

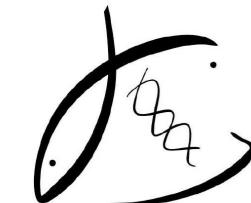
Environmental influences on DNA methylation patterns in oysters and the relationship with phenotypic variation

Steven Roberts
Kenneth K. Chew Endowed Professor
University of Washington
School of Aquatic and Fishery Sciences

December 5, 2016 - University of Chicago



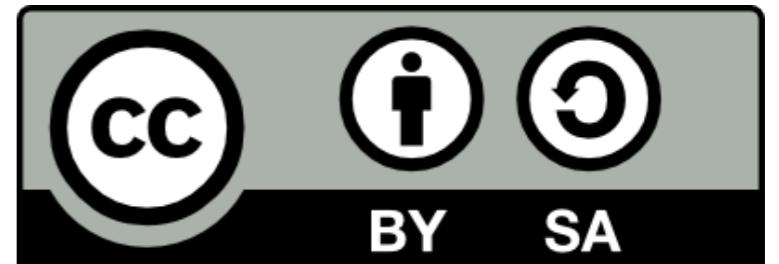
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robertslab.info | @sr320

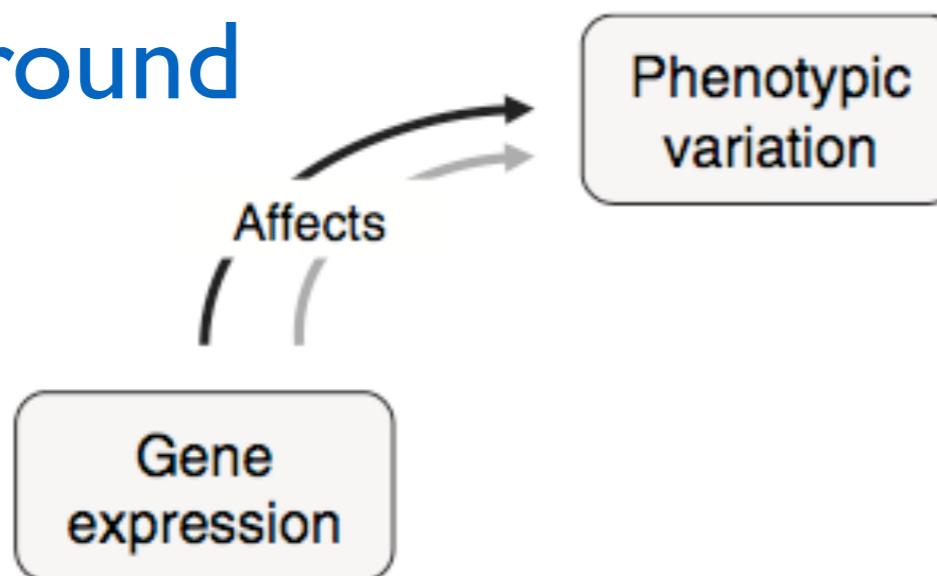
Open Science

- You are free to Share!
- Our lab practices open notebook science
- Data, Preprints, Proposals, Lab Meetings, Web Cams, Slidedecks



These slides plus links @
github.com/sr320/talk-Chicago-eed-2016

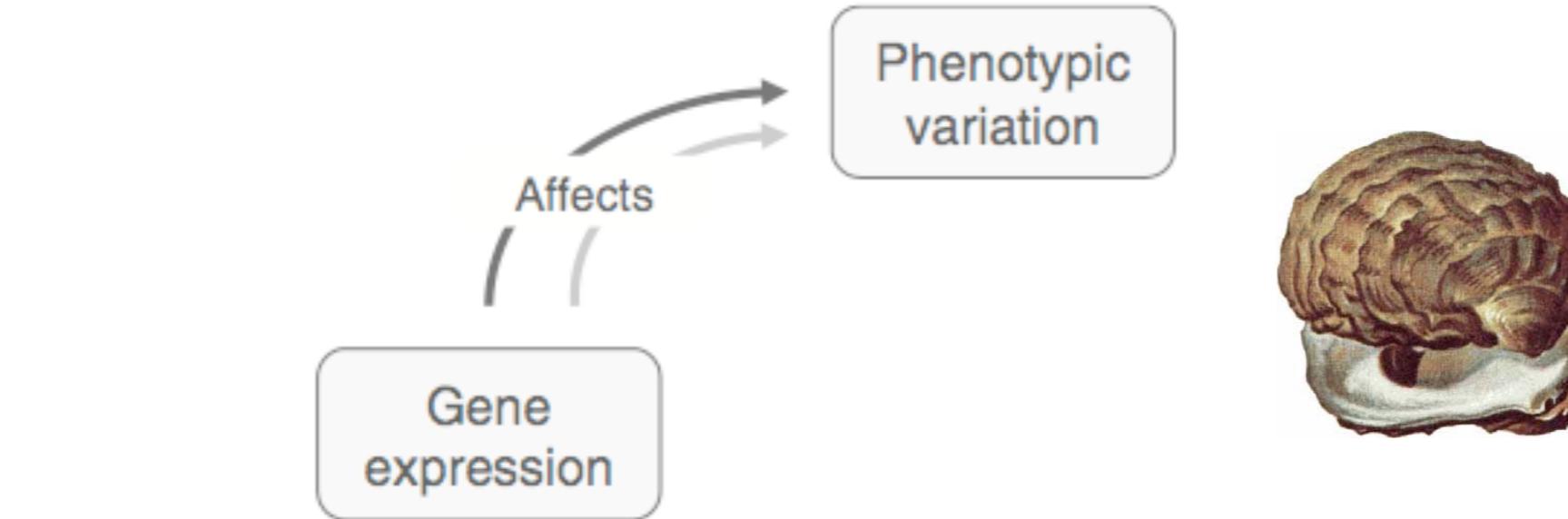
My Background



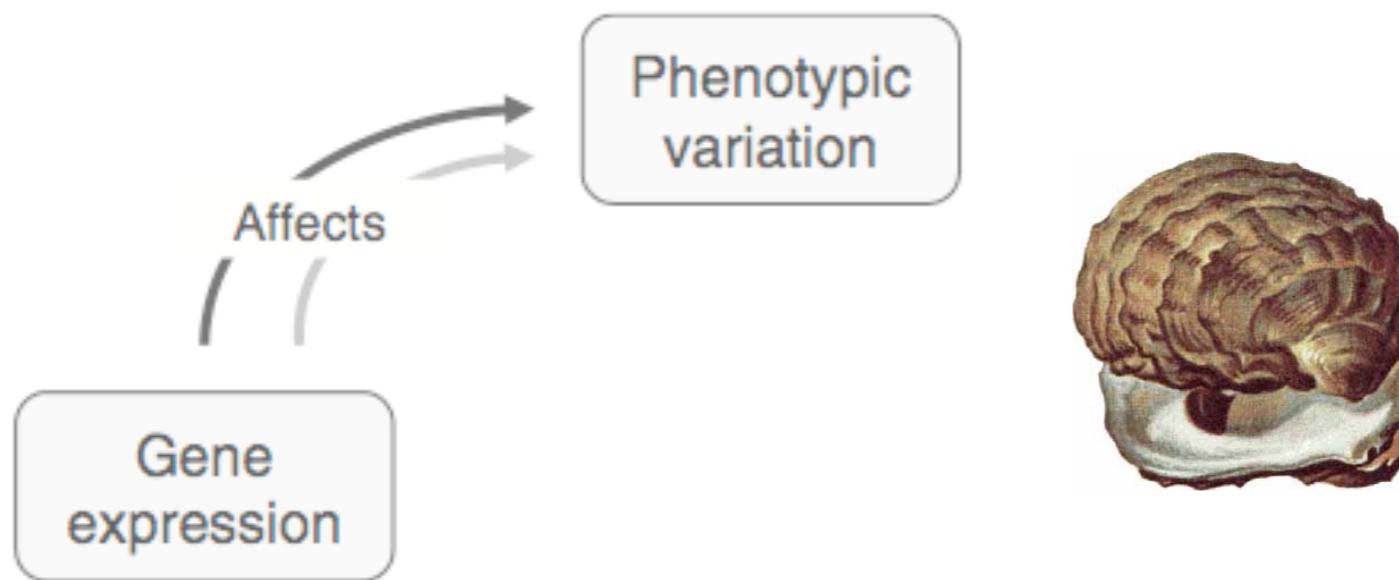
"relevant traits"



Conceptual Models for a functional role of DNA methylation



Conceptual Models for a functional role of DNA methylation

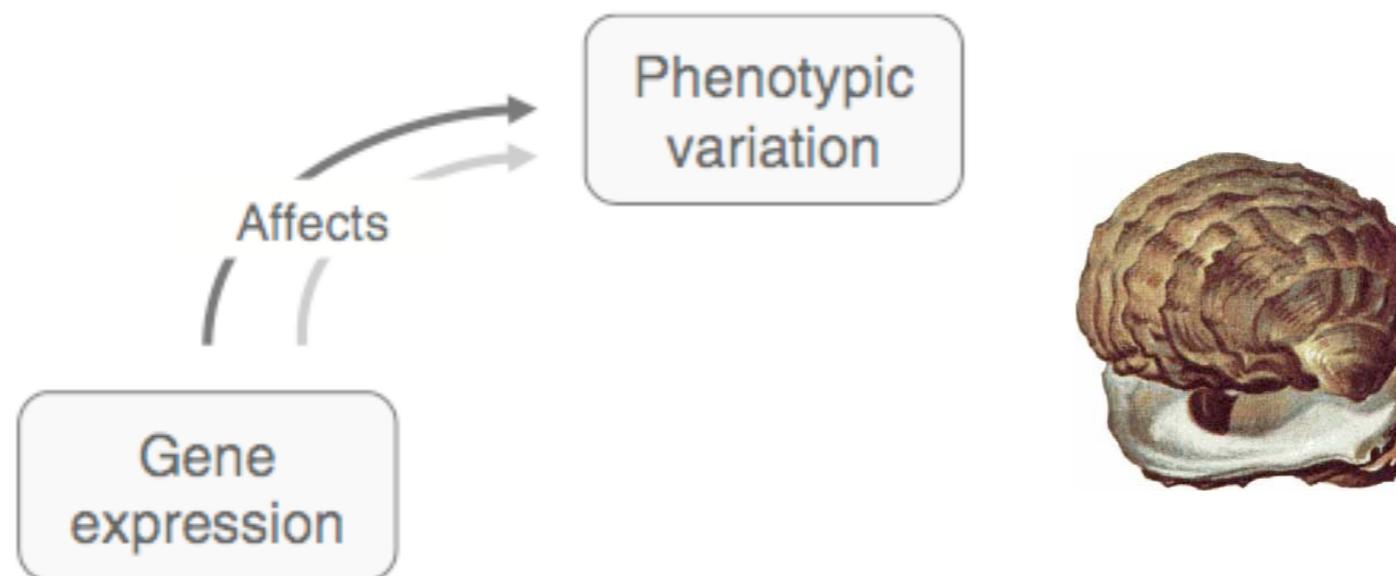


Stochastic Variation

increased transcriptional opportunities
increased likelihood of suitable phenotype

