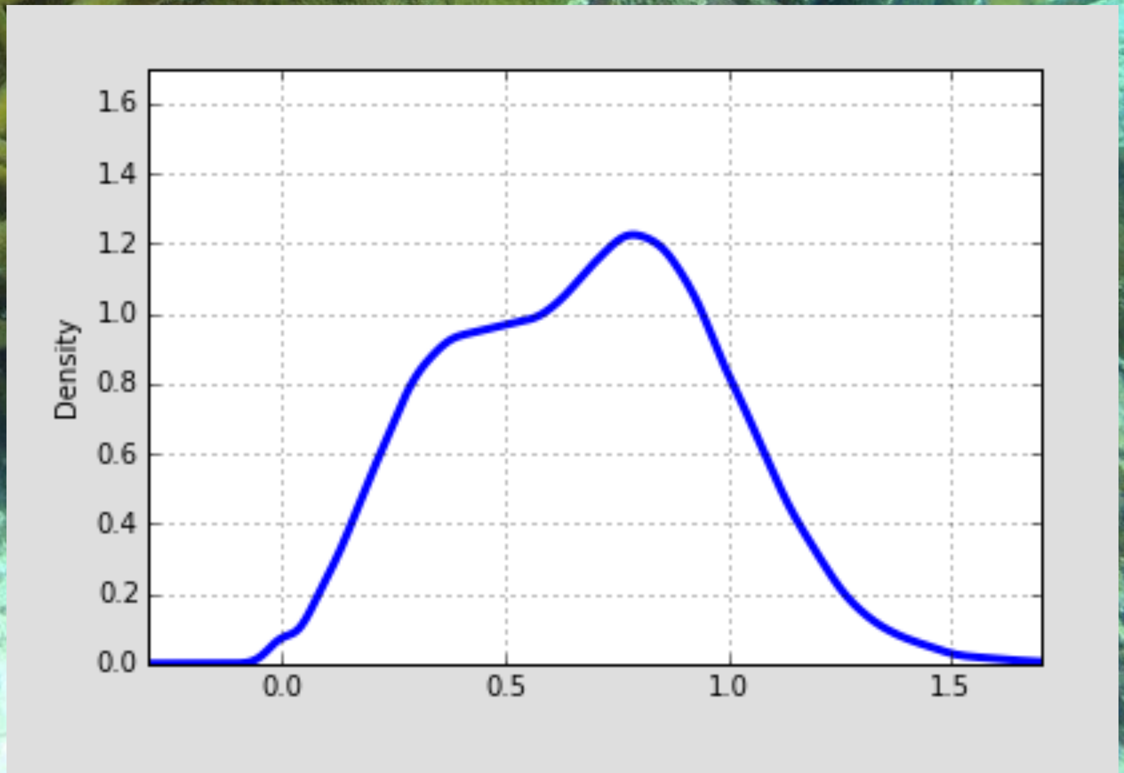
Roberts and Gavery 2012


Jay Dimond
Acropora palmata
Acropora cervicornis

Jay Dimond

Acropora palmata





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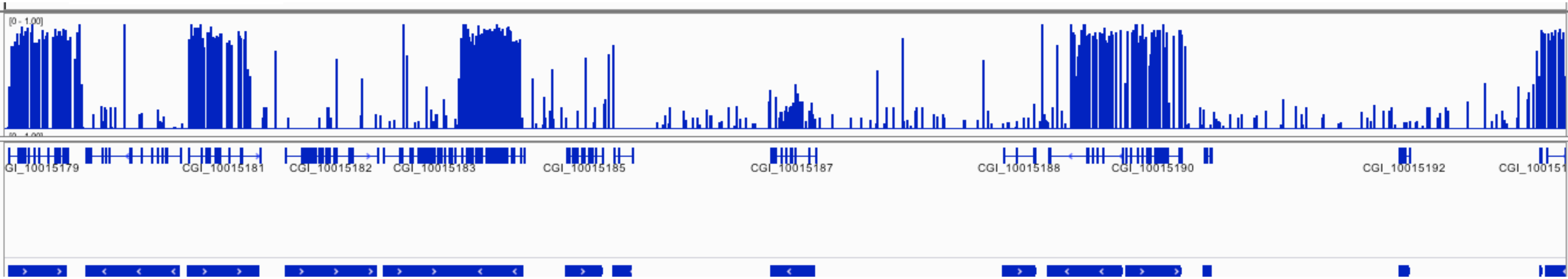


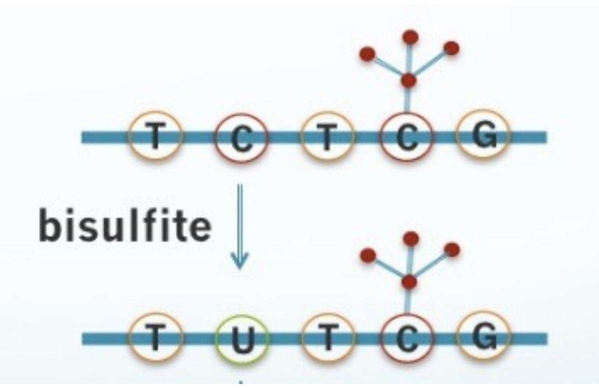
mosaic

associated with gene bodies
based on gene function

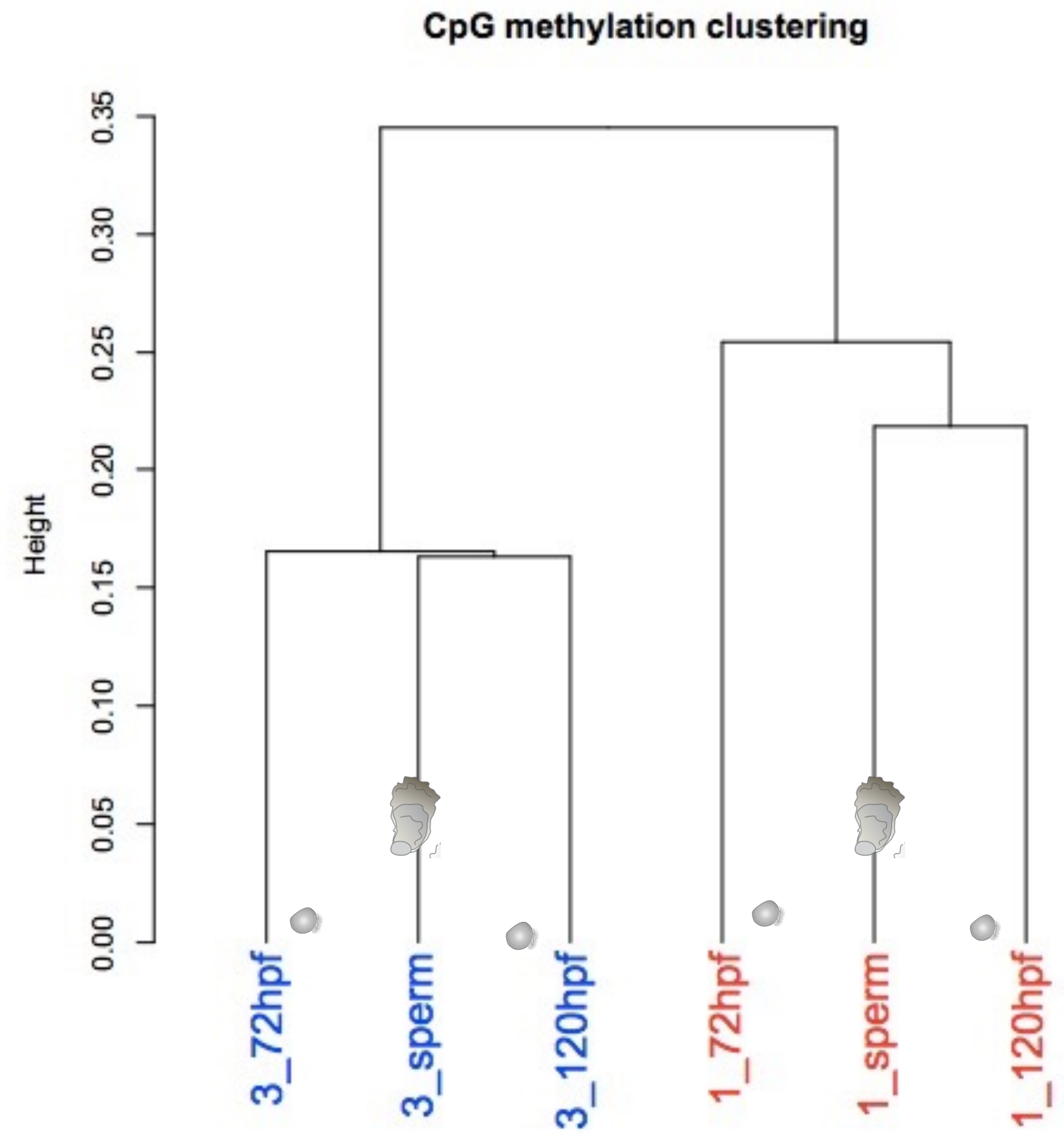
explanation?

Epigenetic variation 1

Family and Developmental Variation



Sperm &
Larvae
(72h & 120h)



Cold Spring Harbor Laboratory

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New Results

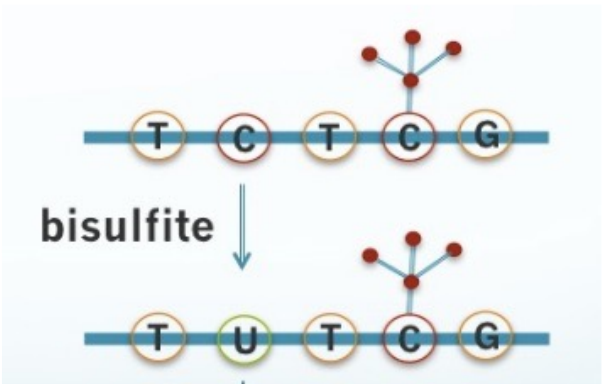
Indication of family-specific DNA methylation patterns in developing oysters