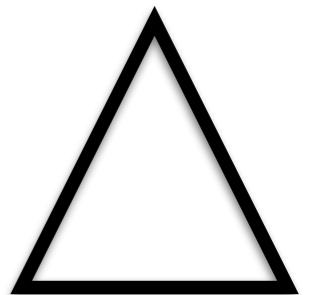


Conceptual Models for a functional role of DNA methylation

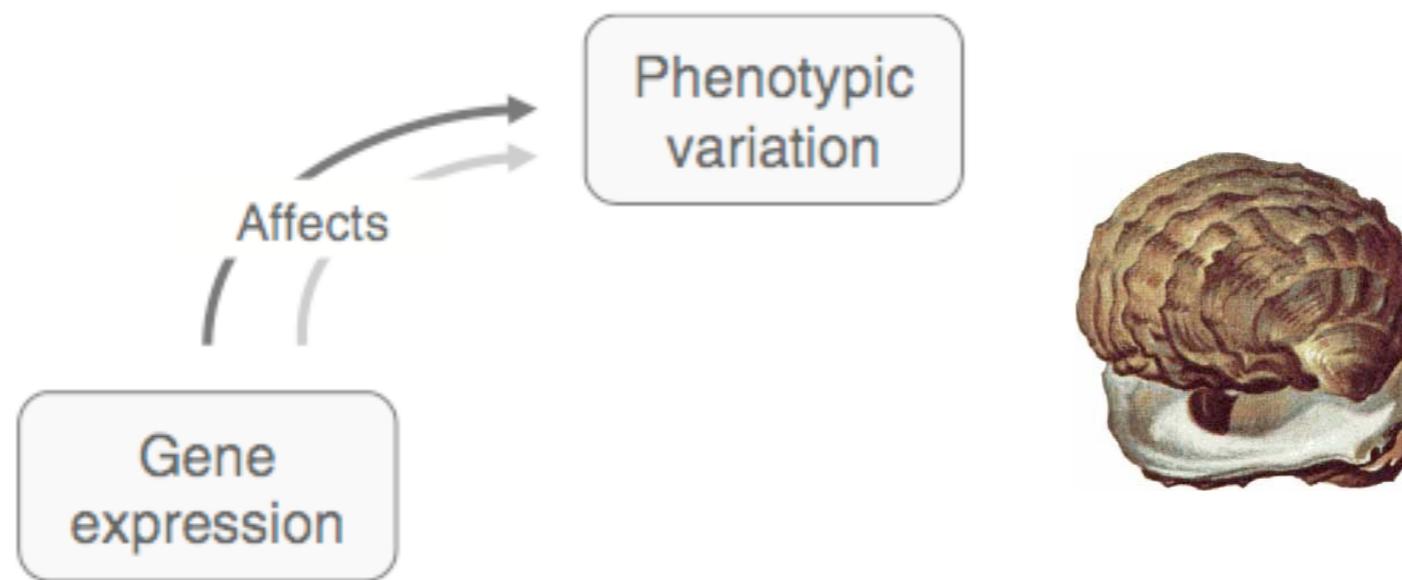


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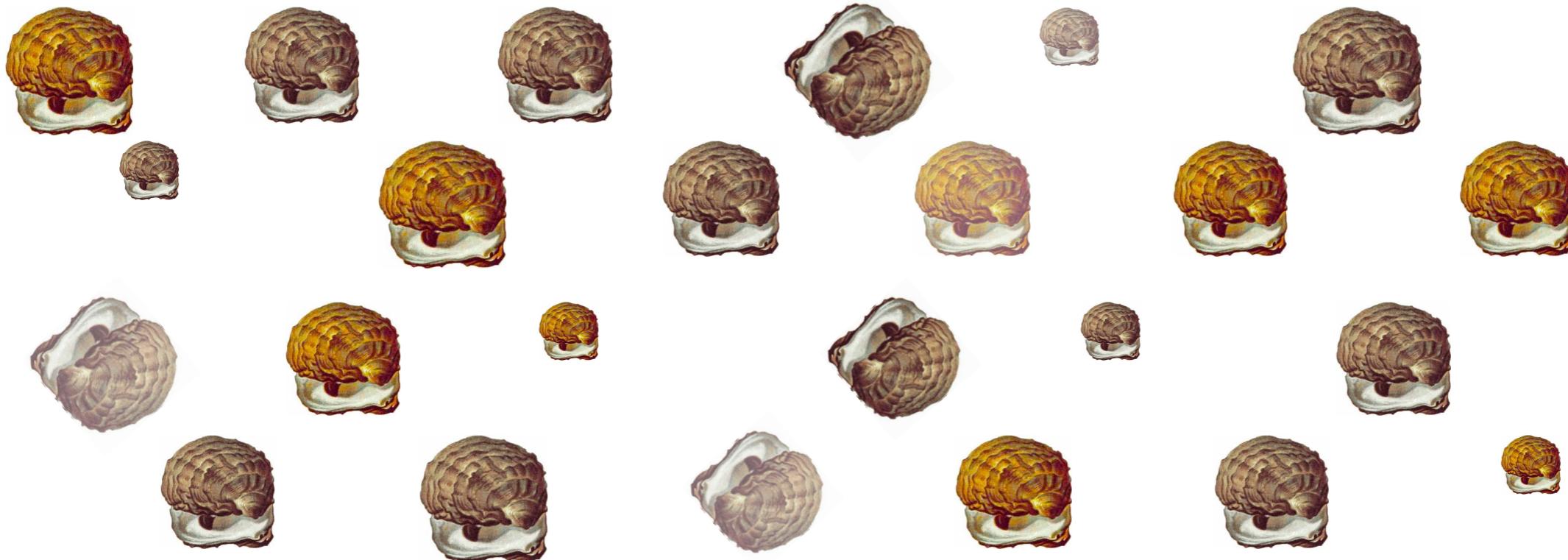


Conceptual Models for a functional role of DNA methylation

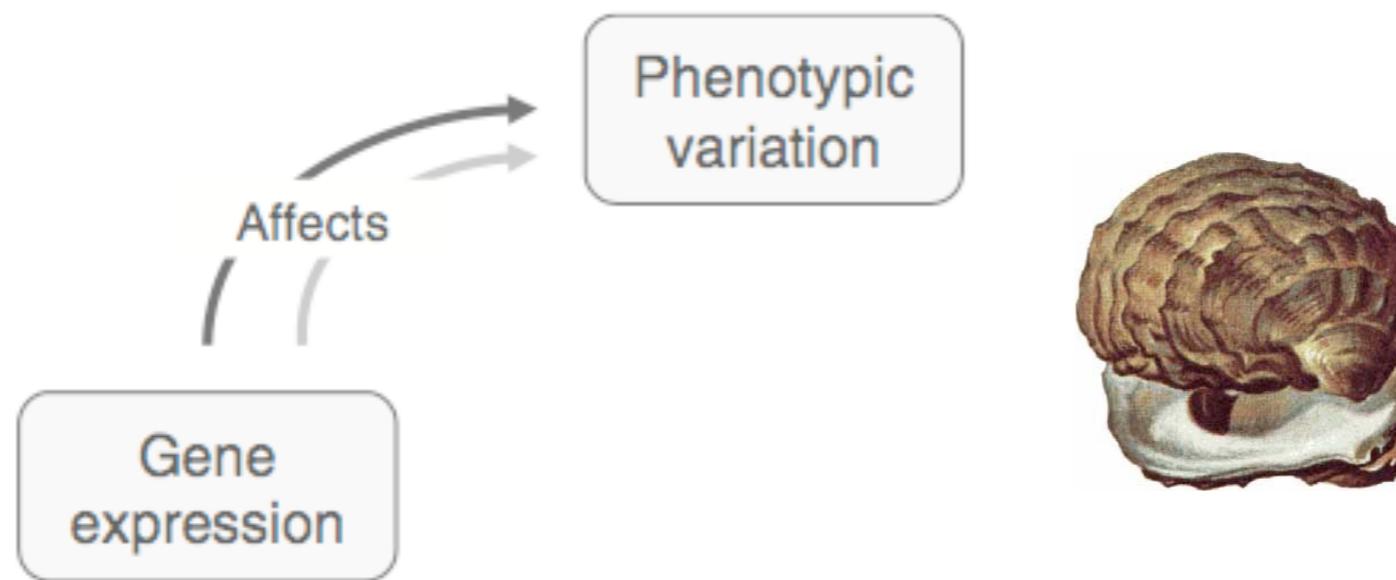


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Conceptual Models for a functional role of DNA methylation



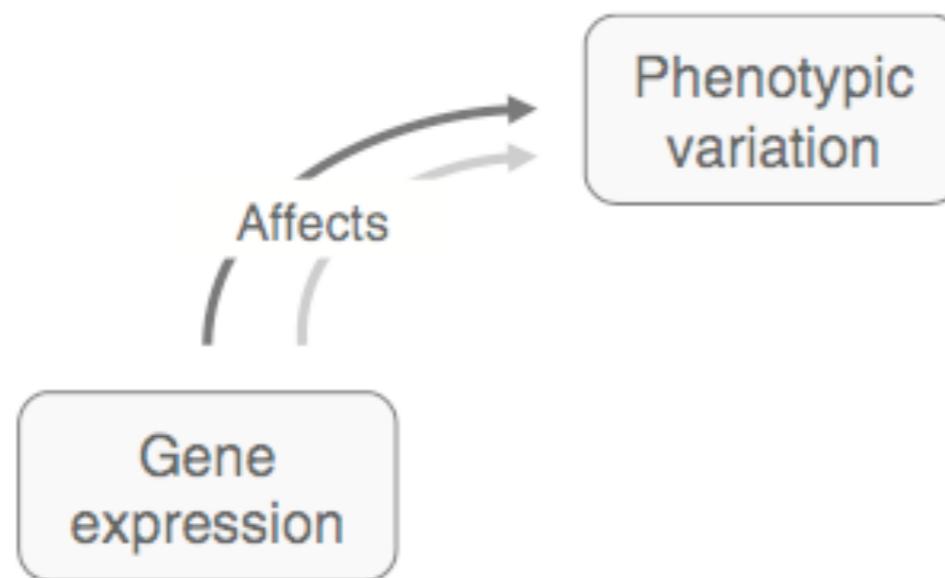
Stochastic Variation

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Conceptual Models for a functional role of DNA methylation



Stochastic Variation

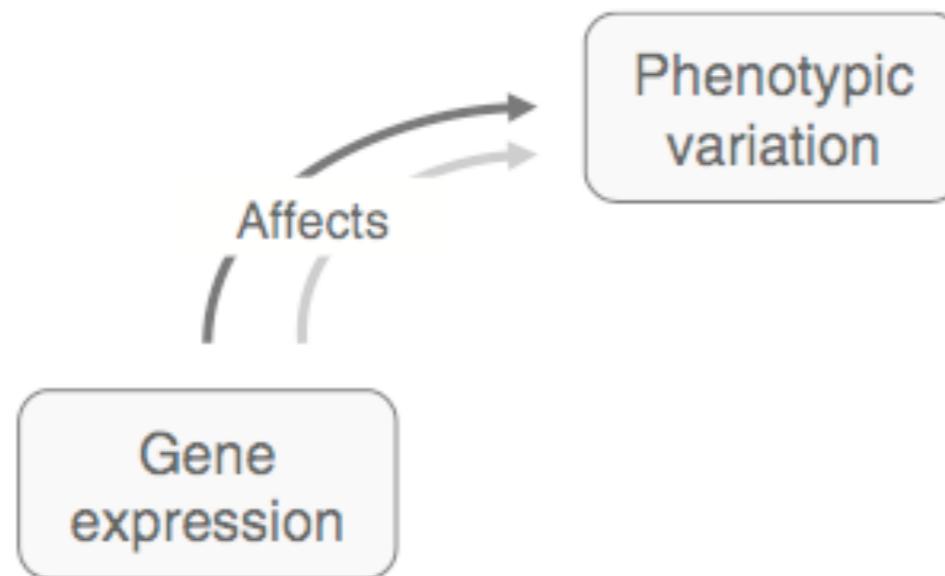
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Conceptual Models for a functional role of DNA methylation



Stochastic Variation

increased transcriptional opportunities

increased likelihood of suitable phenotype

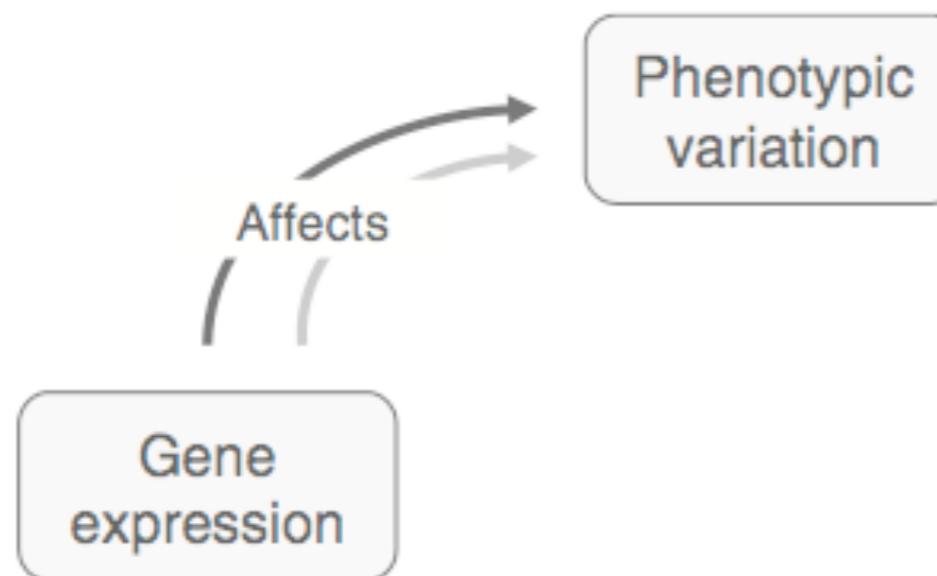


Biological Scale?
Organism
Cell
Tissue

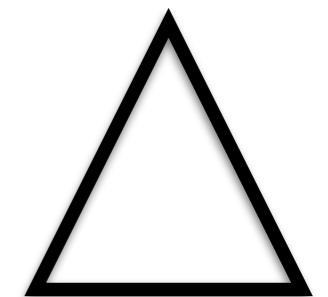


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Conceptual Models for a functional role of DNA methylation