Claire E. Olson , Steven B. Roberts

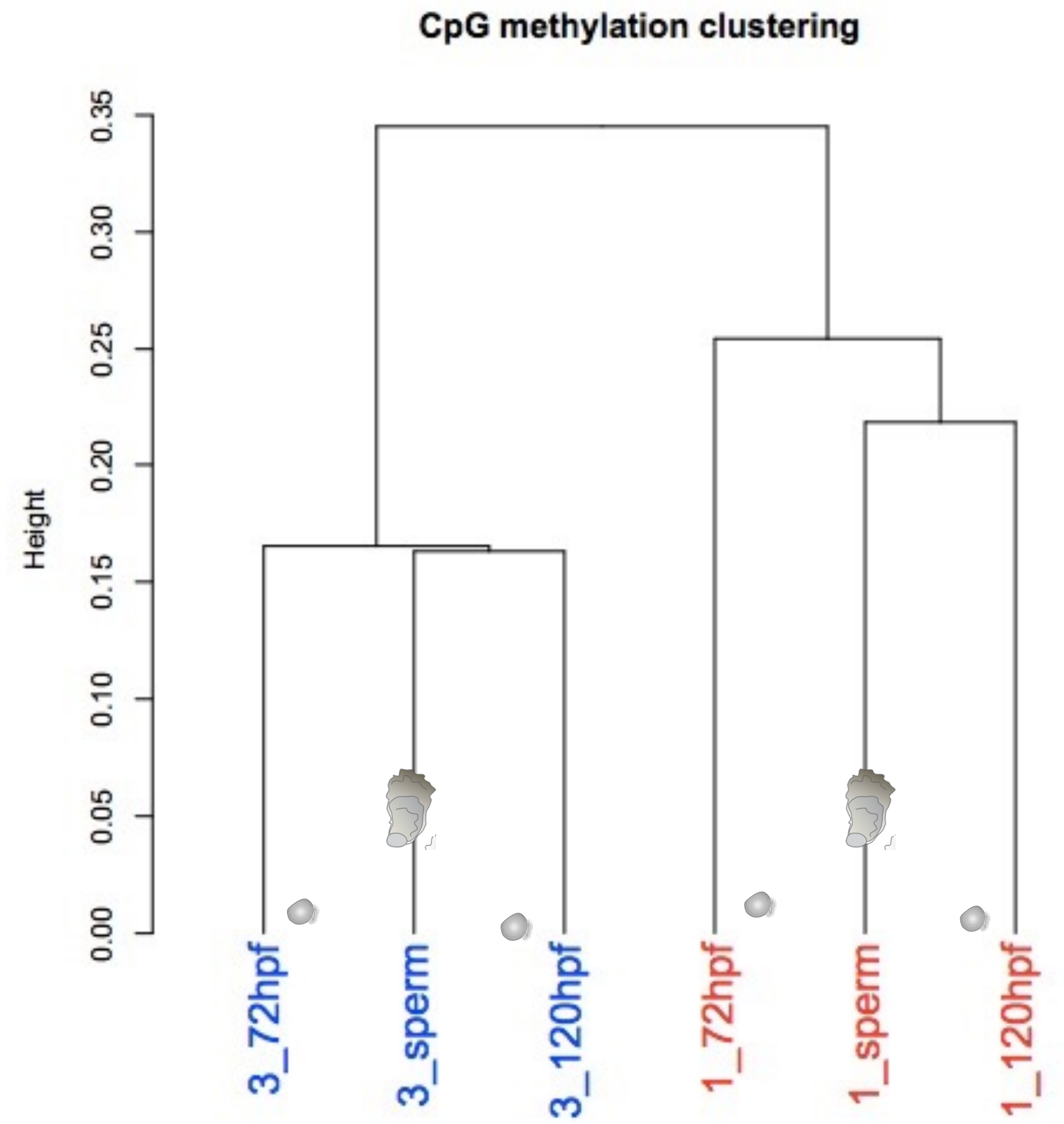
doi: http://dx.doi.org/10.1101/012831

Epigenetic variation 1

Family and Developmental Variation



Inheritance



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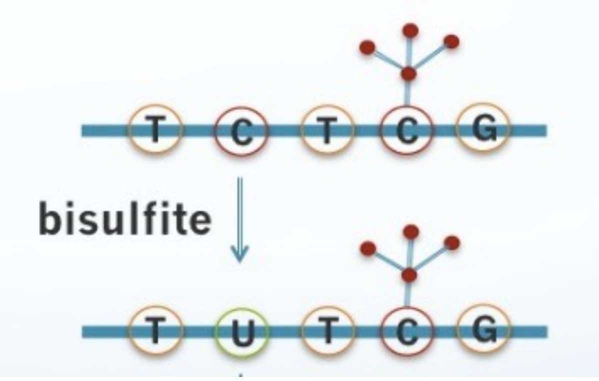
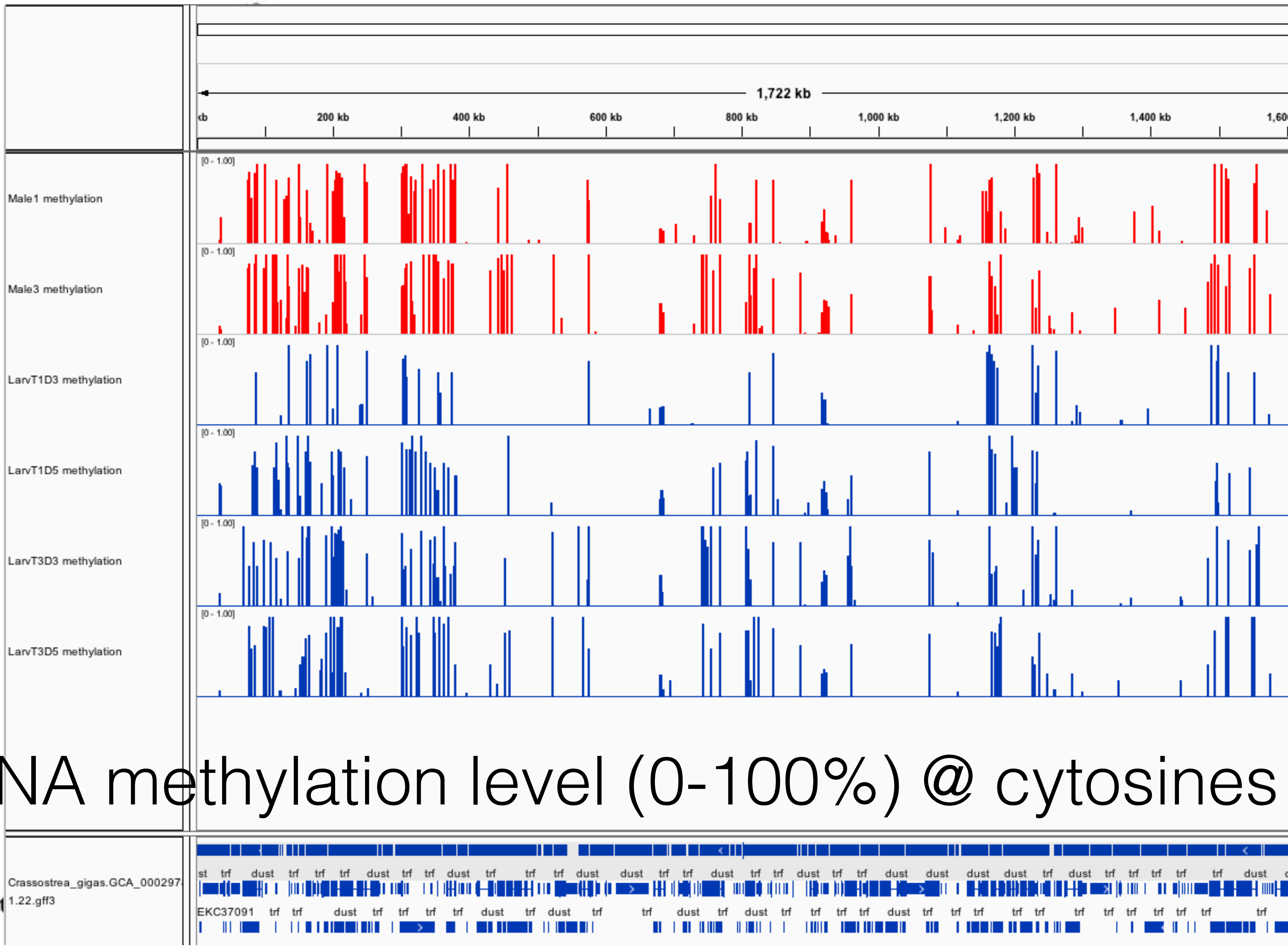


CpG methylation clustering

Sperm & Larvae (72h & 120h)



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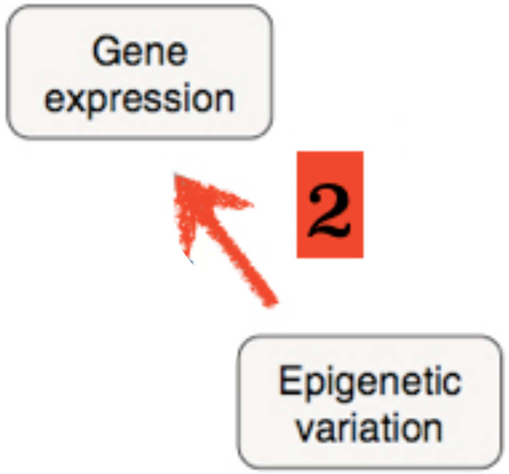
Epigenetic variation 1

Summary

- Sparsely (~16 %), mosaic methylated genome
- Gene body methylation correlated with function
- DNA methylation patterns are inherited
- DMRs are predominant in transposable elements

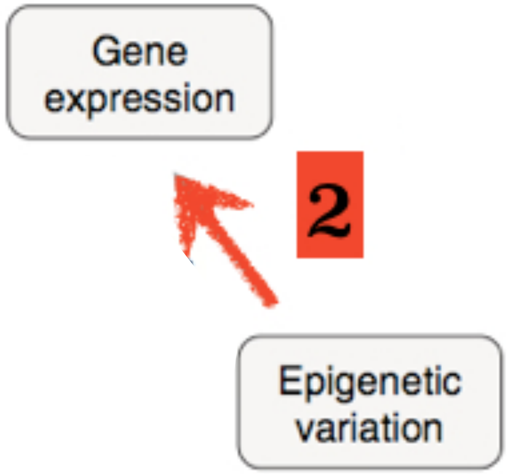


Gene expression

2

Epigenetic variation

Function?



Gene expression

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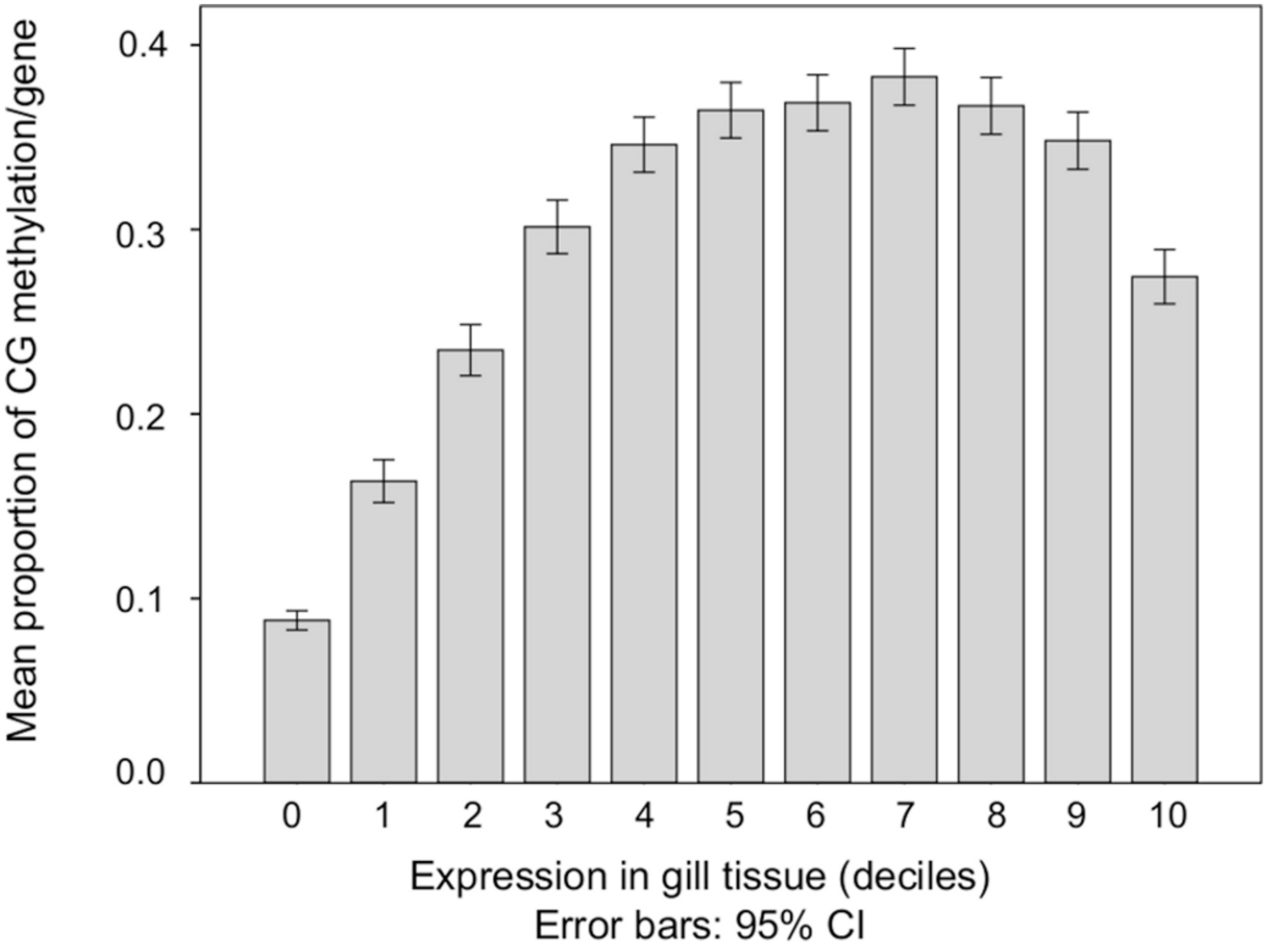
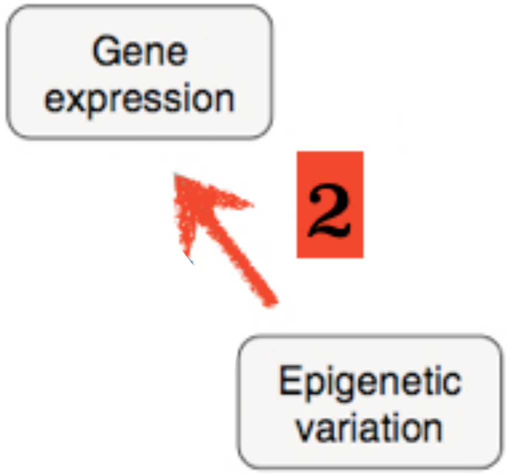


PeerJ

Predominant intragenic methylation is associated with gene expression characteristics in a bivalve mollusc

Mackenzie R. Gavery and Steven B. Roberts

School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA



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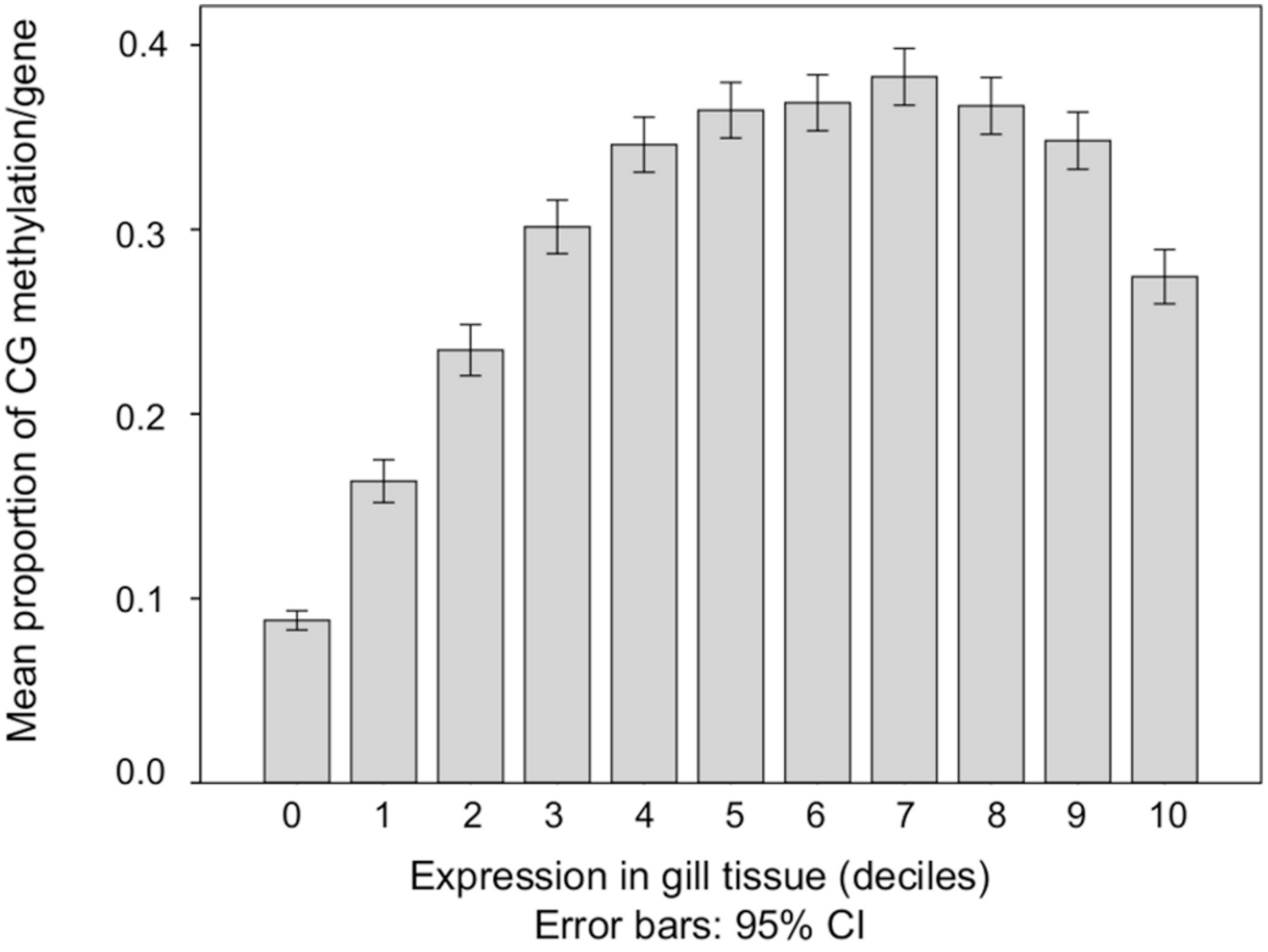