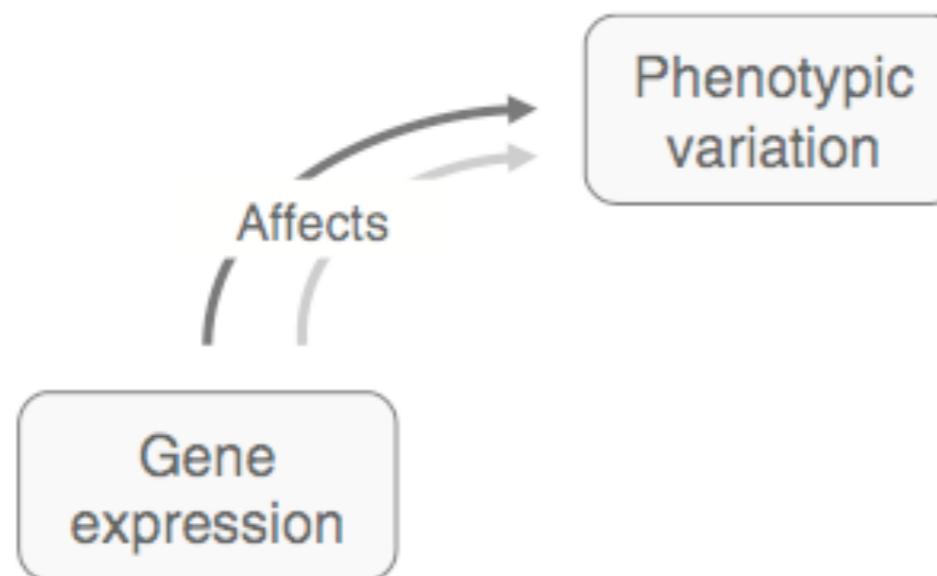


Target Regulation
results in beneficial phenotype



*

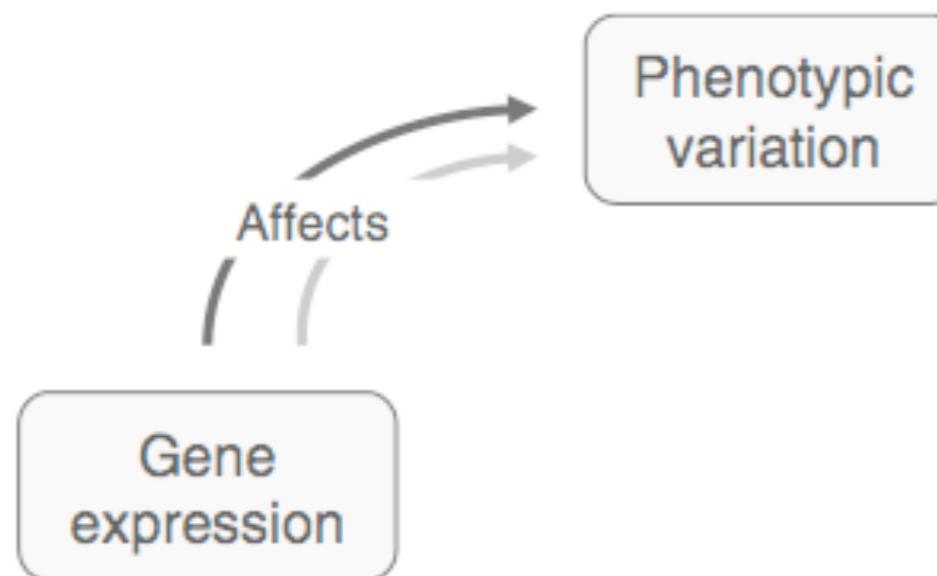
Conceptual Models for a functional role of DNA methylation



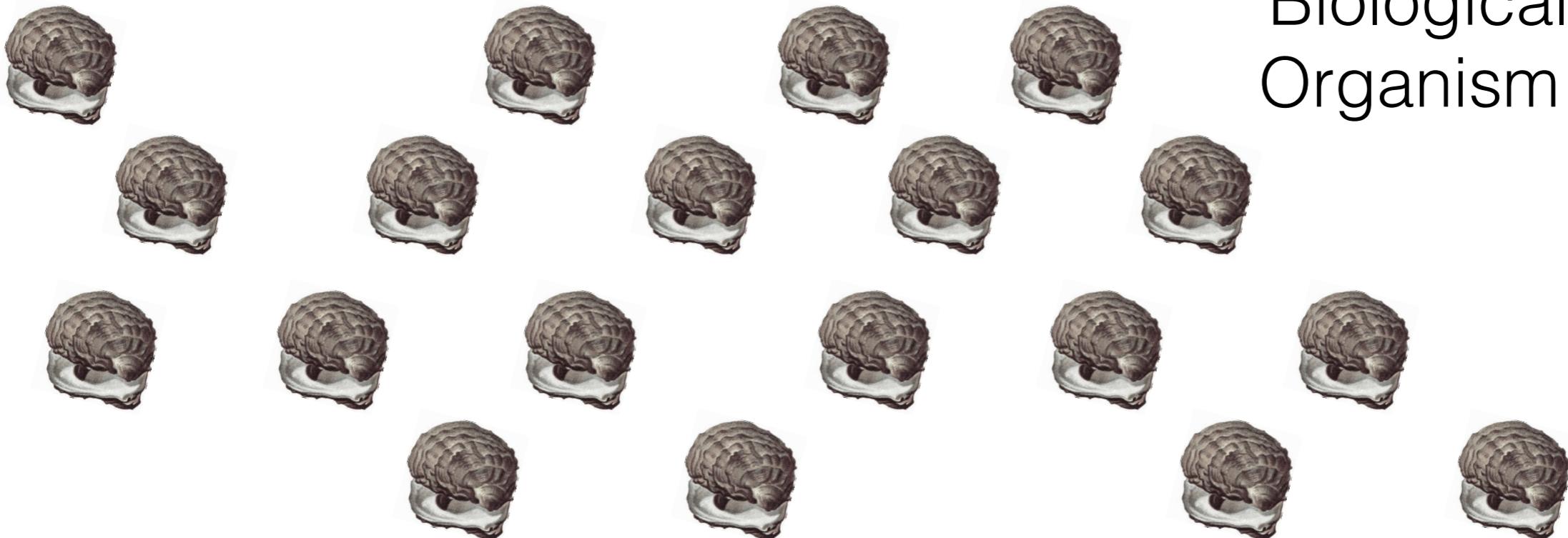
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Conceptual Models for a functional role of DNA methylation



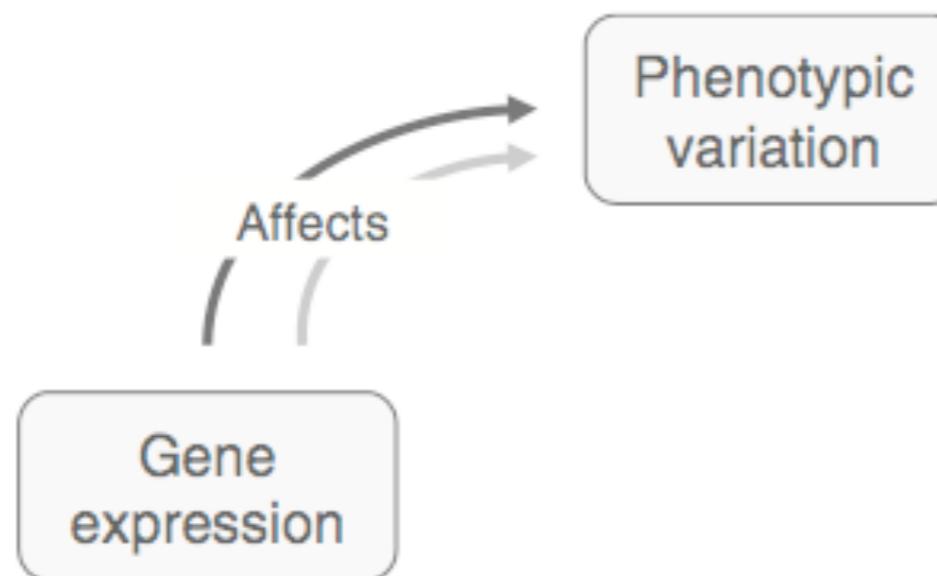
Target Regulation
results in beneficial phenotype



Biological Scale?
Organism

*

Conceptual Models for a functional role of DNA methylation

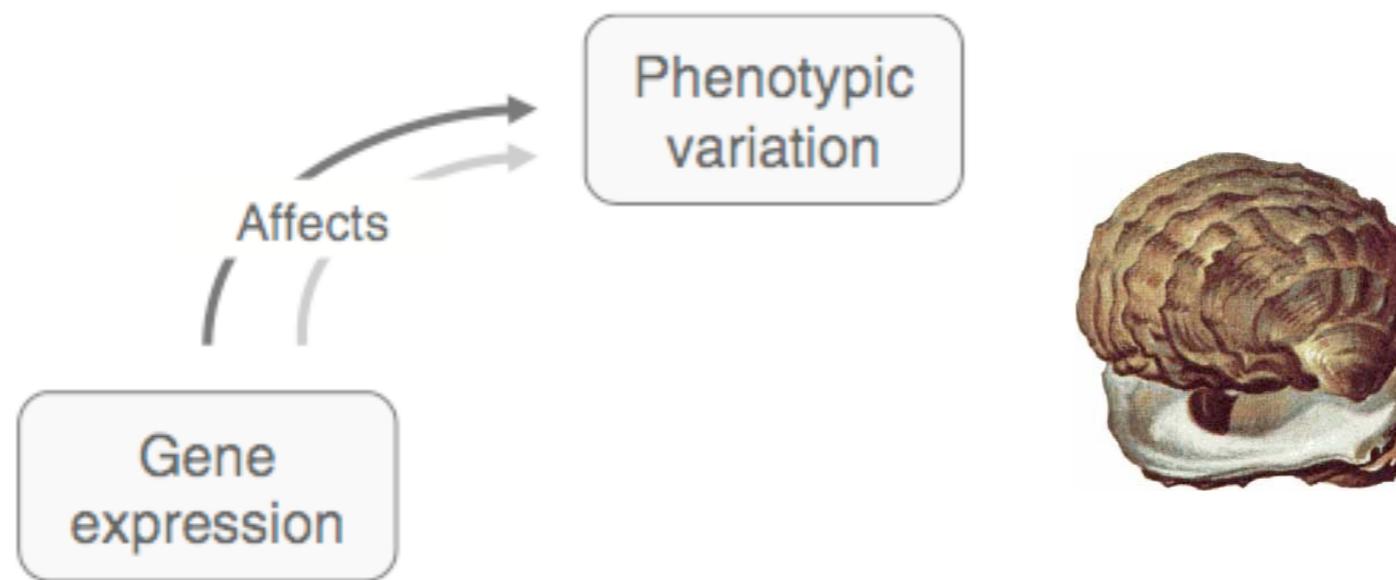


Mystery - Natural Epigenetic Variation Exists



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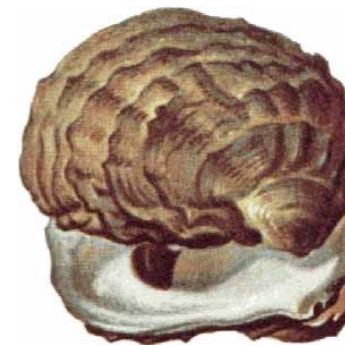
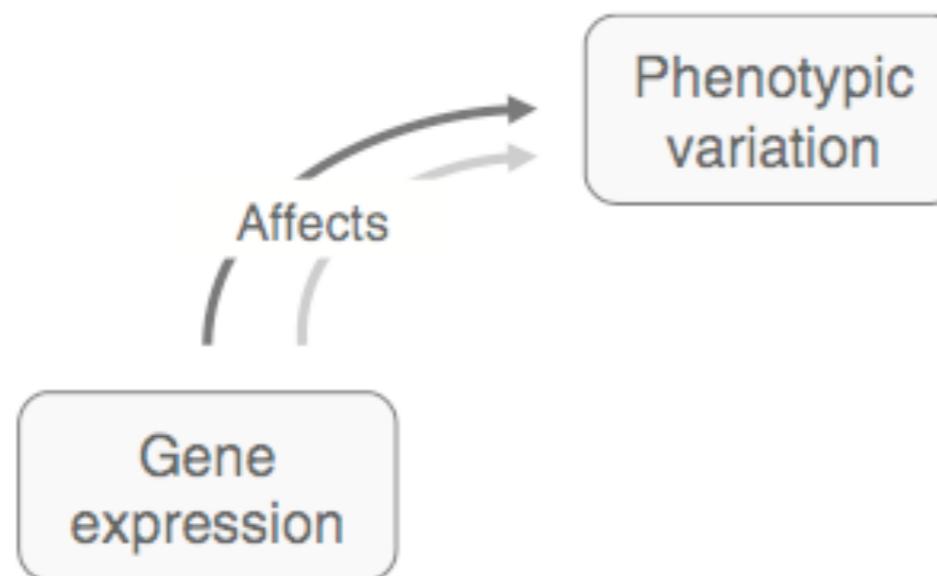
Conceptual Models for a functional role of DNA methylation



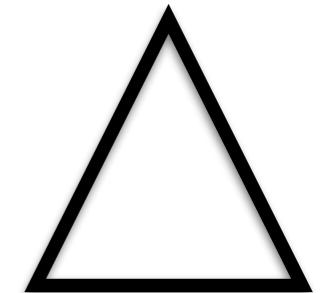
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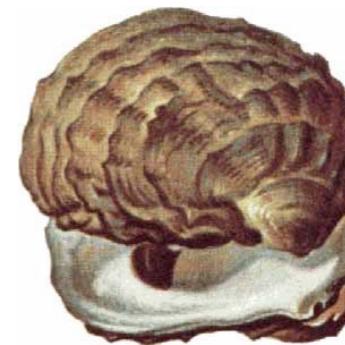
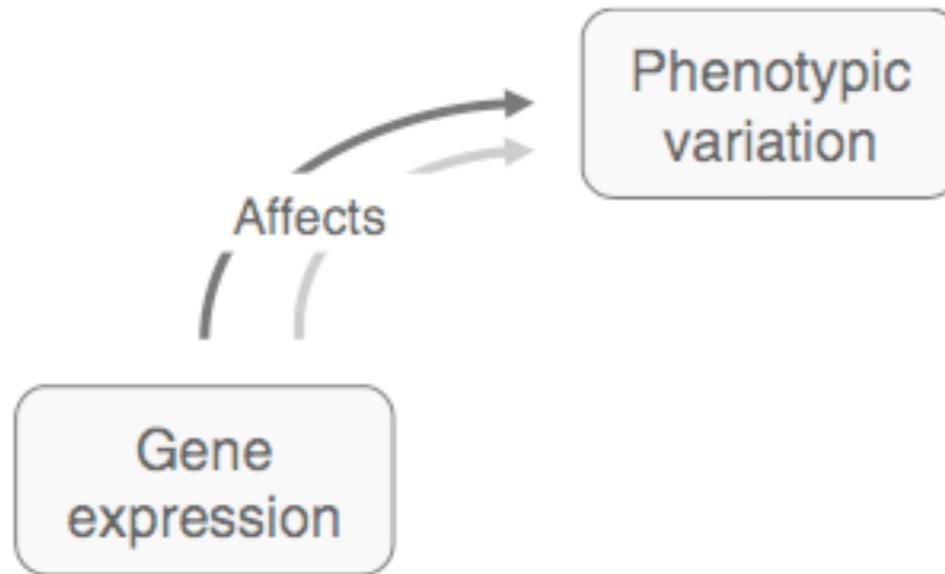
Conceptual Models for a functional role of DNA methylation



Mystery - Natural Epigenetic Variation Exist
that is subject selection



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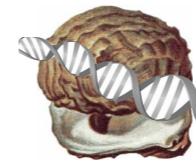


Conceptual Models for a functional role of DNA methylation

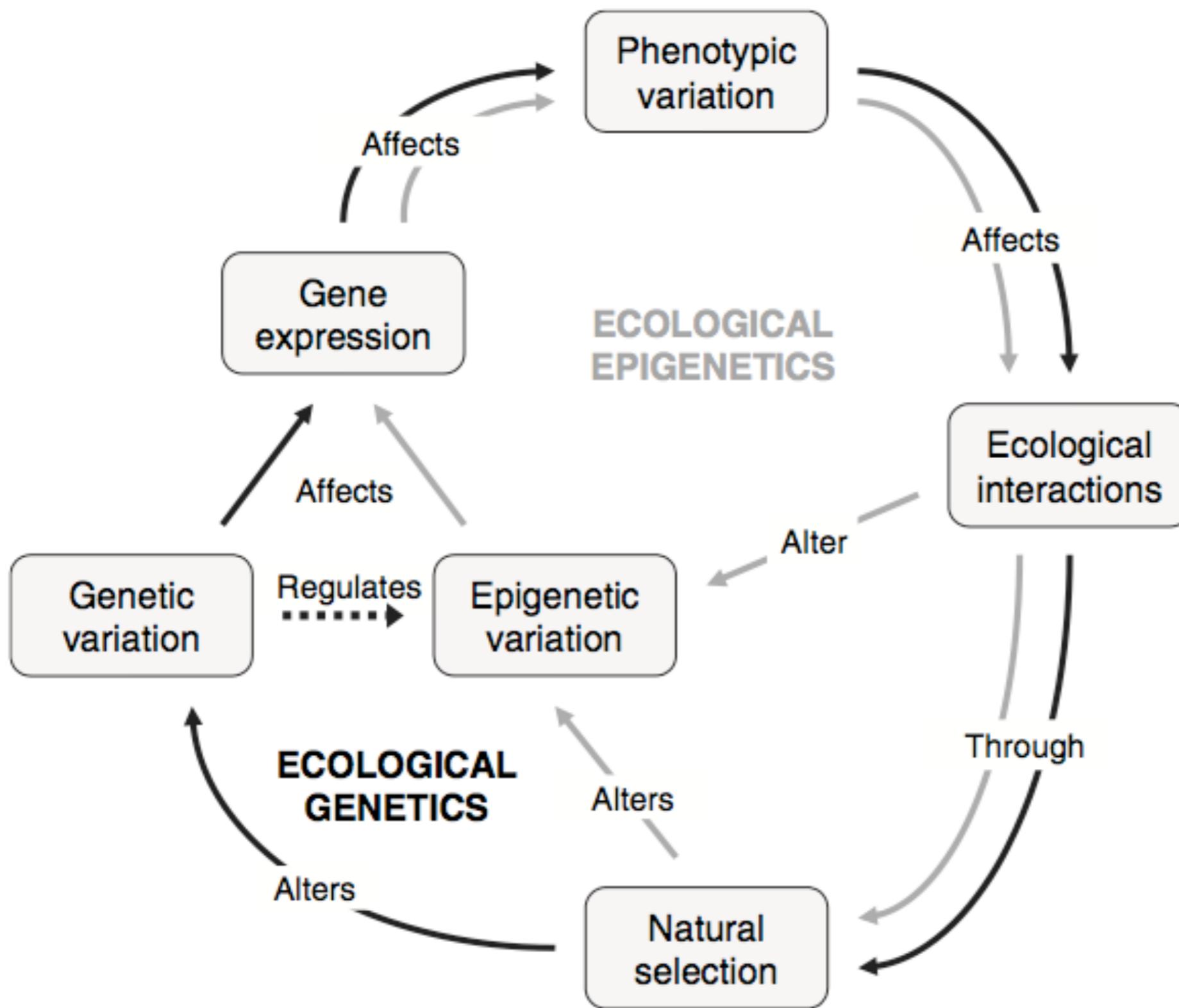
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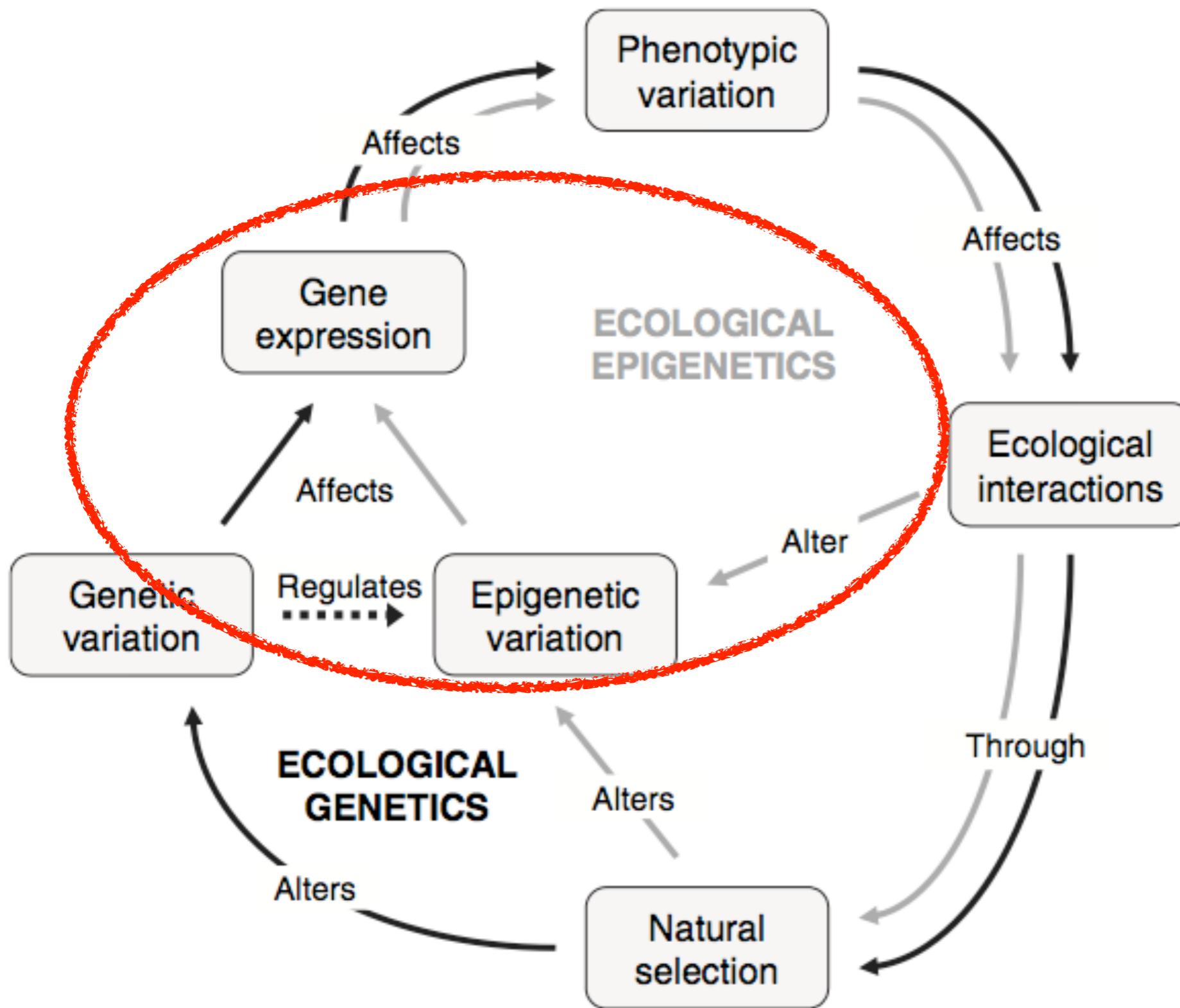