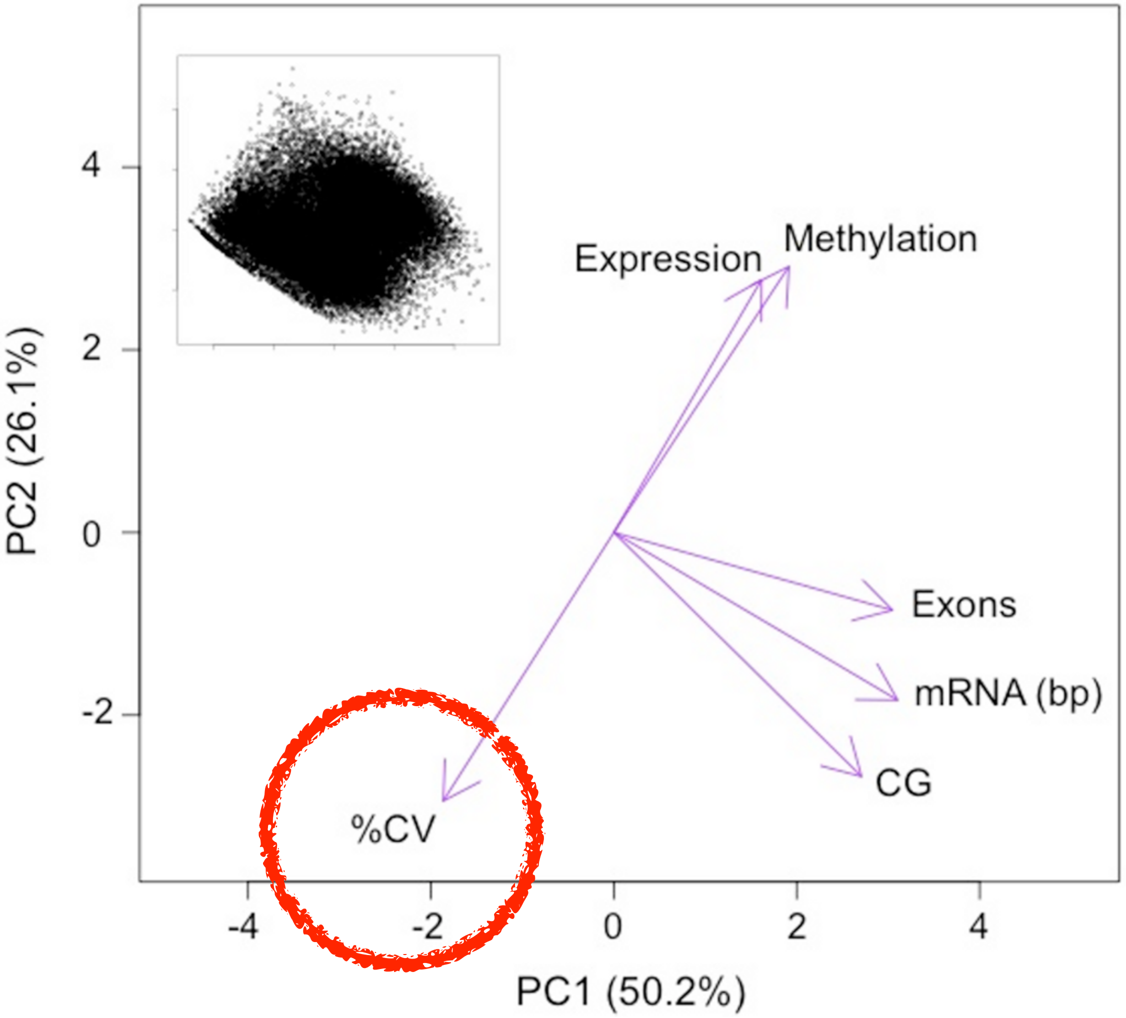

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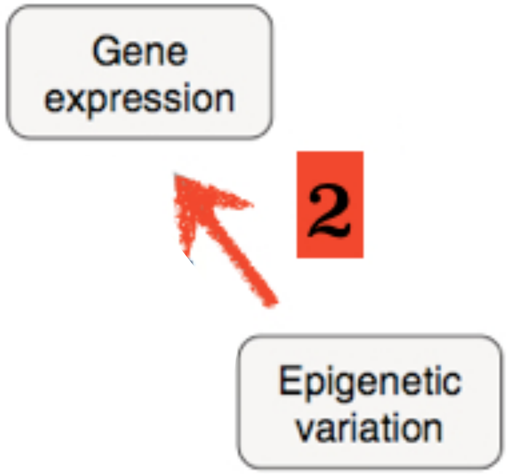
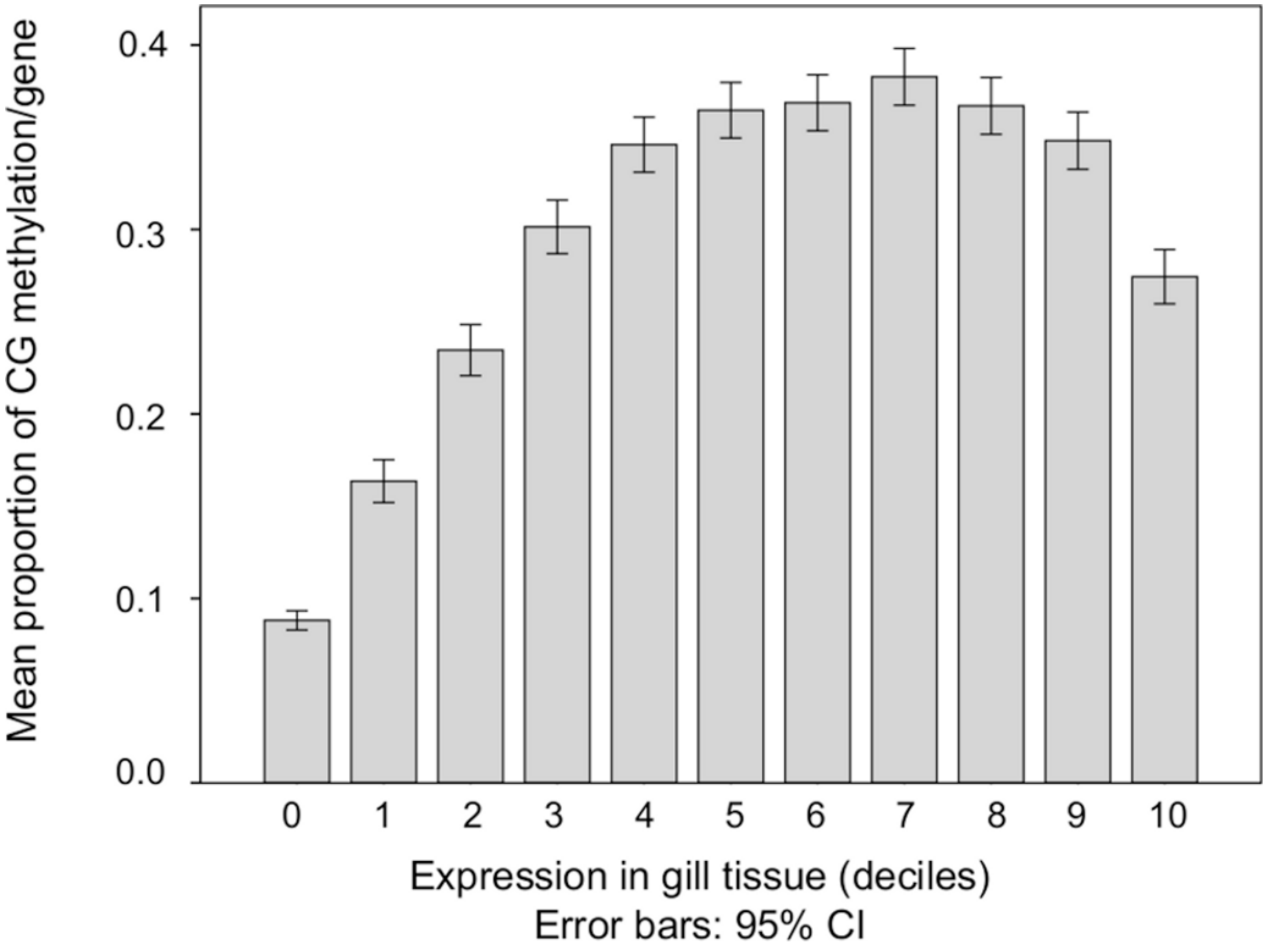
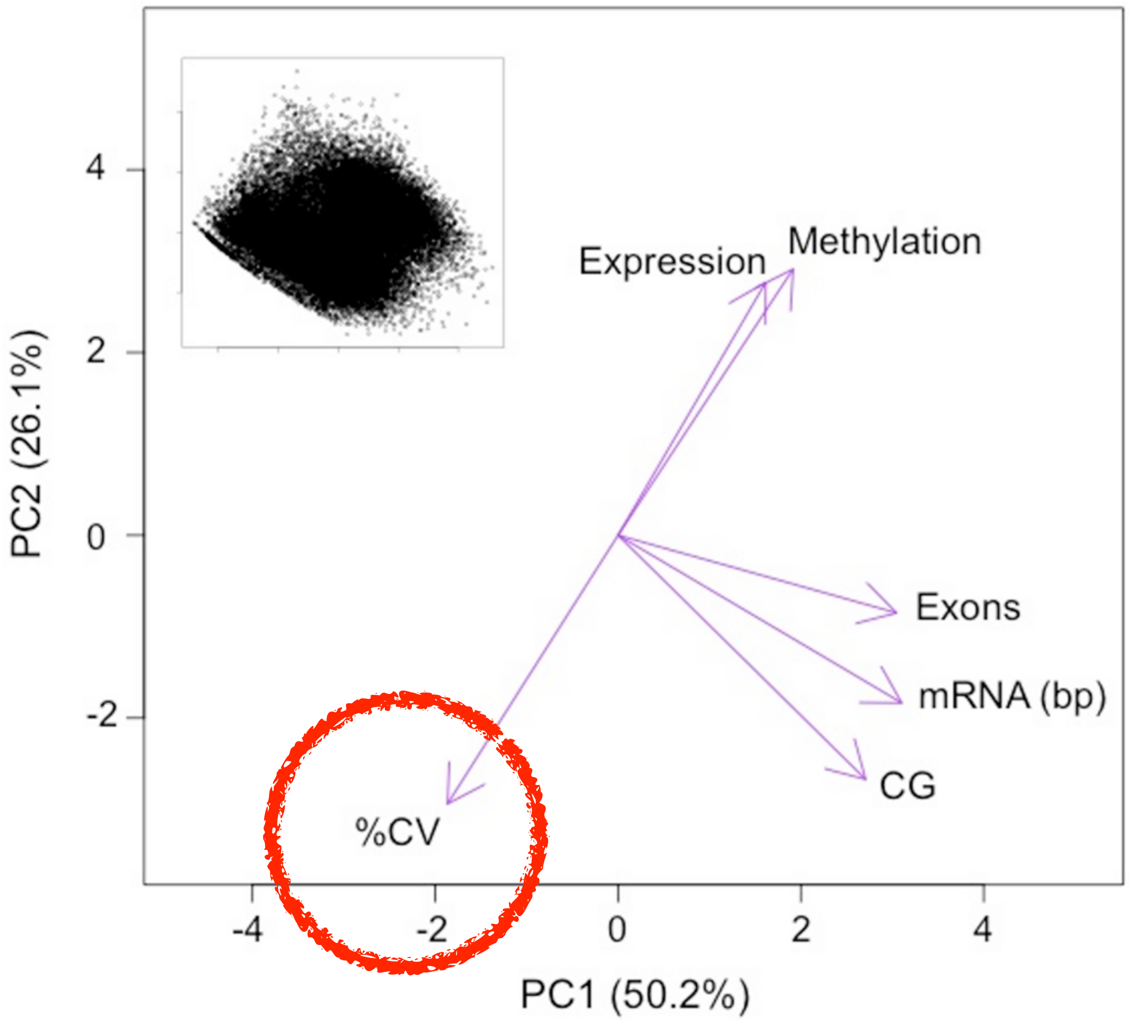


Theory: **Does not** influence expression level but rather alternative splicing.





PeerJ

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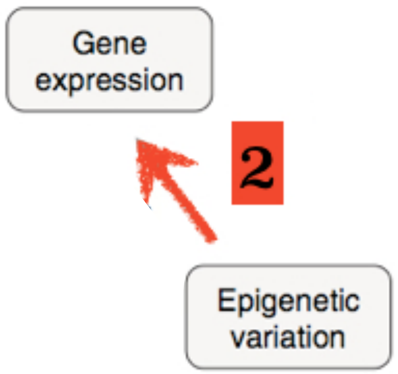
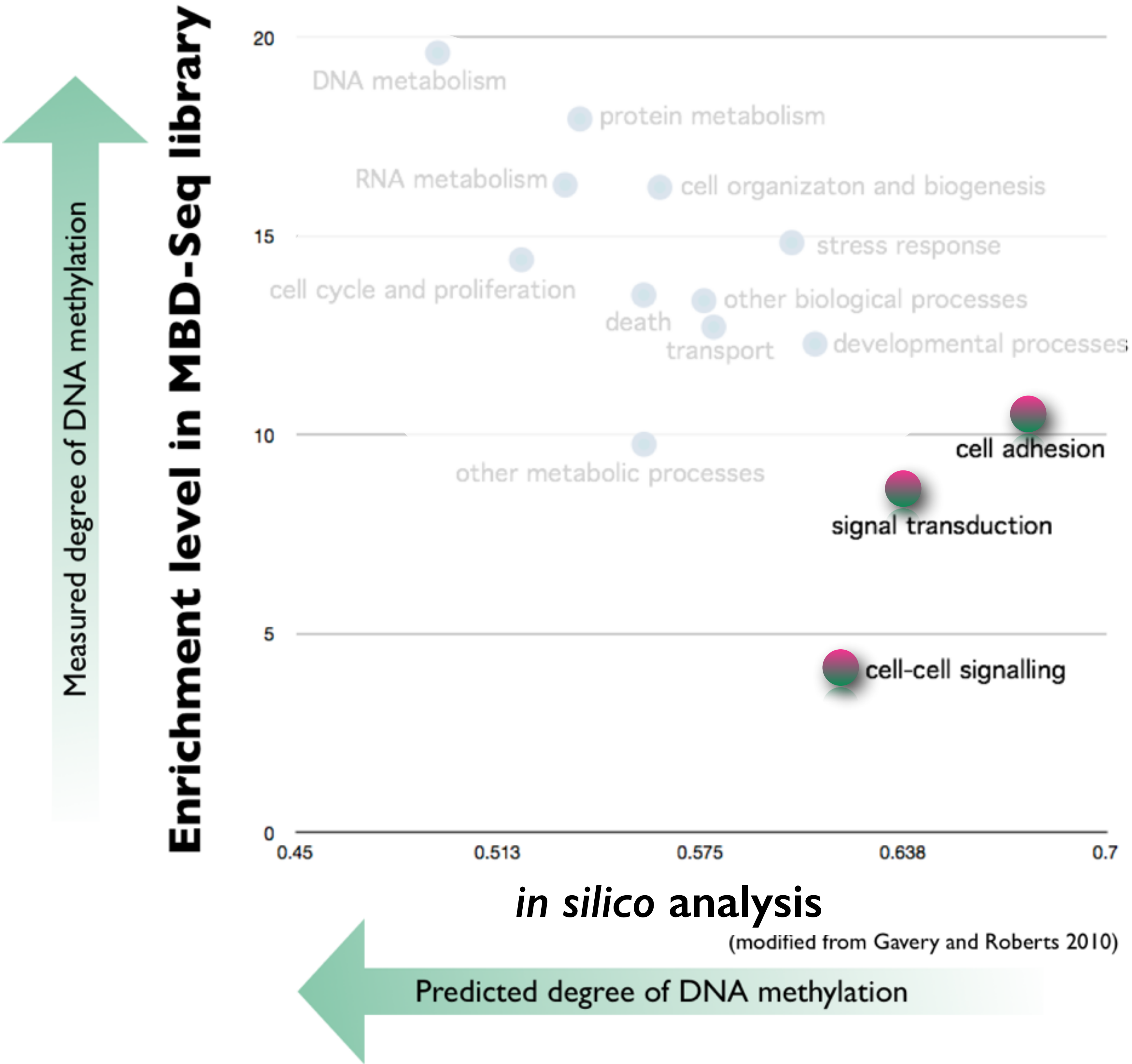
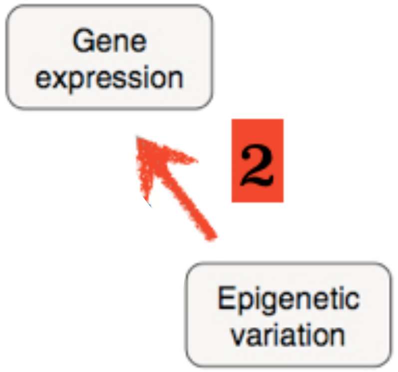
In species that experience a diverse range of environmental conditions, processes have evolved to increase the number of potential phenotypes in a population in order to improve the chances for an individual’s survival.