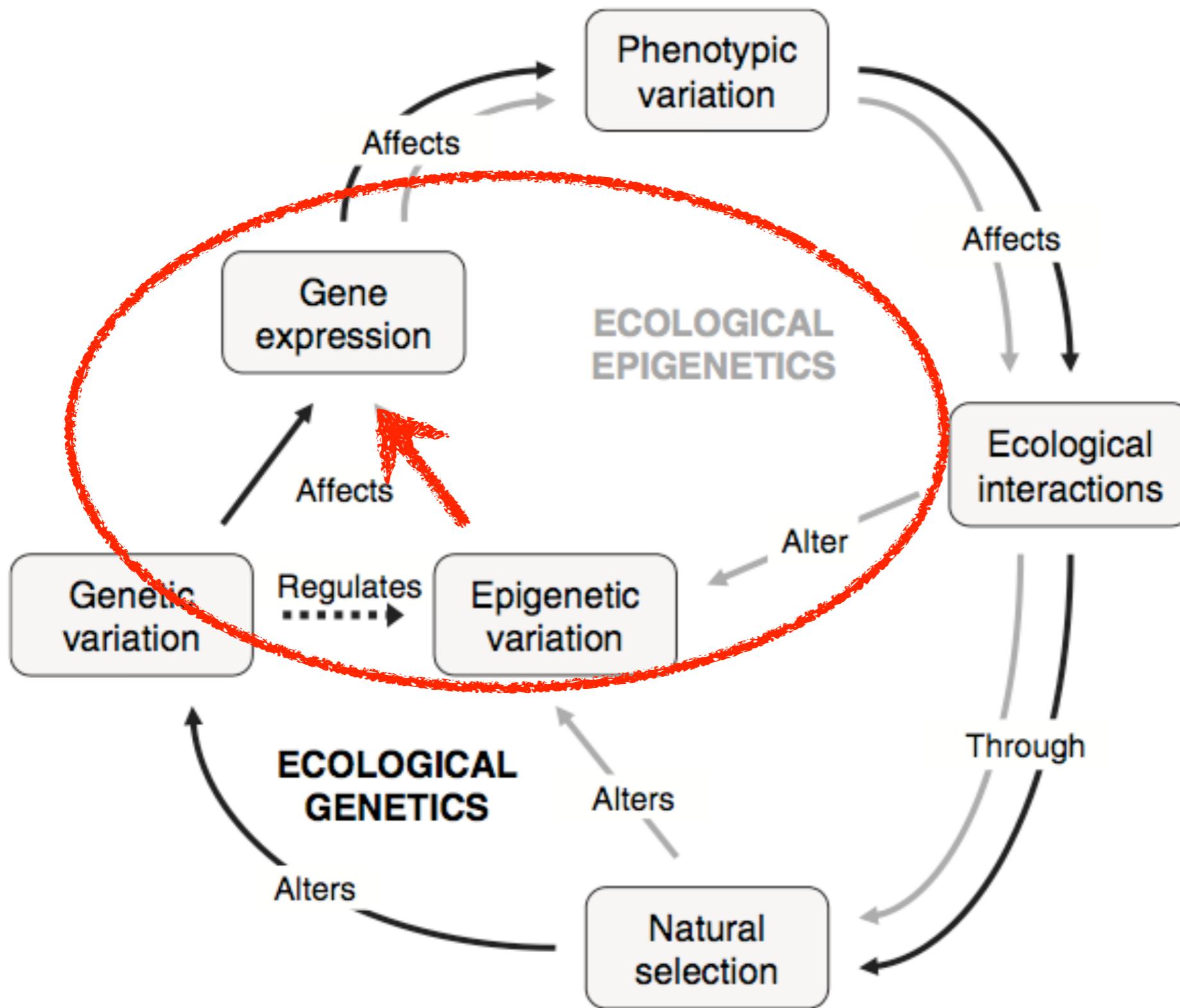
Biological Scale?
Population



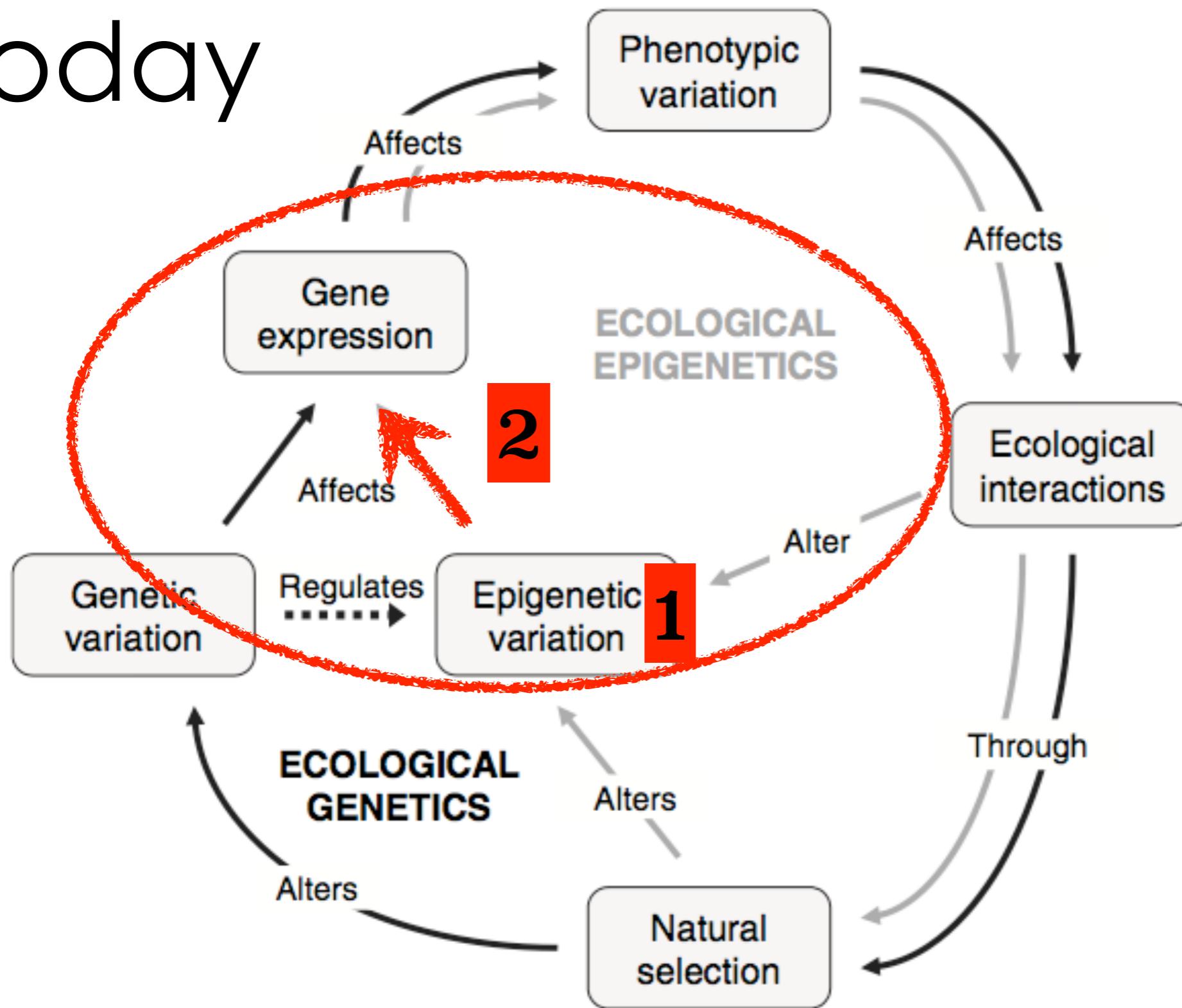
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Today



Ecology Letters, (2008) 11: 106–115

doi: 10.1111/j.1461-0248.2007.01130.x

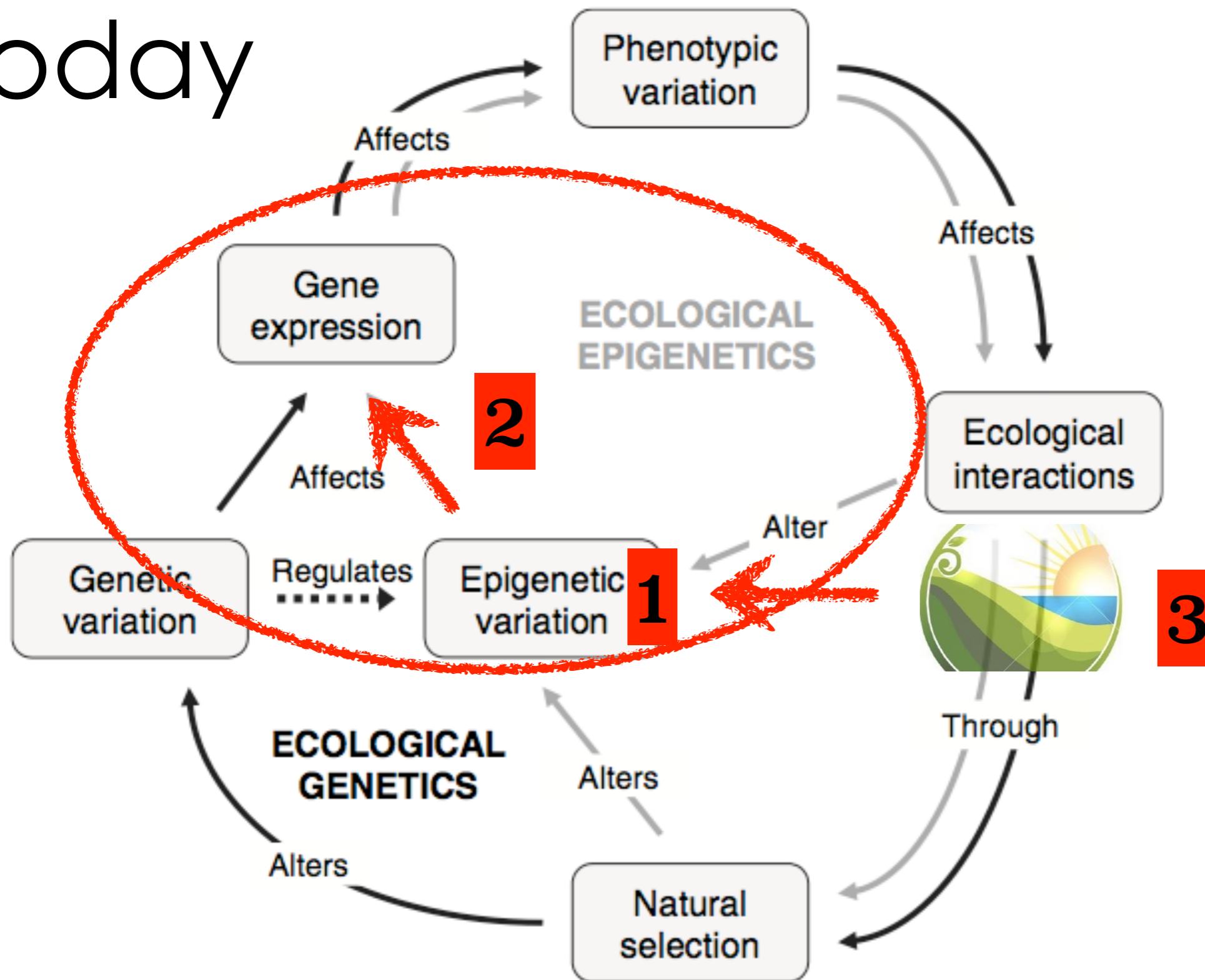
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IDEA AND
PERSPECTIVE