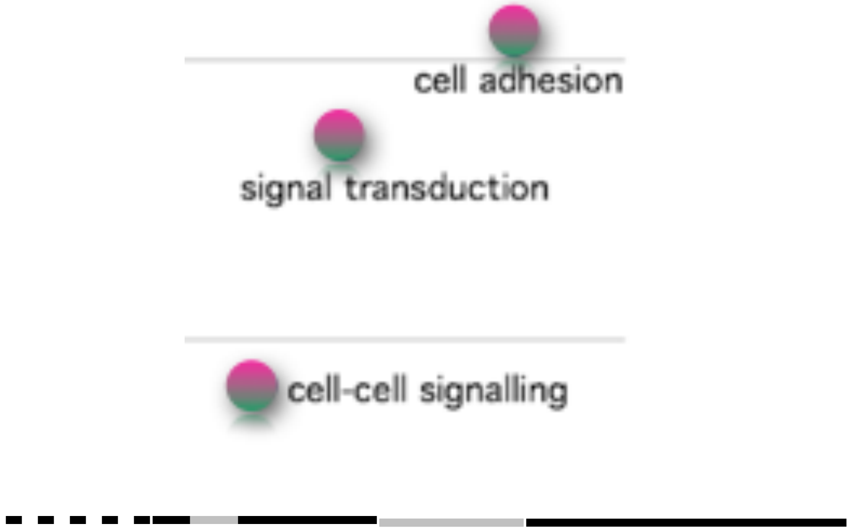


(modified from Gavery and Roberts 2010)

Roberts and Gavery 2012

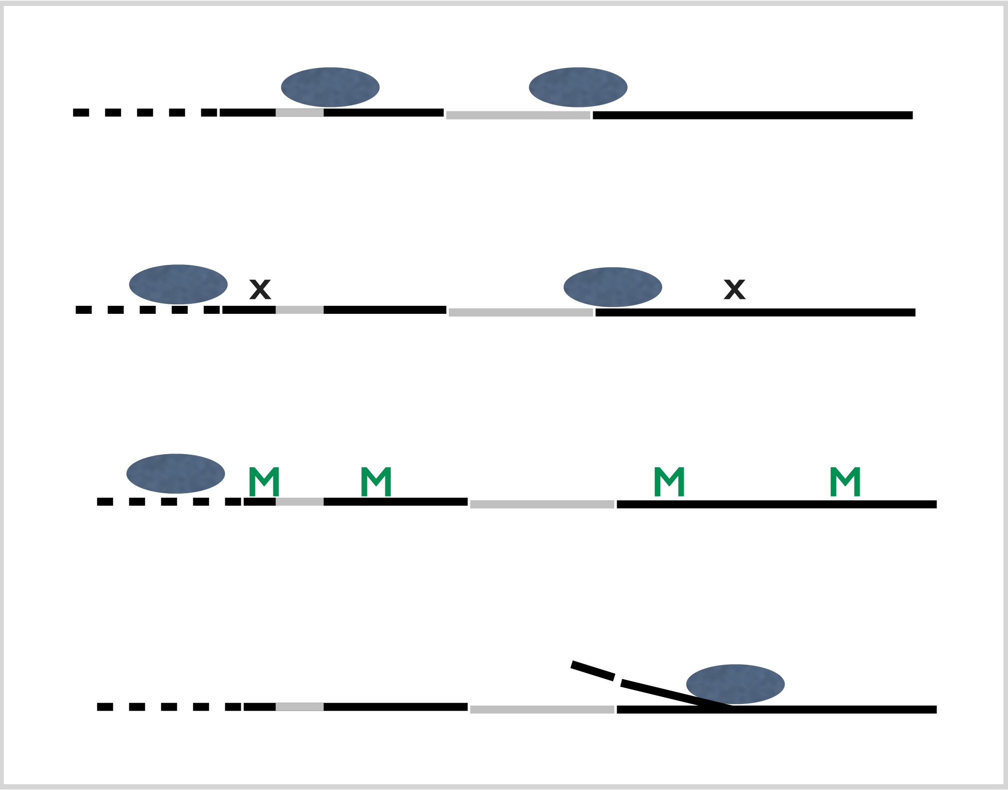


Transcriptional opportunities



sparse methylation

tissue / temporal specific and inducible genes



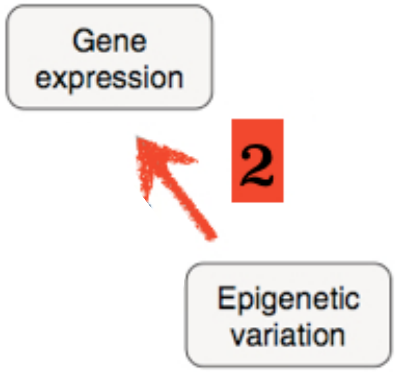
alternative start sites

sequence mutation
change AA, premature stop codon

conventional transcription
transient methylation

alternate transcript
exon skipping

Roberts and Gavery 2012



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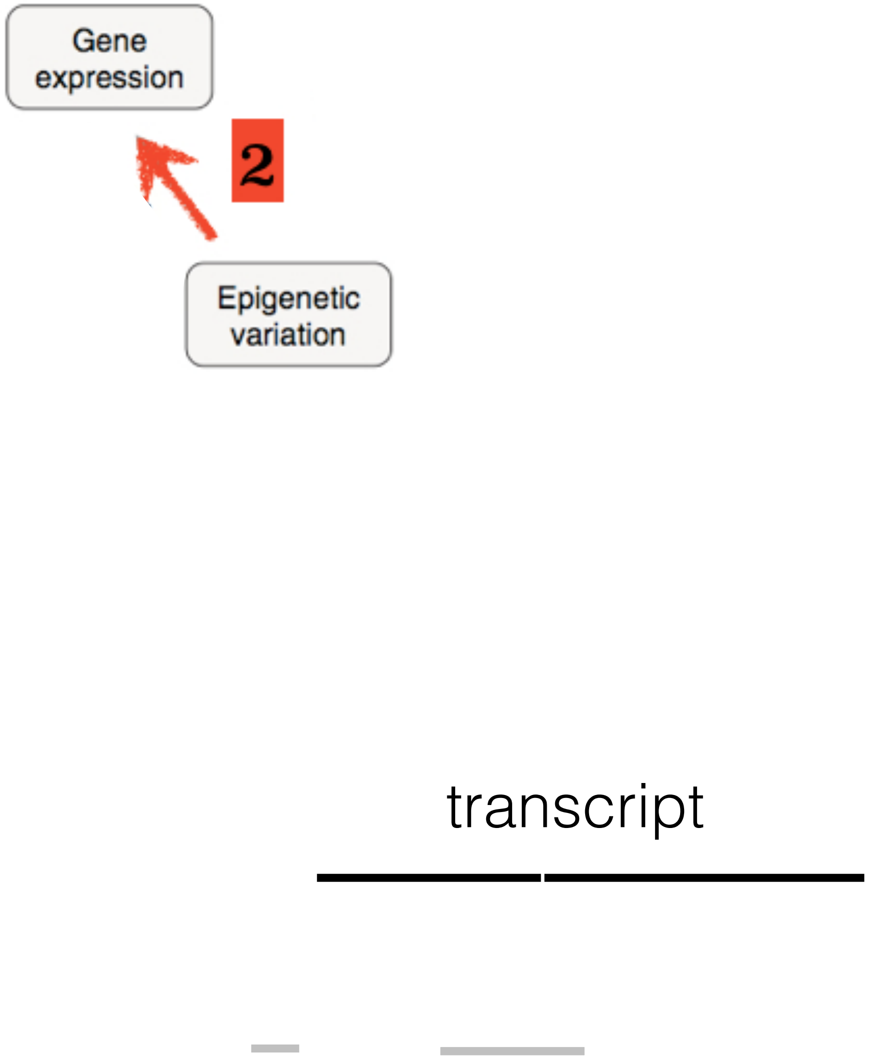


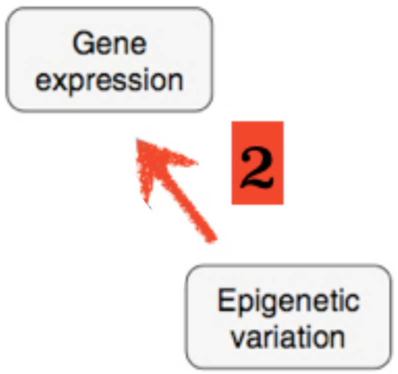
Gene expression

2

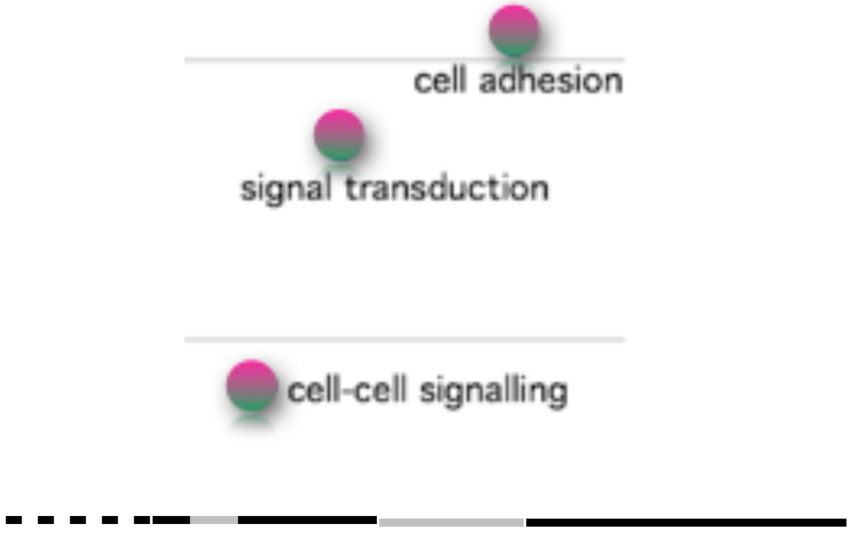
Epigenetic variation

transcript

Roberts and Gavery 2012

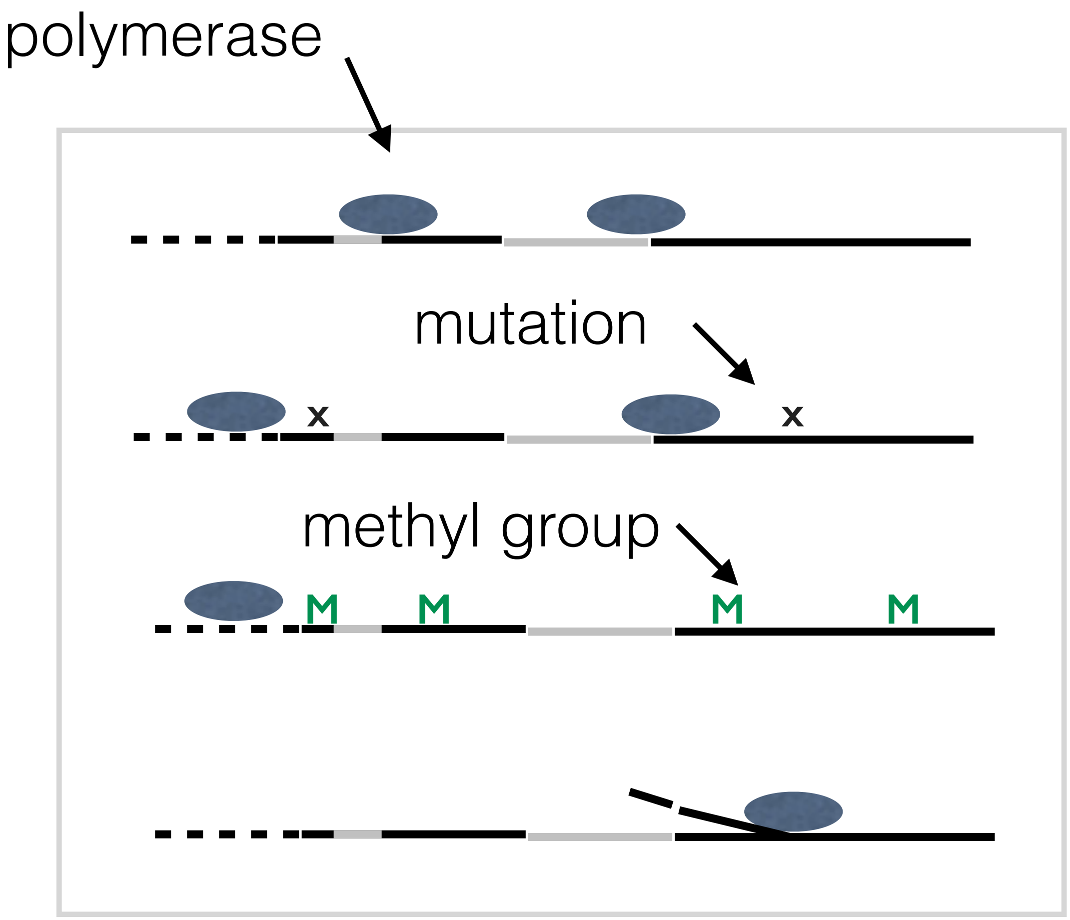


Transcriptional opportunities



sparse methylation

tissue / temporal specific and inducible genes



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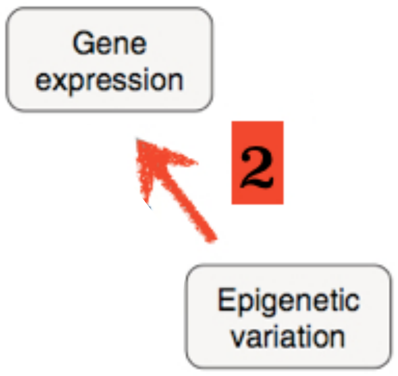
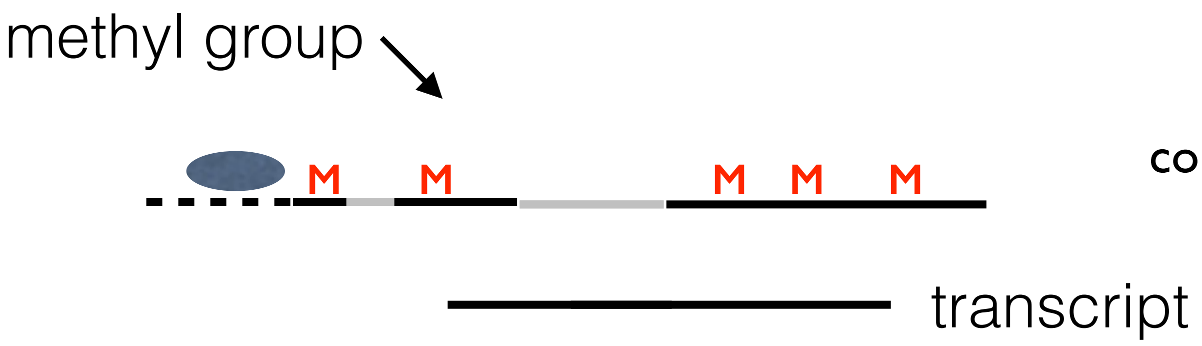


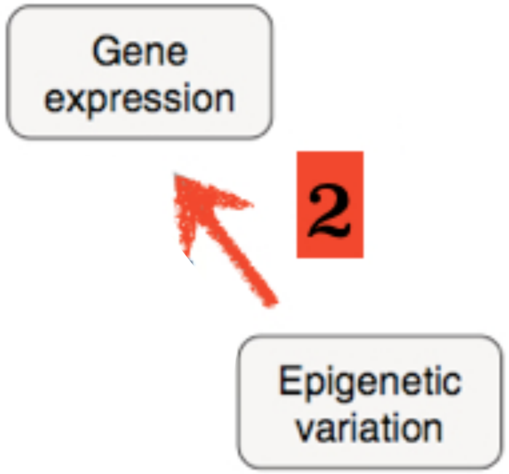
Transcriptional opportunities

germline methylation

ubiquitously expressed,
critical genes



conventional transcription
5’ UTR promotor

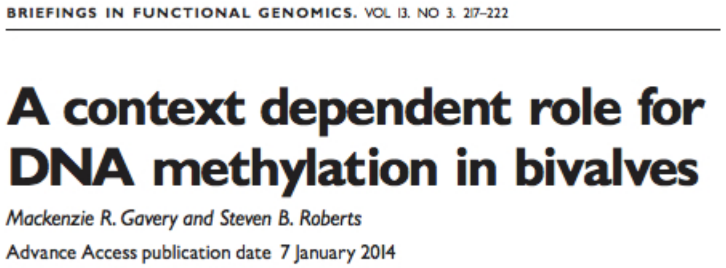


Gene expression

2

Epigenetic variation

Stochastic Variation



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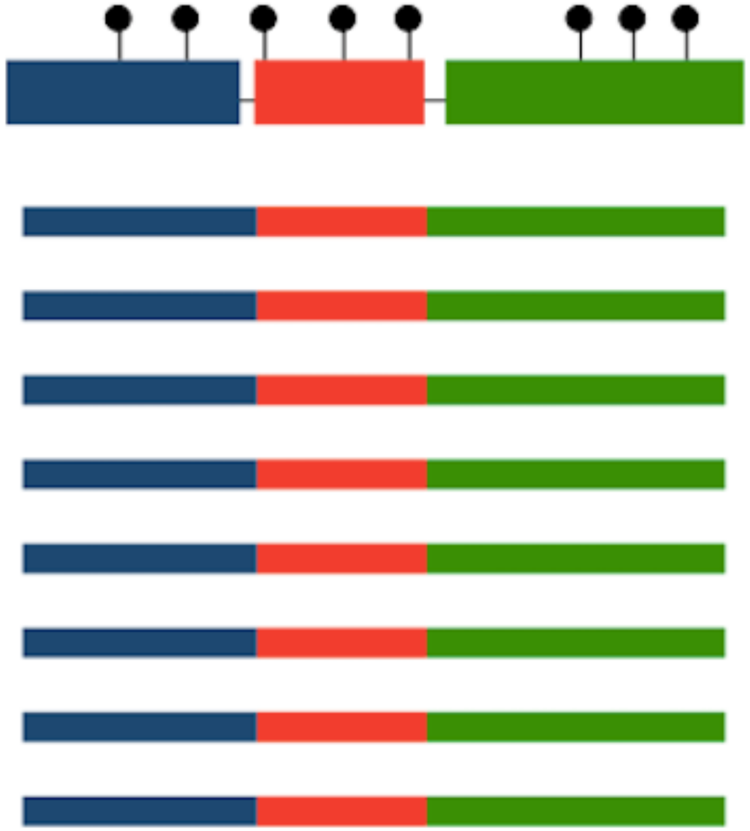
A context dependent role for DNA methylation in bivalves

Mackenzie R. Gavery and Steven B. Roberts

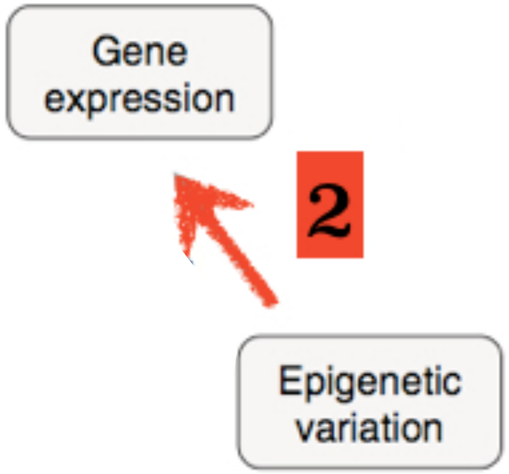
Advance Access publication date 7 January 2014

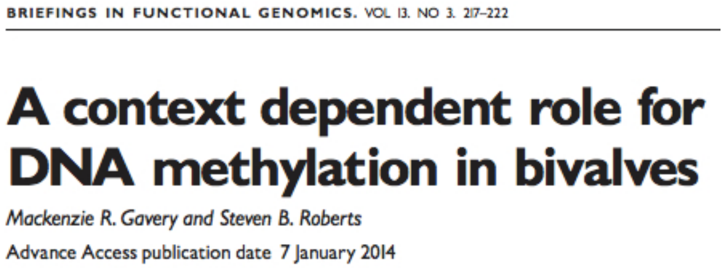


housekeeping

response to change

Stochastic Variation

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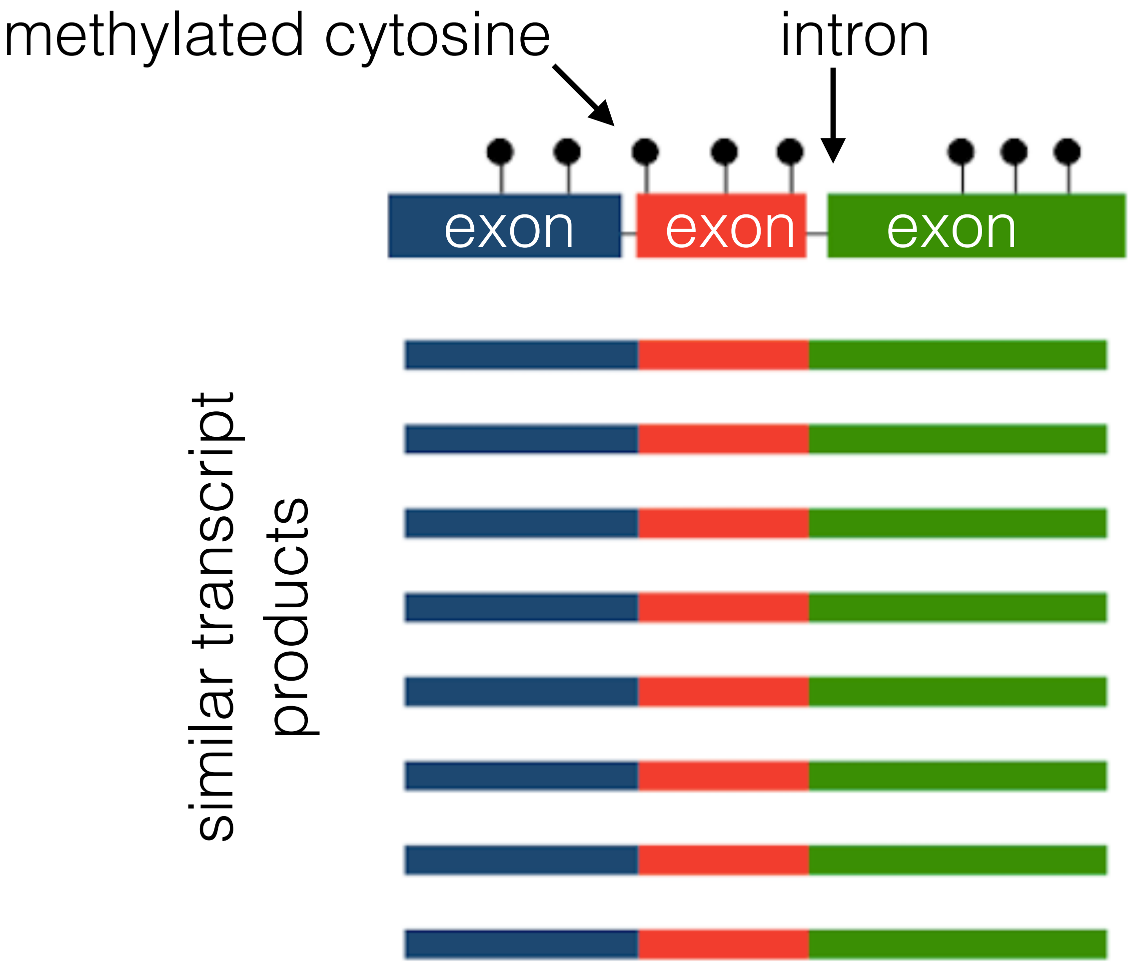

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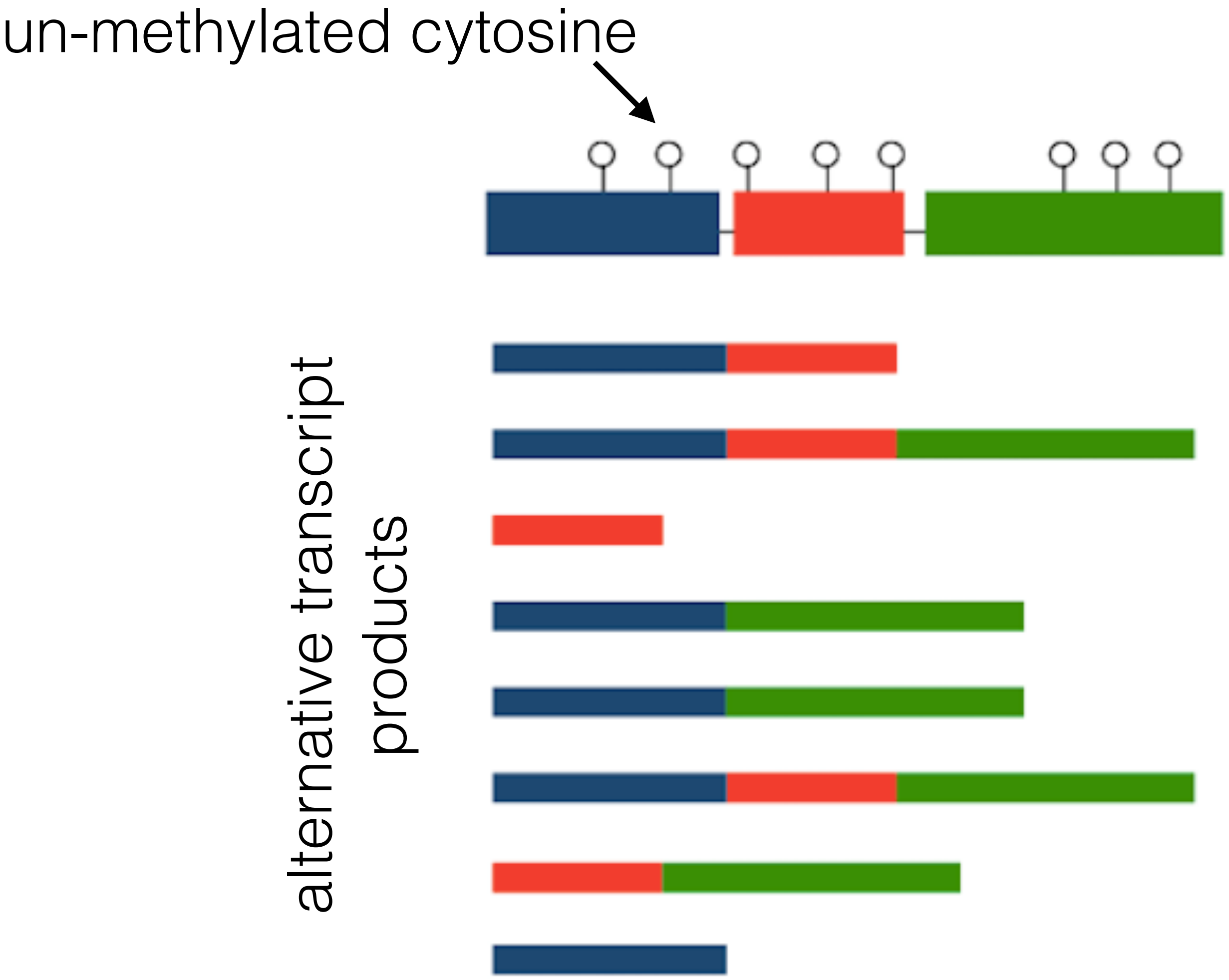
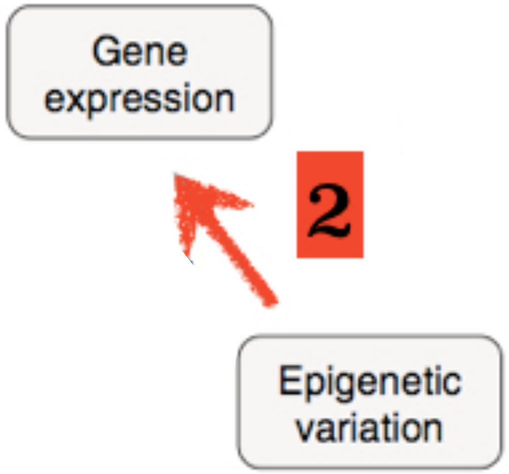