Epigenetics for ecologists

Oliver Bossdorf,^{1,*} Christina L.
Richards² and Massimo Pigliucci³

Today



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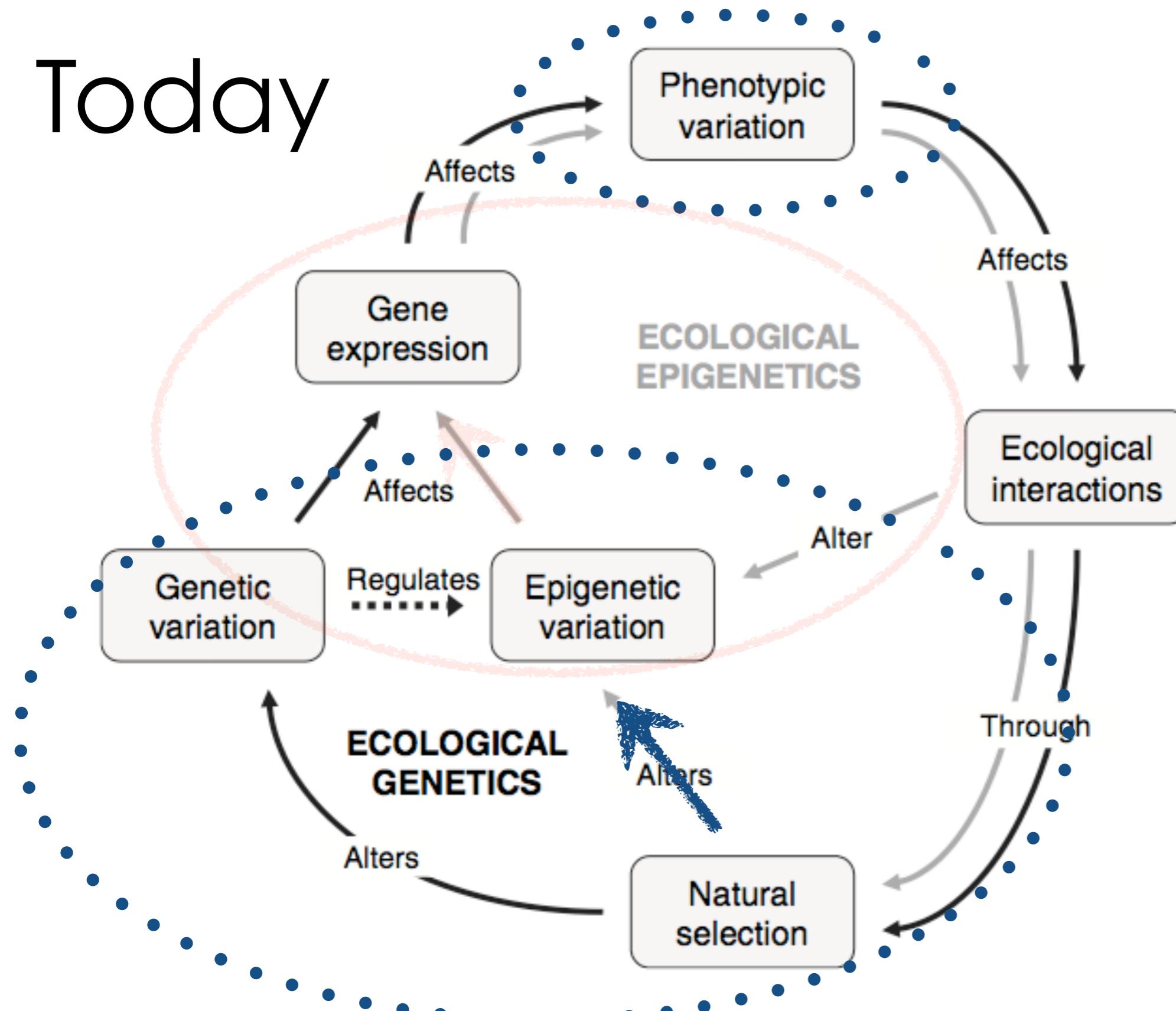
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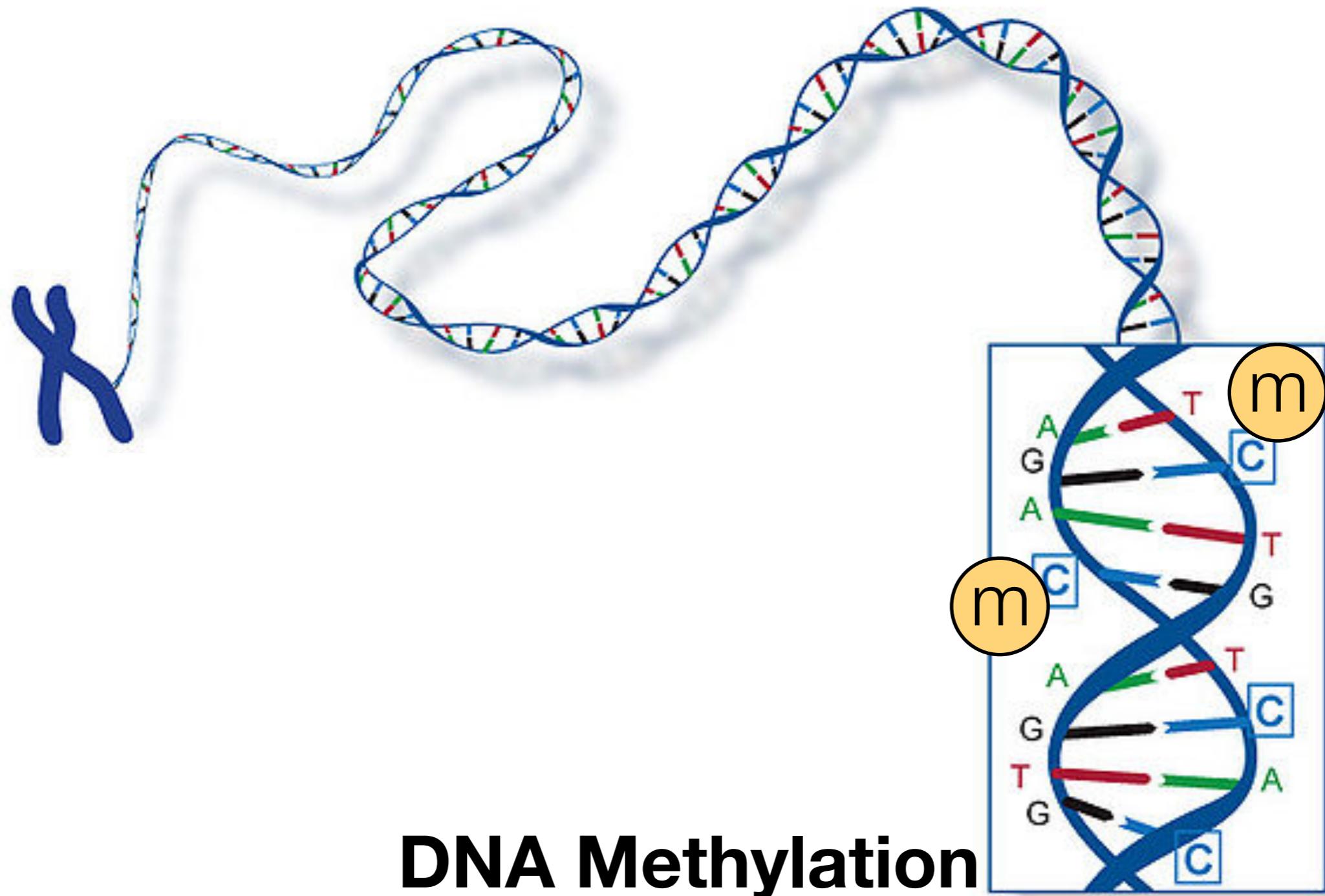
Genome Resources



Genome Resources

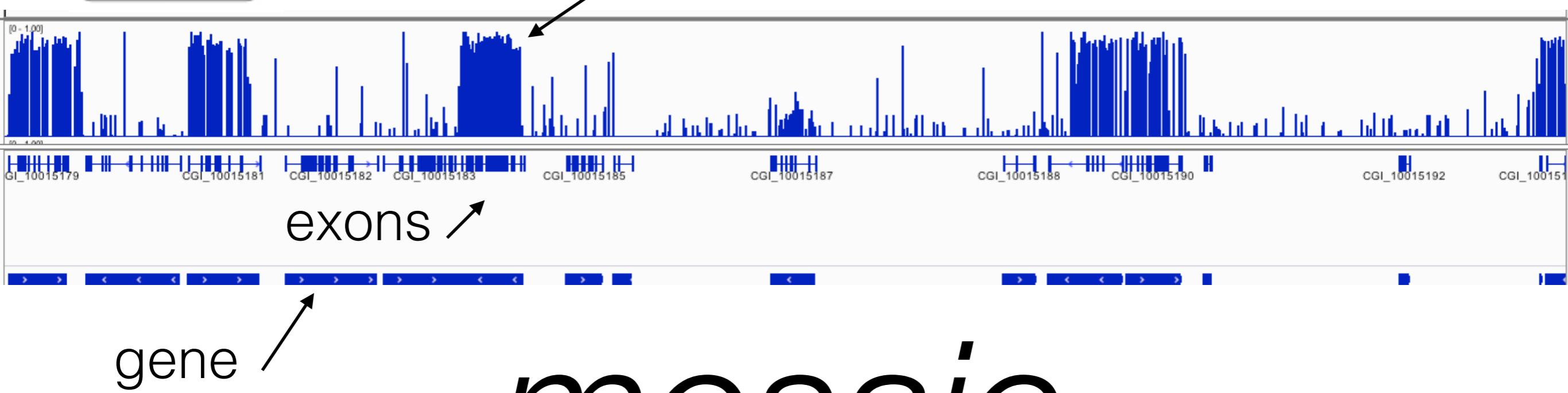






Epigenetic variation **1**

DNA methylation level (0-100%) @ cytosines



exons
gene

mosaic

associated with gene bodies

Epigenetic variation **1**

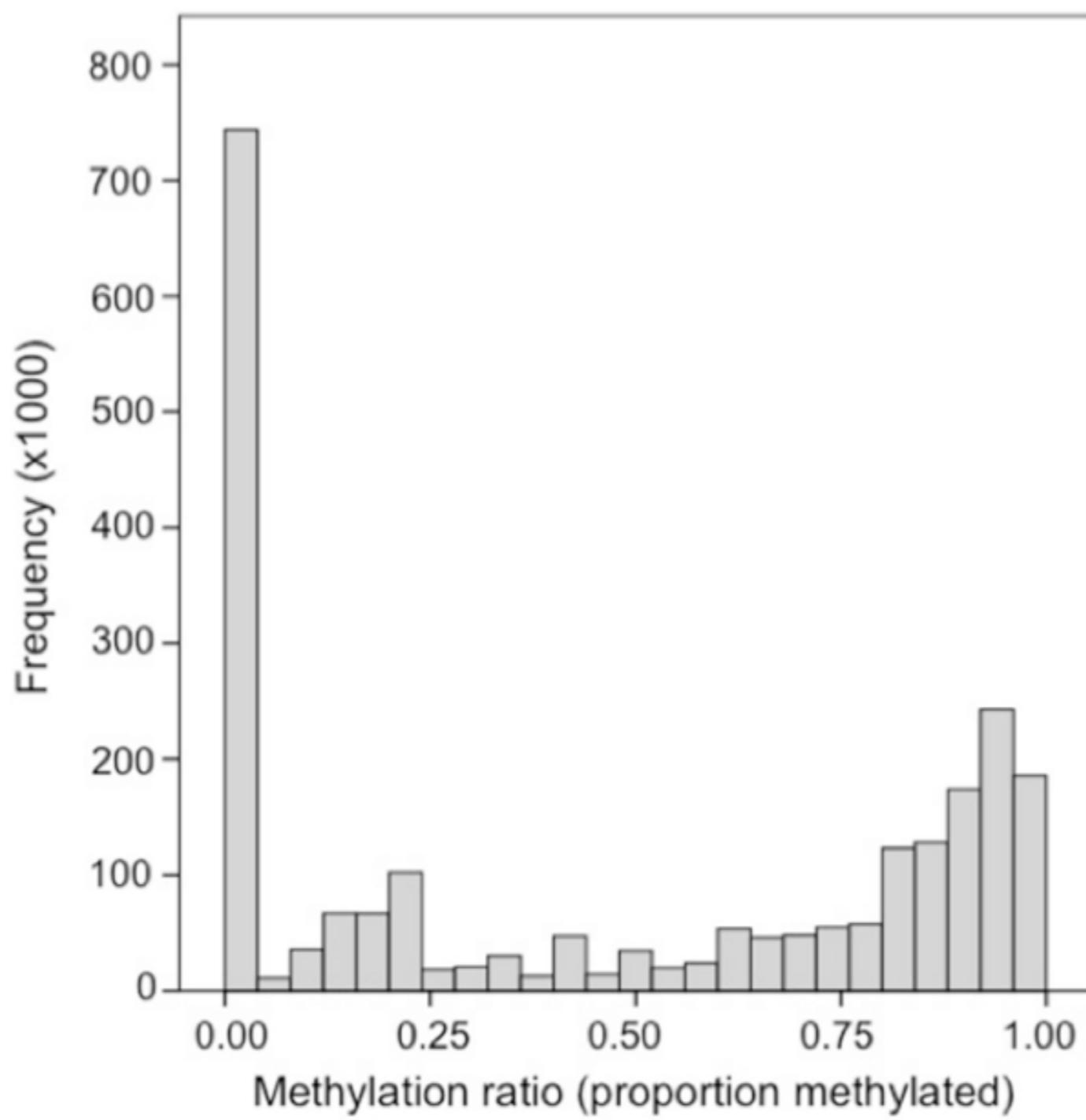


Figure 1 Frequency distribution of methylation ratios for CpG dinucleotides in oyster gill tissue. A total of 2,625,745 CpG dinucleotides with $\geq 5 \times$ coverage are represented.