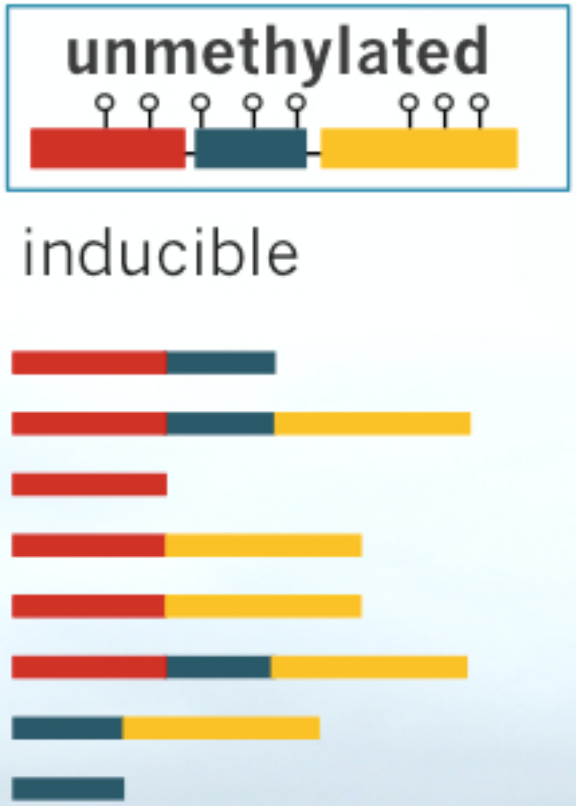
response to change

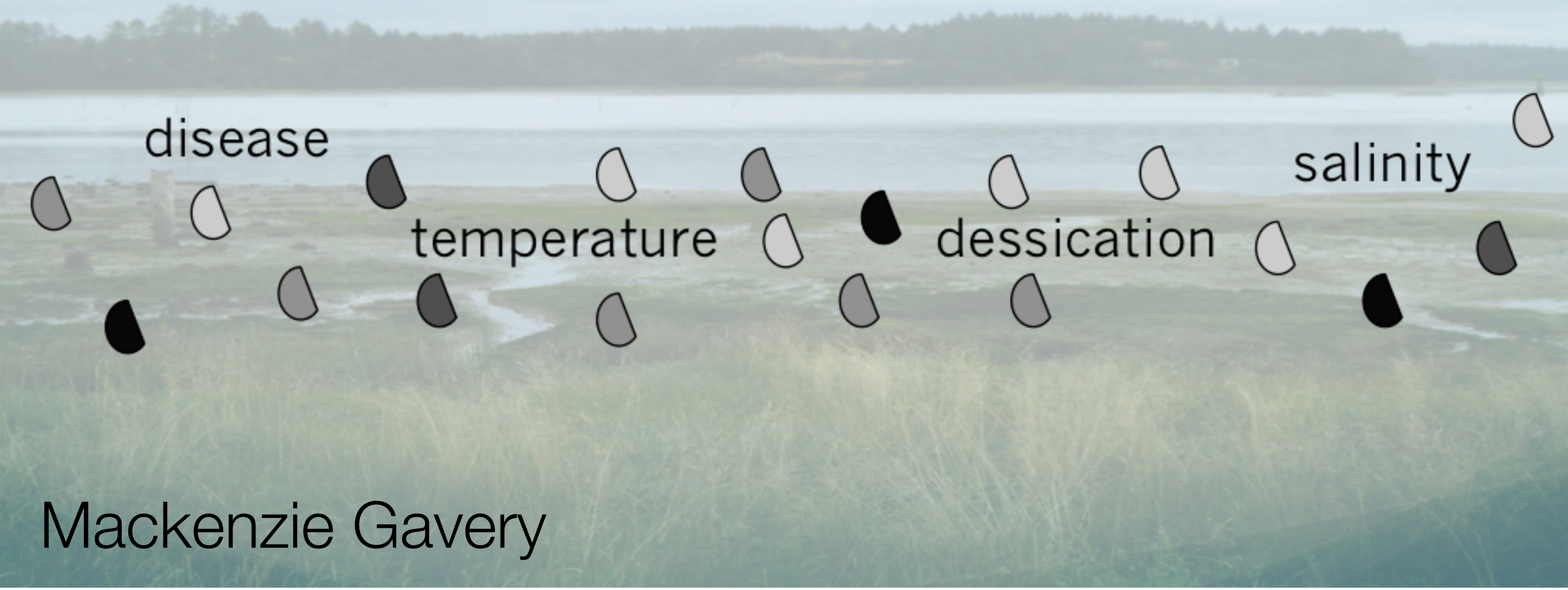


Gene expression

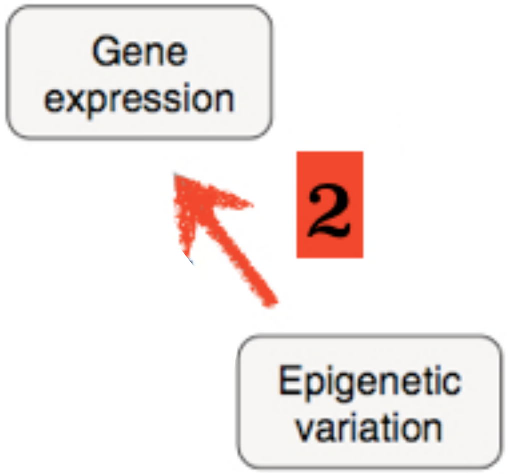
2

Epigenetic variation

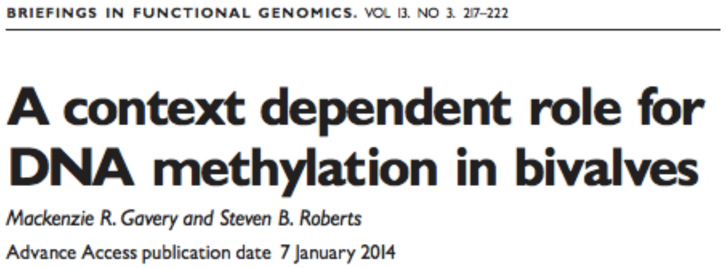




Mackenzie Gavery



Targeted Regulation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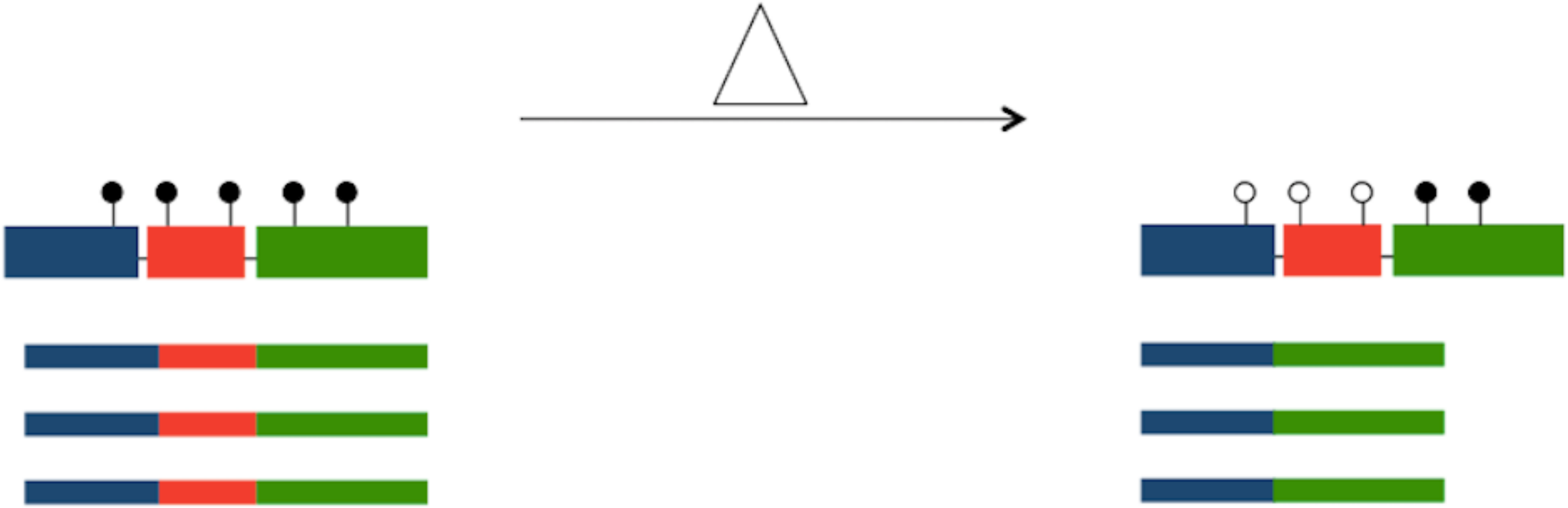
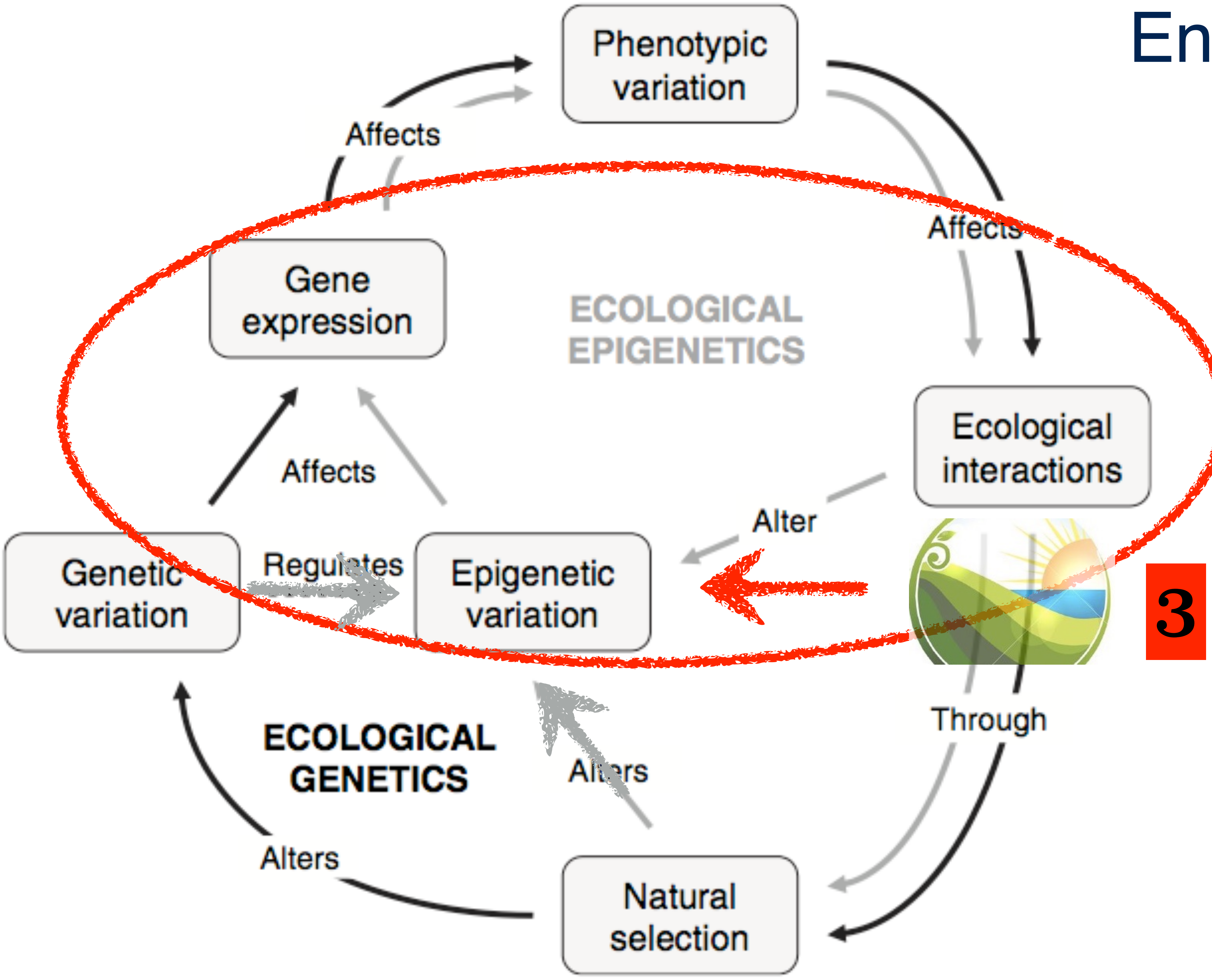


Environmental Influence



modified from

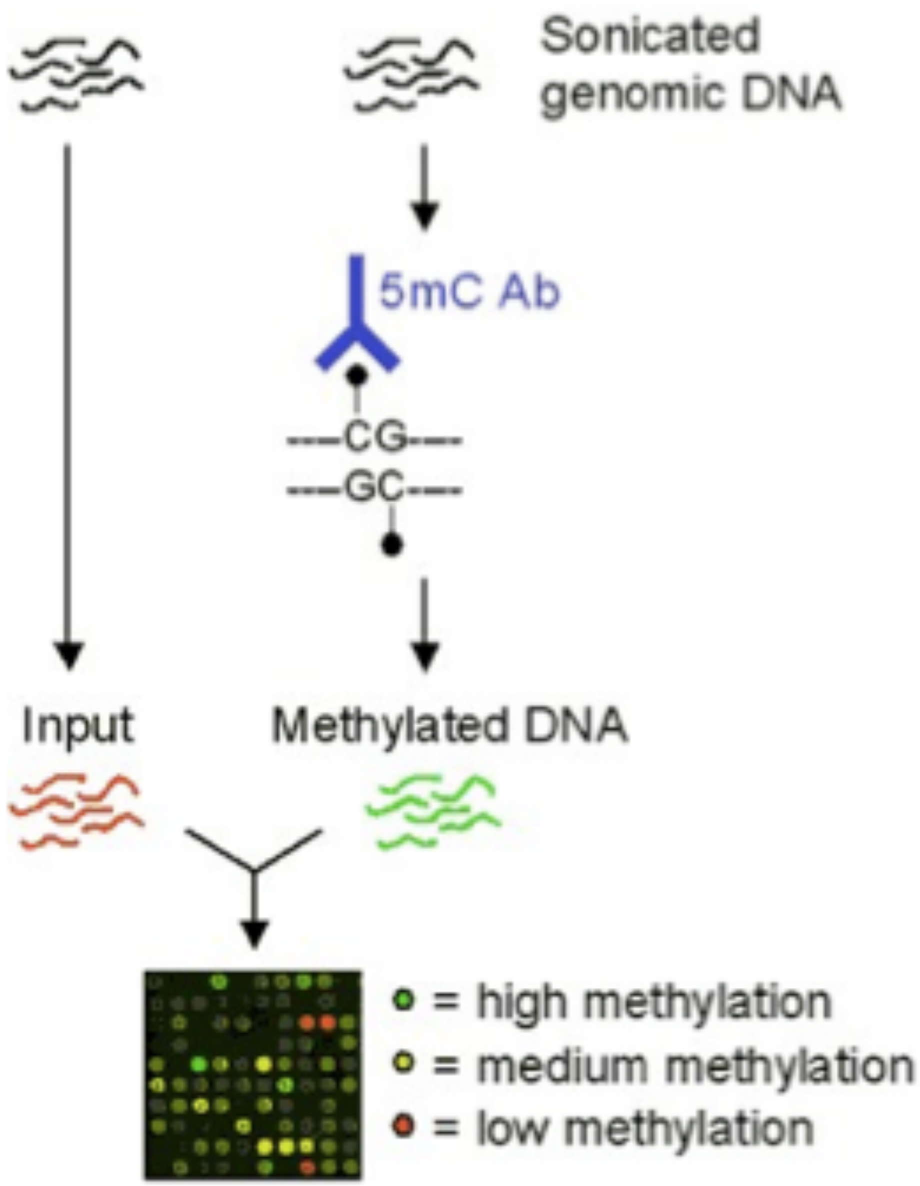
Ecology Letters, (2008) **11**: 106–115 doi: 10.1111/j.1461-0248.2007.01130.x

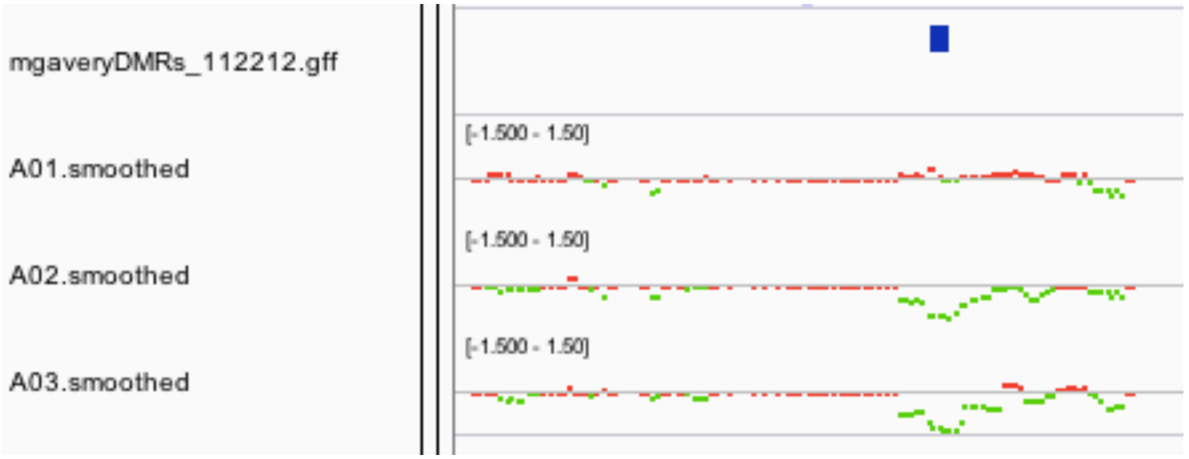
IDEA AND PERSPECTIVE

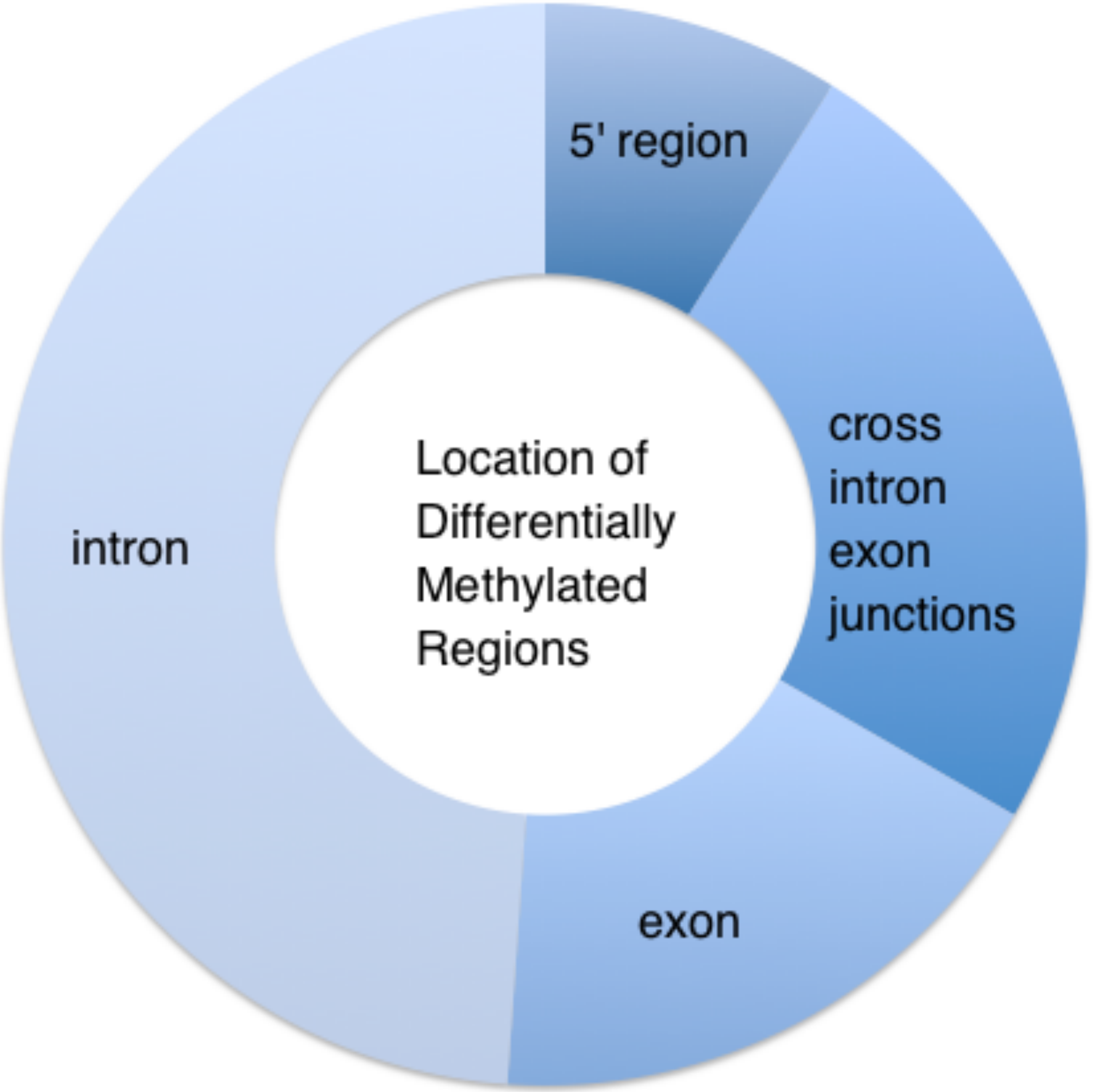
Epigenetics for ecologists

Oliver Bossdorf,[1]* Christina L. Richards[2] and Massimo Pigliucci[3]

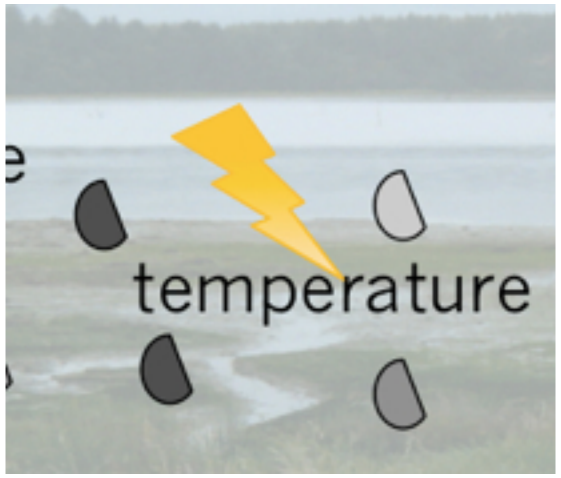
Environmental impact (Estrogens)



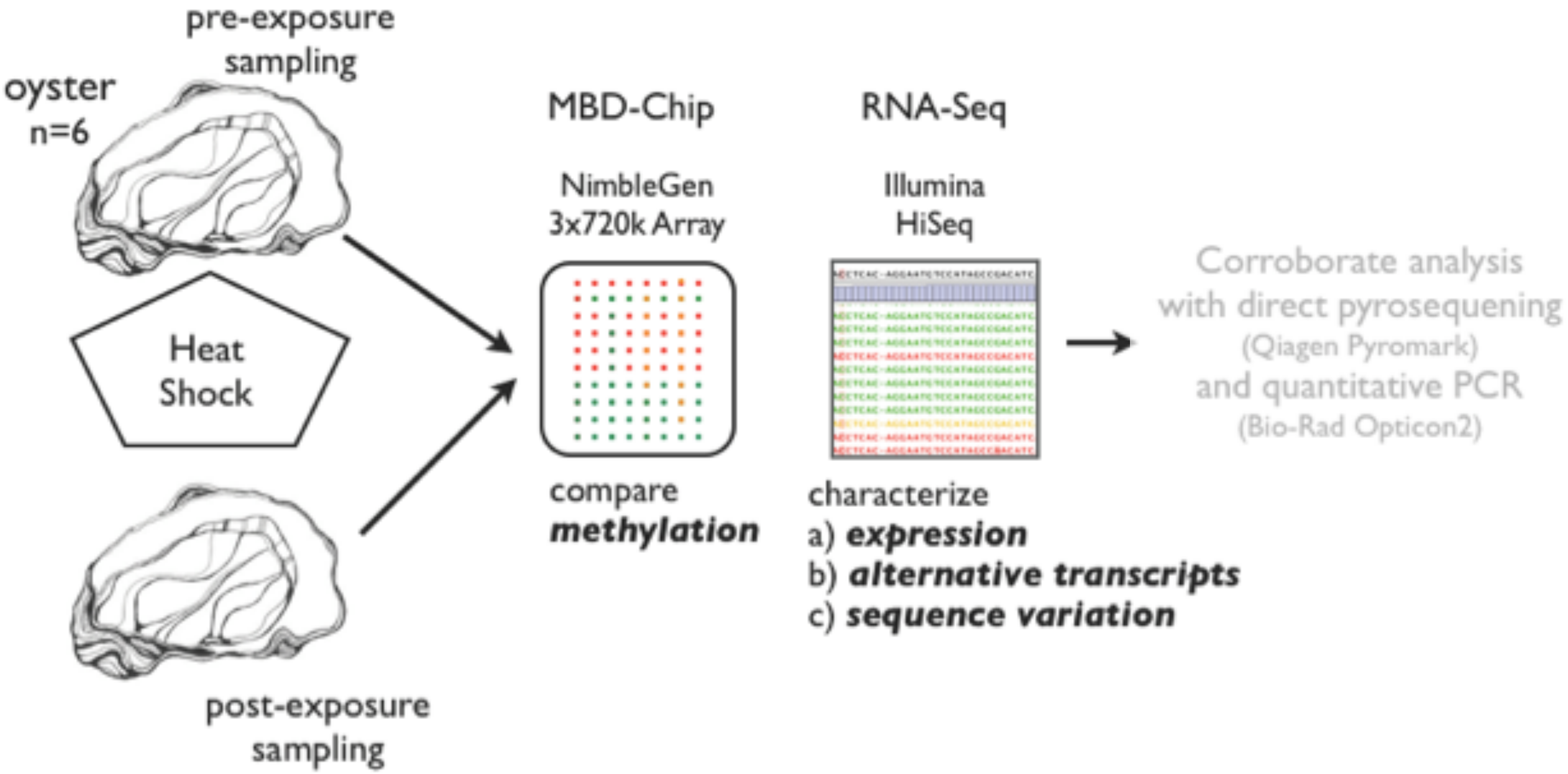




Environment and gene expression



stochastic or targeted?



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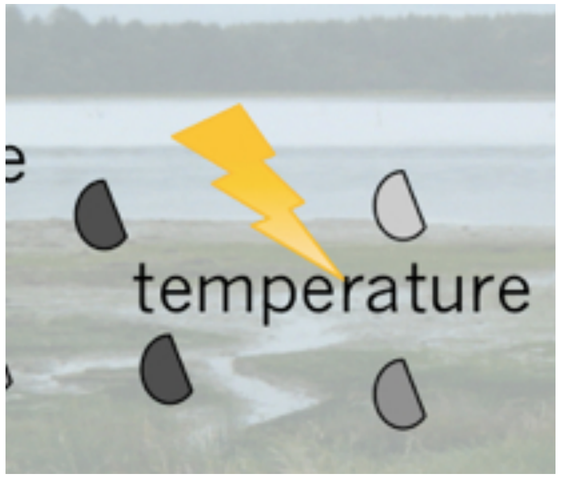
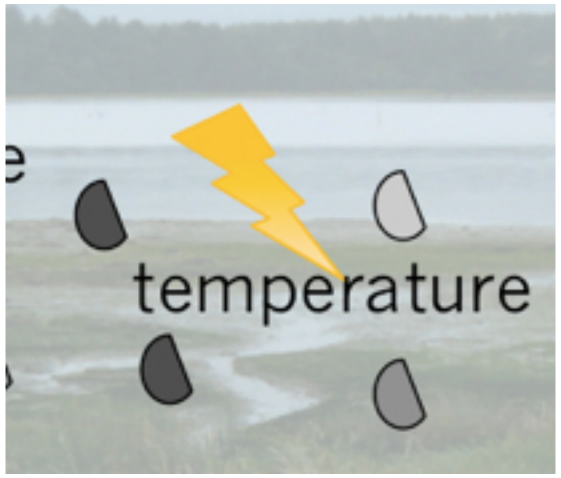


stochastic or targeted?