Epigenetic variation **1**

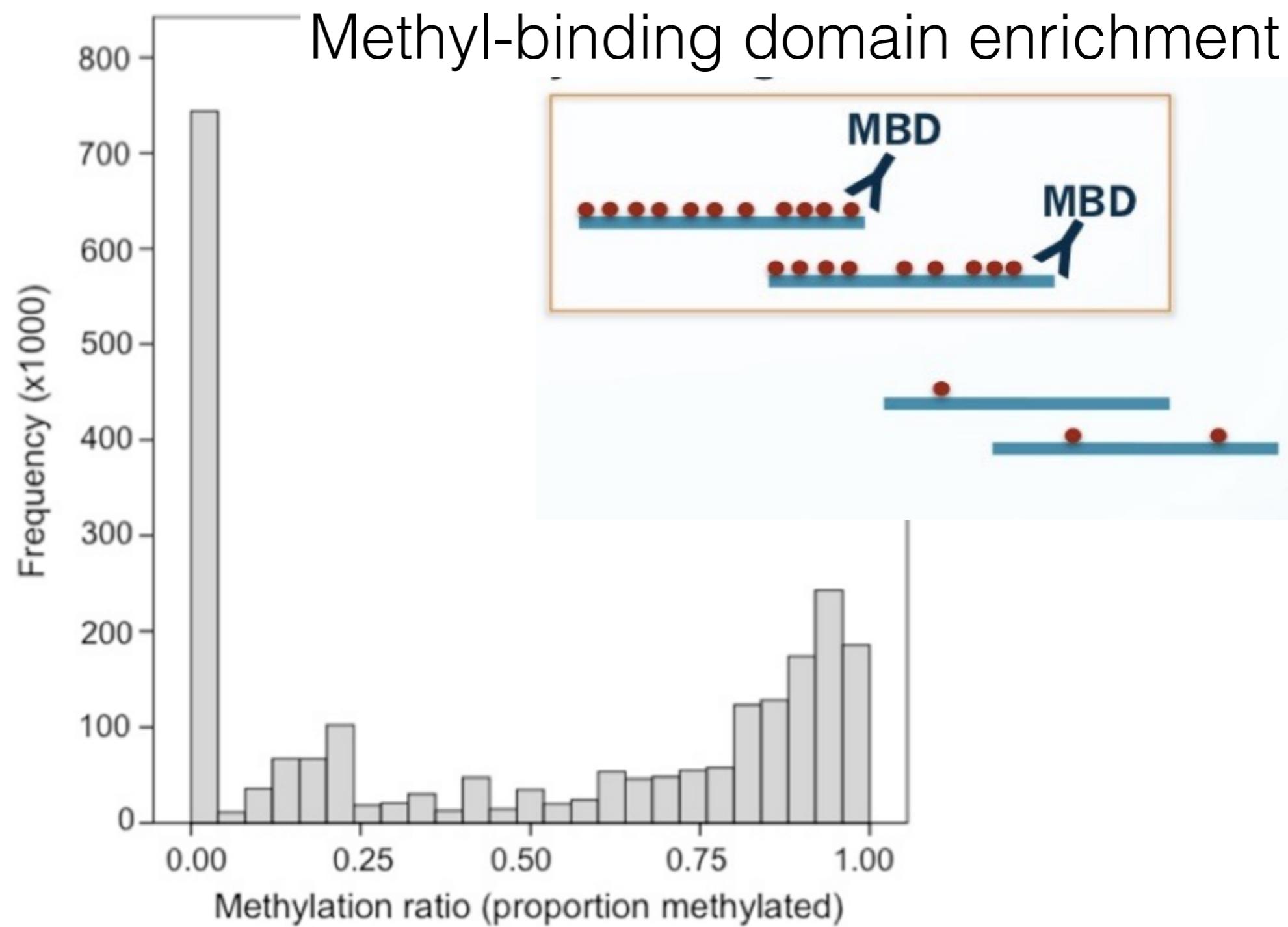
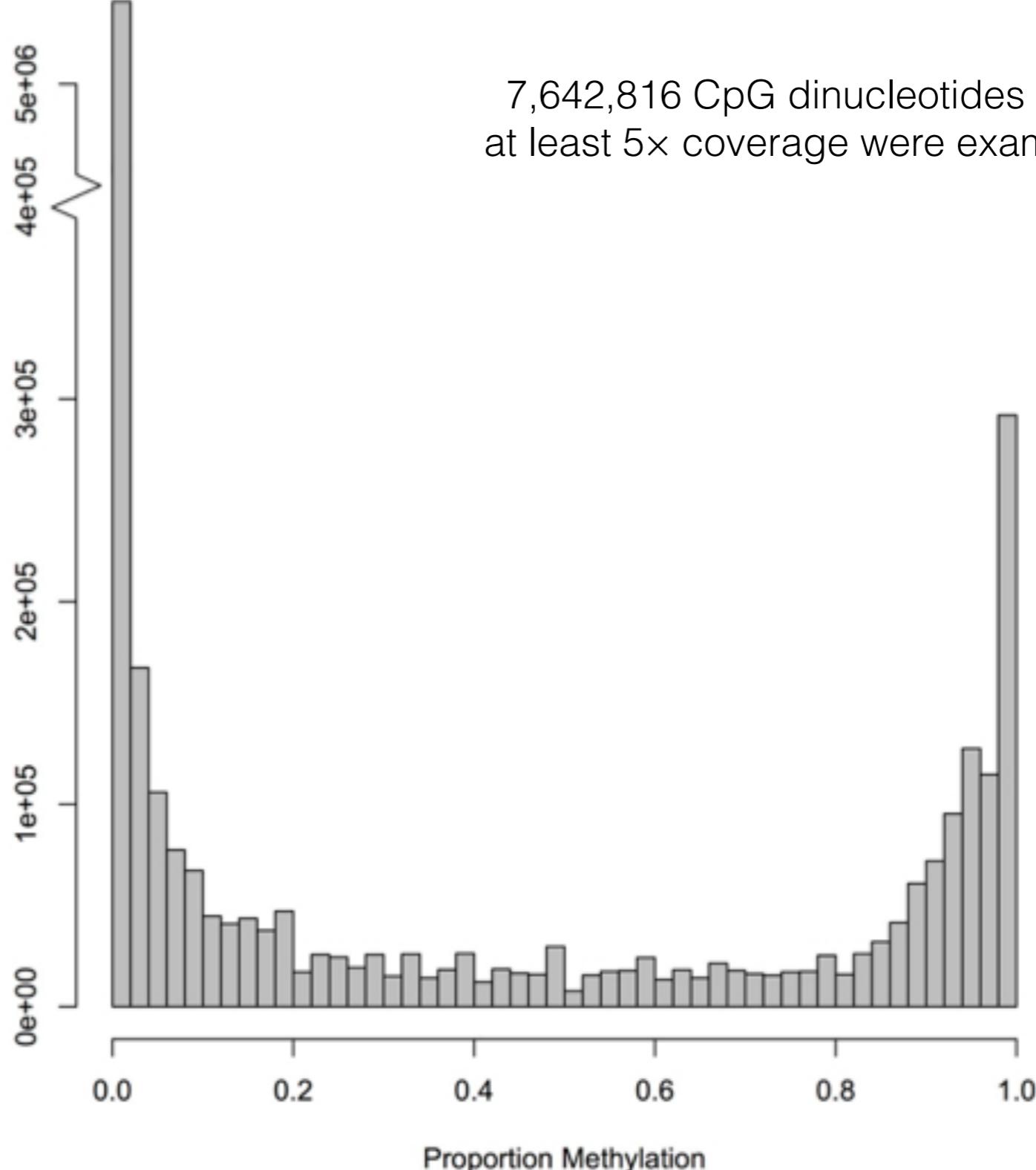
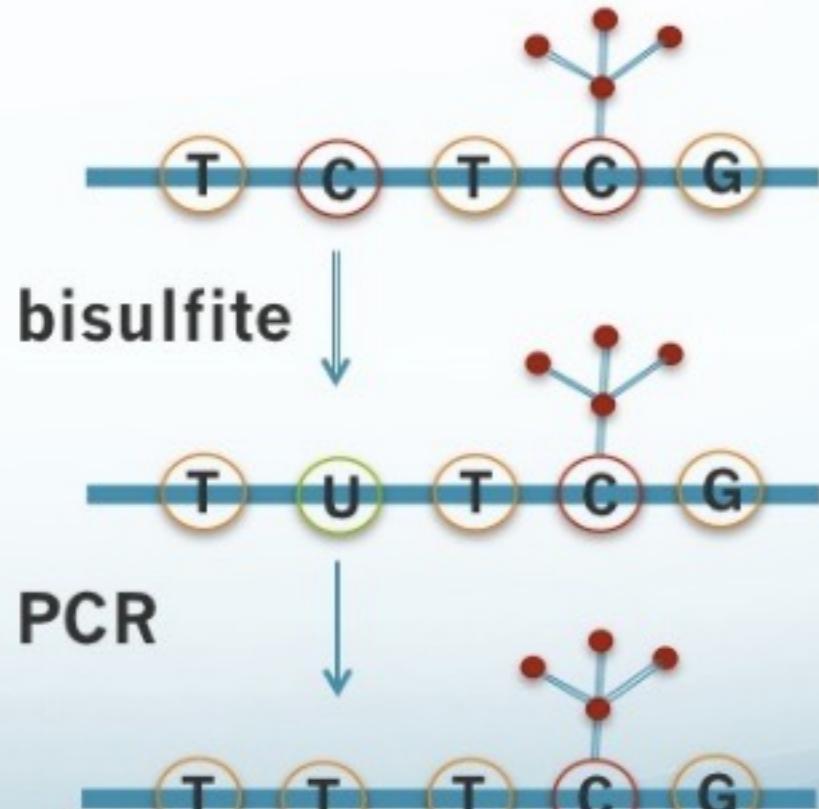


Figure 1 Frequency distribution of methylation ratios for CpG dinucleotides in oyster gill tissue. A total of 2,625,745 CpG dinucleotides with $\geq 5 \times$ coverage are represented.