Oyster	Hypo-methylated	Hyper-methylated
2	7224	2803
4	6560	3587
6	7645	4044

Environment and gene expression

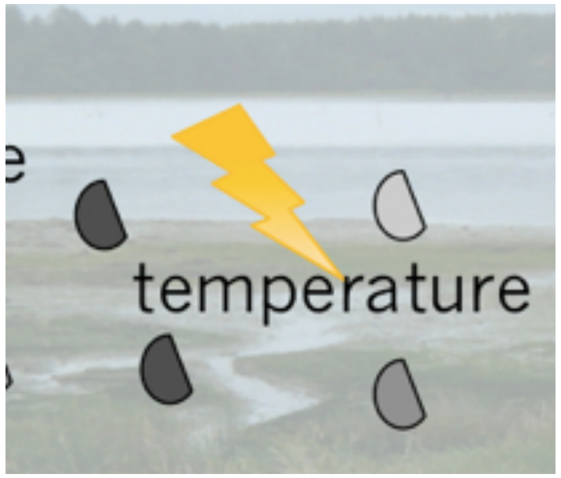


stochastic or targeted?

Oyster	Hypo-methylated	Hyper-methylated
2	7224	2803
4	6560	3587
6	7645	4044

No obvious association with genome feature including *differentially expressed genes*

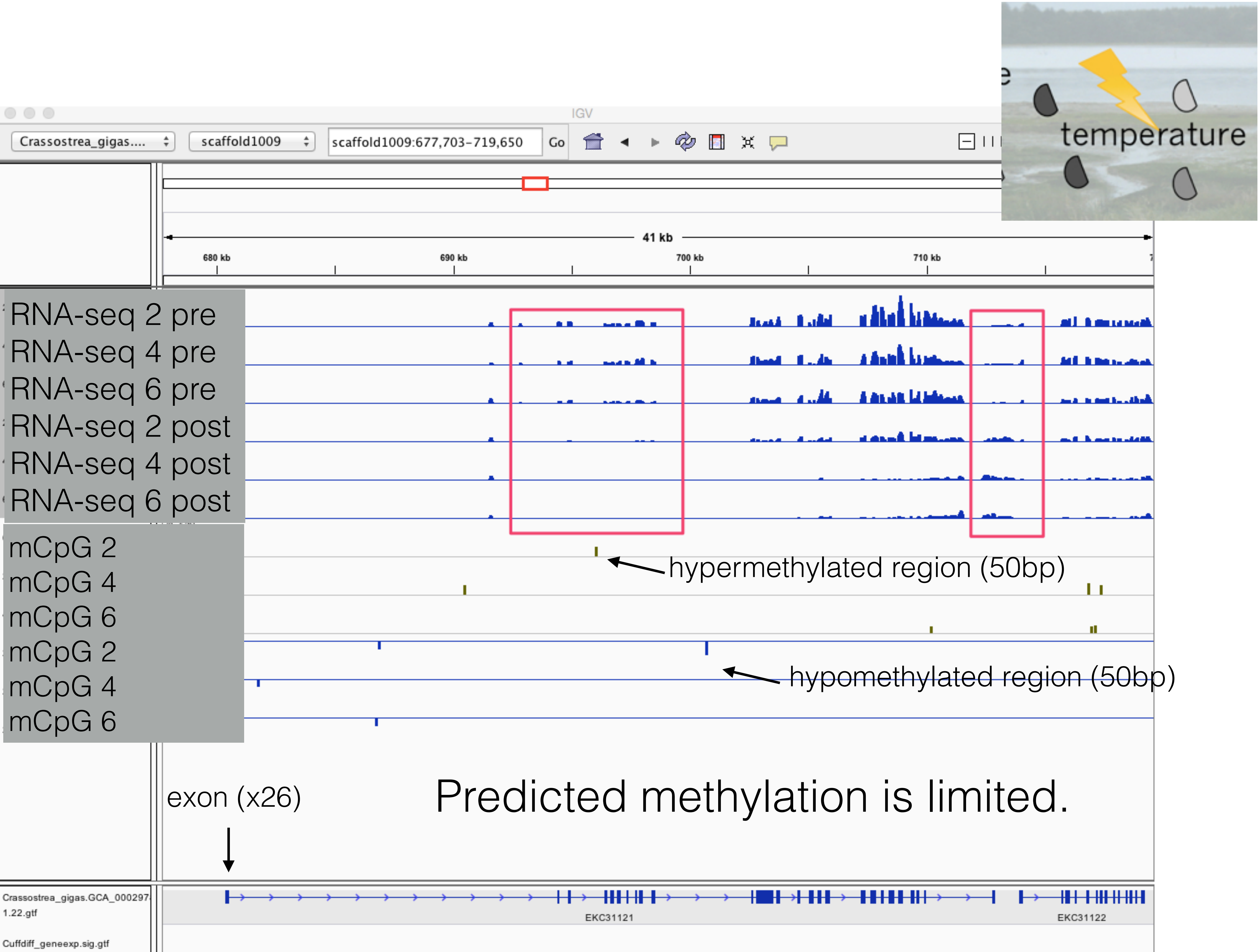
Environment and gene expression



stochastic or targeted
or ..?

Oyster	Hypo-methylated	Hyper-methylated
2	7224	2803
4	6560	3587
6	7645	4044

Changes in methylation
(either direction)
are more prevalent
in introns, repeats,
and
transposable elements.



temperature

RNA-seq 2 pre
RNA-seq 4 pre
RNA-seq 6 pre
RNA-seq 2 post
RNA-seq 4 post
RNA-seq 6 post

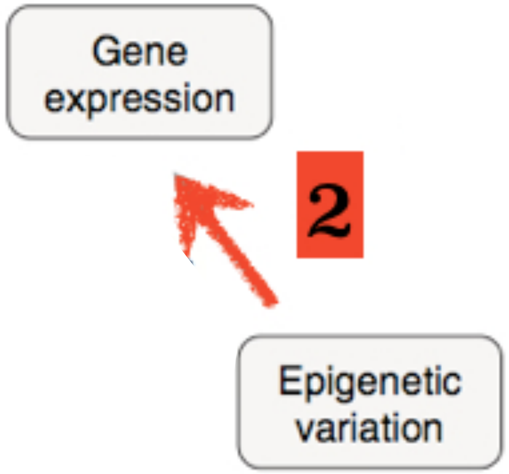
mCpG 2
mCpG 4
mCpG 6
mCpG 2
mCpG 4
mCpG 6

hypermethylated region (50bp)

hypomethylated region (50bp)

exon (x26)

Predicted methylation is limited.



more questions….
interesting but what is controlling?

Take Home

Oyster genome has a fantastic degree of diversity contributing to phenotypic plasticity & adaptation potential.

Take Home

Oyster genome has a fantastic degree of diversity contributing to phenotypic plasticity & adaptation potential.

- large gene families
- very high mutation rate (snp/50bp)
- numerous exons per gene (potential for alternatives)
- genome full of repeats region
- high number of transposable elements
- lack of methylation of transposable suggest mobility
- family variation of methylation
- limited methylation environmental response genes

is associated with spurious transcription

- inheritance of epigenetic marks as mechanism of improved adaptation

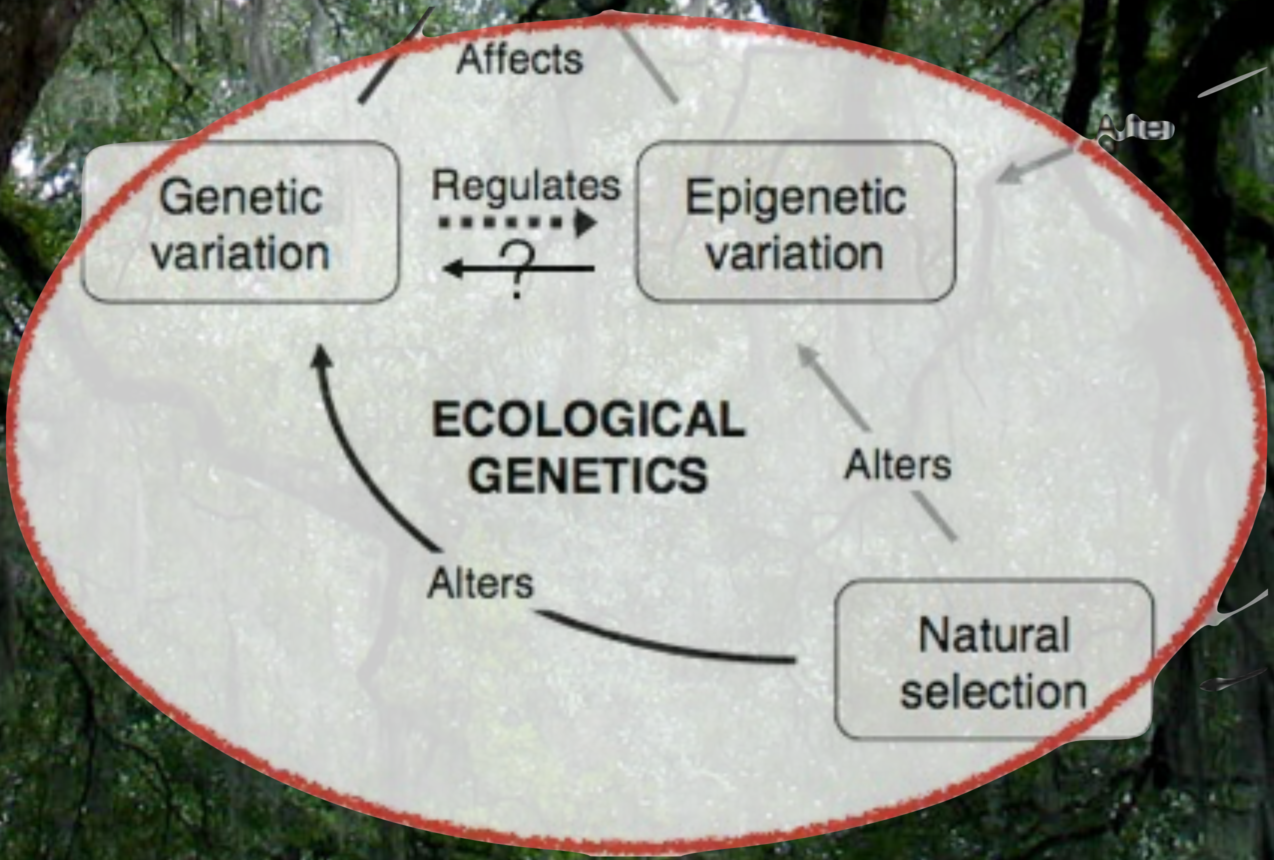
Next Steps

Transposable Elements

Consider other epigenetic process

Photo credit: Flickr, Creative Commons, csessums

Next Steps



Affects

Genetic variation

Regulates

?

Epigenetic variation

ECOLOGICAL GENETICS

Alters

Alters

Natural selection

Photo credit: Flickr, Creative Commons, csessums

Very new ~~data~~

Heritability

Plasticity

Local Adaptation

Genetics

versus

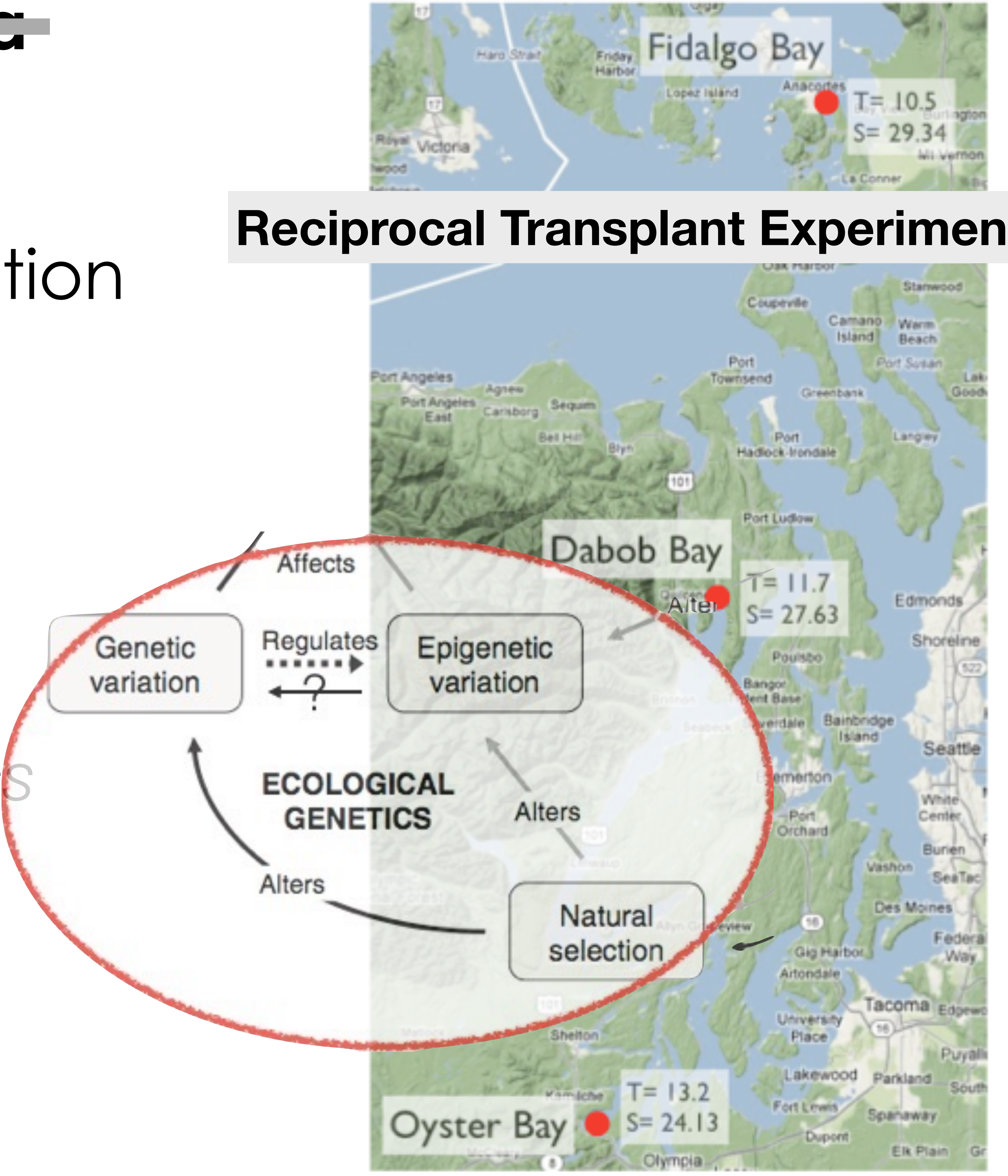
Epigenetics

Reciprocal Transplant Experiment

Very new ~~data~~

Heritability
Plasticity
Local Adaptation

Reciprocal Transplant Experiment



Genetics
versus
Epigenetics

Acknowledgements

Mackenzie Gavery
Claire Olson
Sam White
Brent Vadopalas
Jake Heare
Jay Dimond

NSF
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

Bill Howe
Dan Halperin

eScience Institute
USDA

slides, data & more @
github.com/sr320/talk-CICESE-2015