Epigenetic variation **1**

– Bisulfite conversion

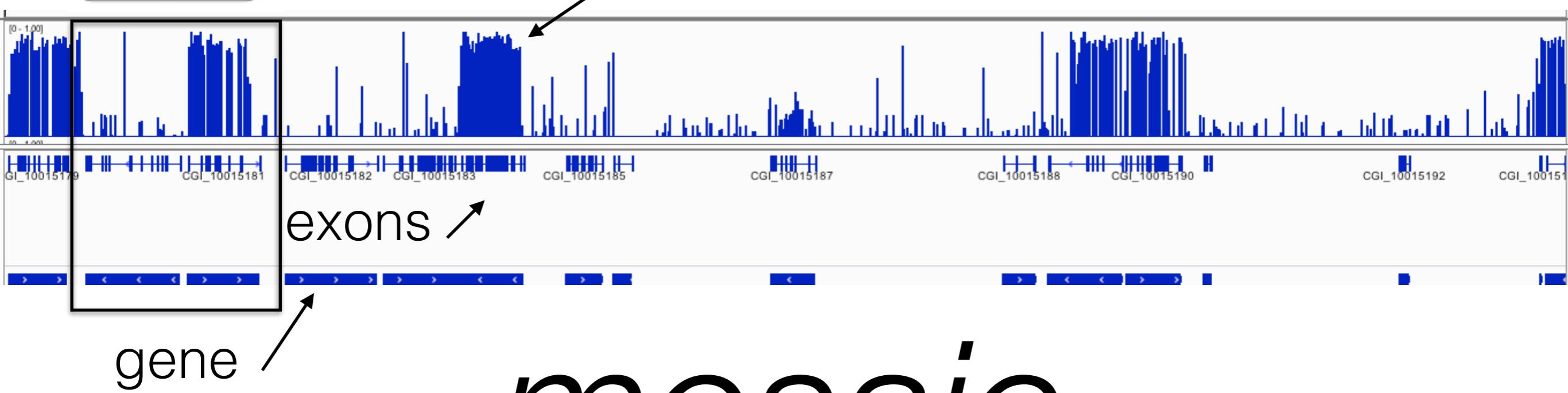


7,642,816 CpG dinucleotides with at least 5x coverage were examined



Epigenetic variation **1**

DNA methylation level (0-100%) @ cytosines

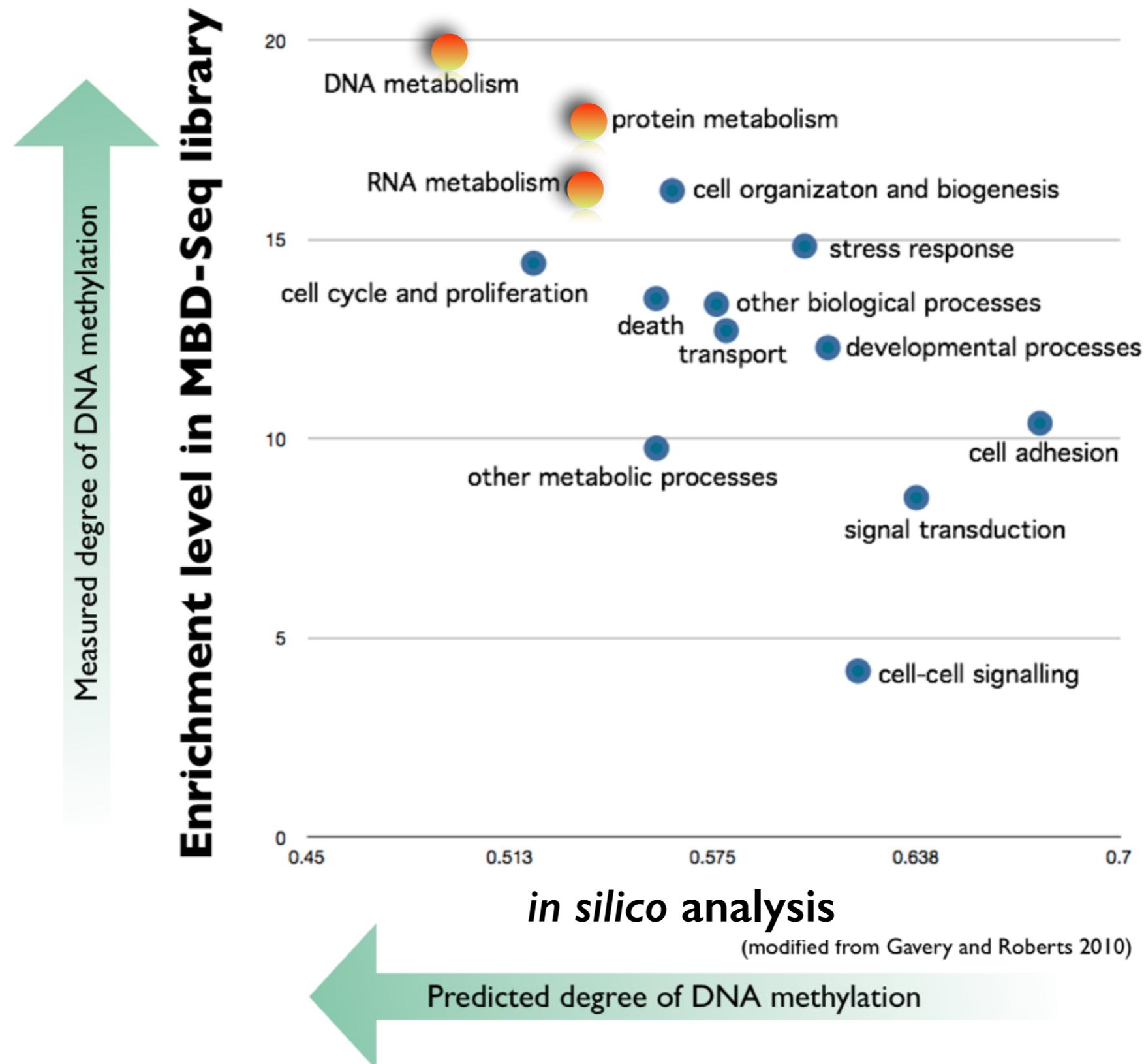


mosaic

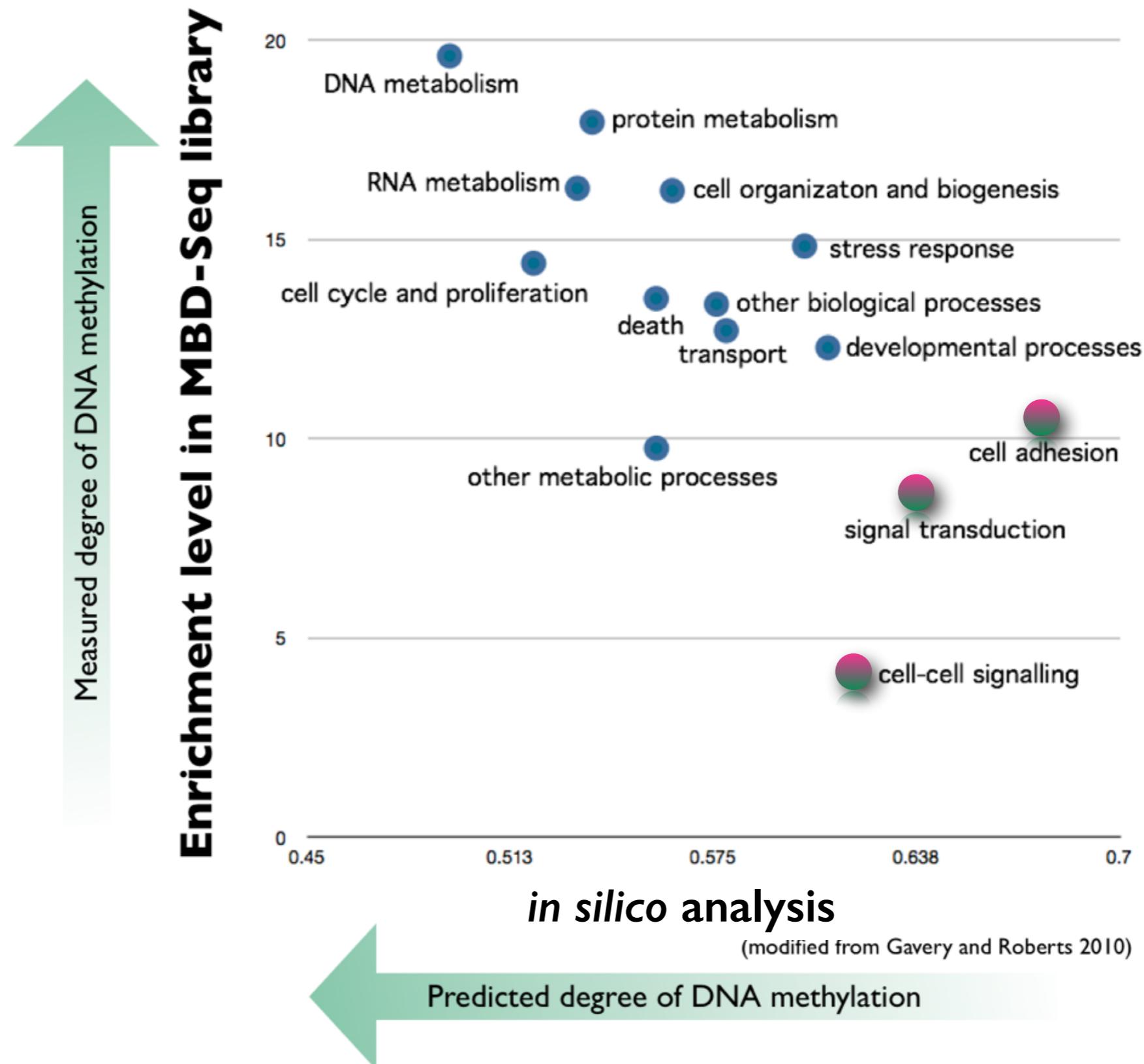
Why are only a subset of genes methylated?

associated with gene bodies

Epigenetic variation **1**



Epigenetic variation **1**



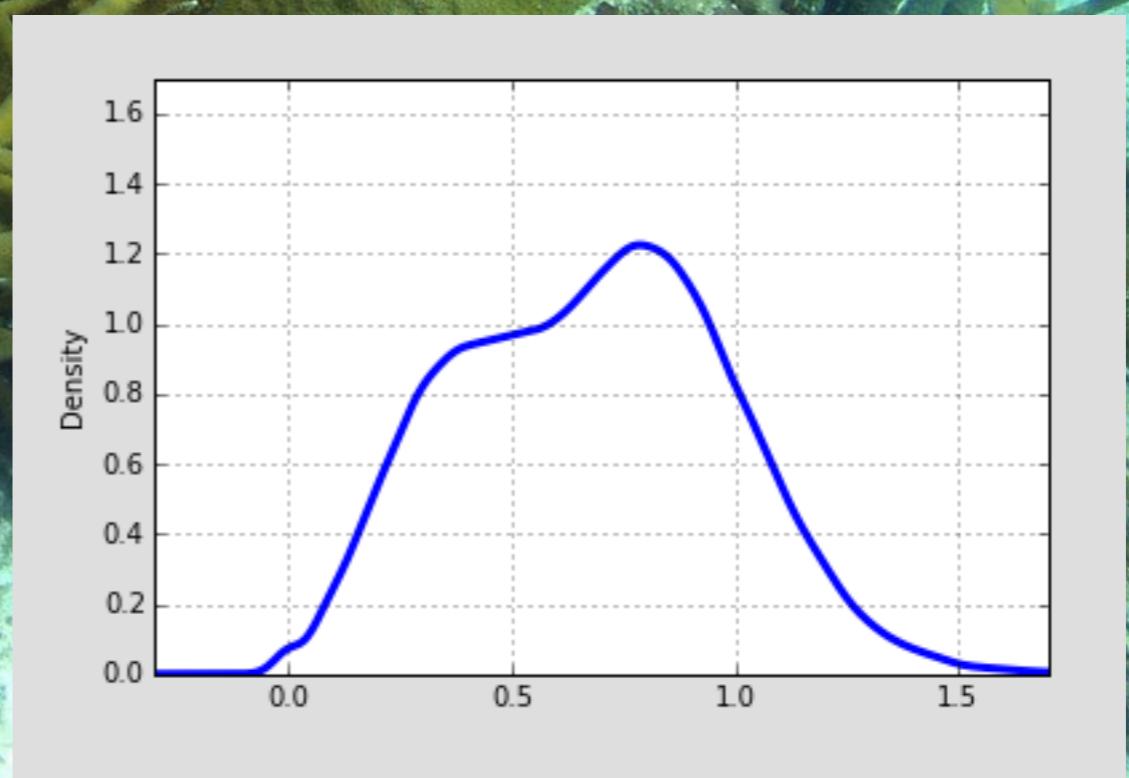
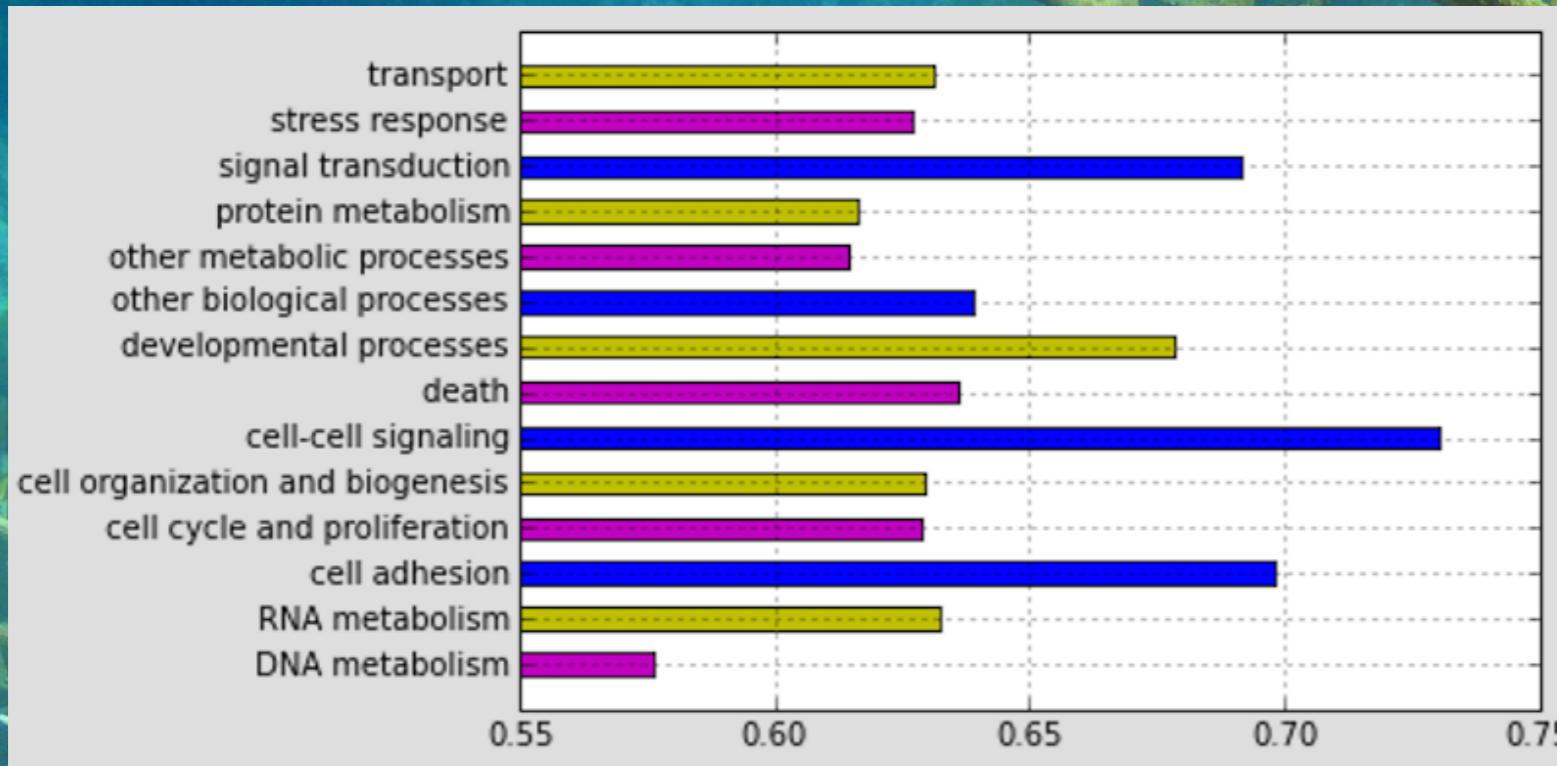
Jay Dimond

Acropora palmata

Acropora cervicornis

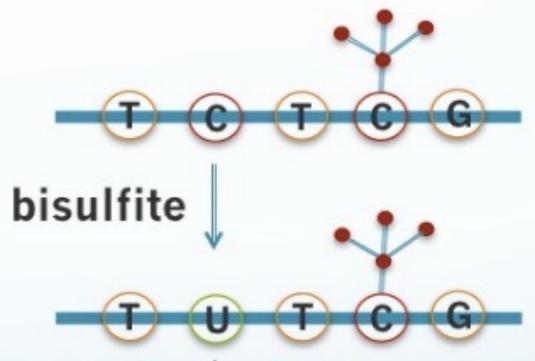
Jay Dimond

Acropora palmata



Epigenetic variation **1**

Family and Developmental Variation



Sperm &
Larvae
(72h & 120h)



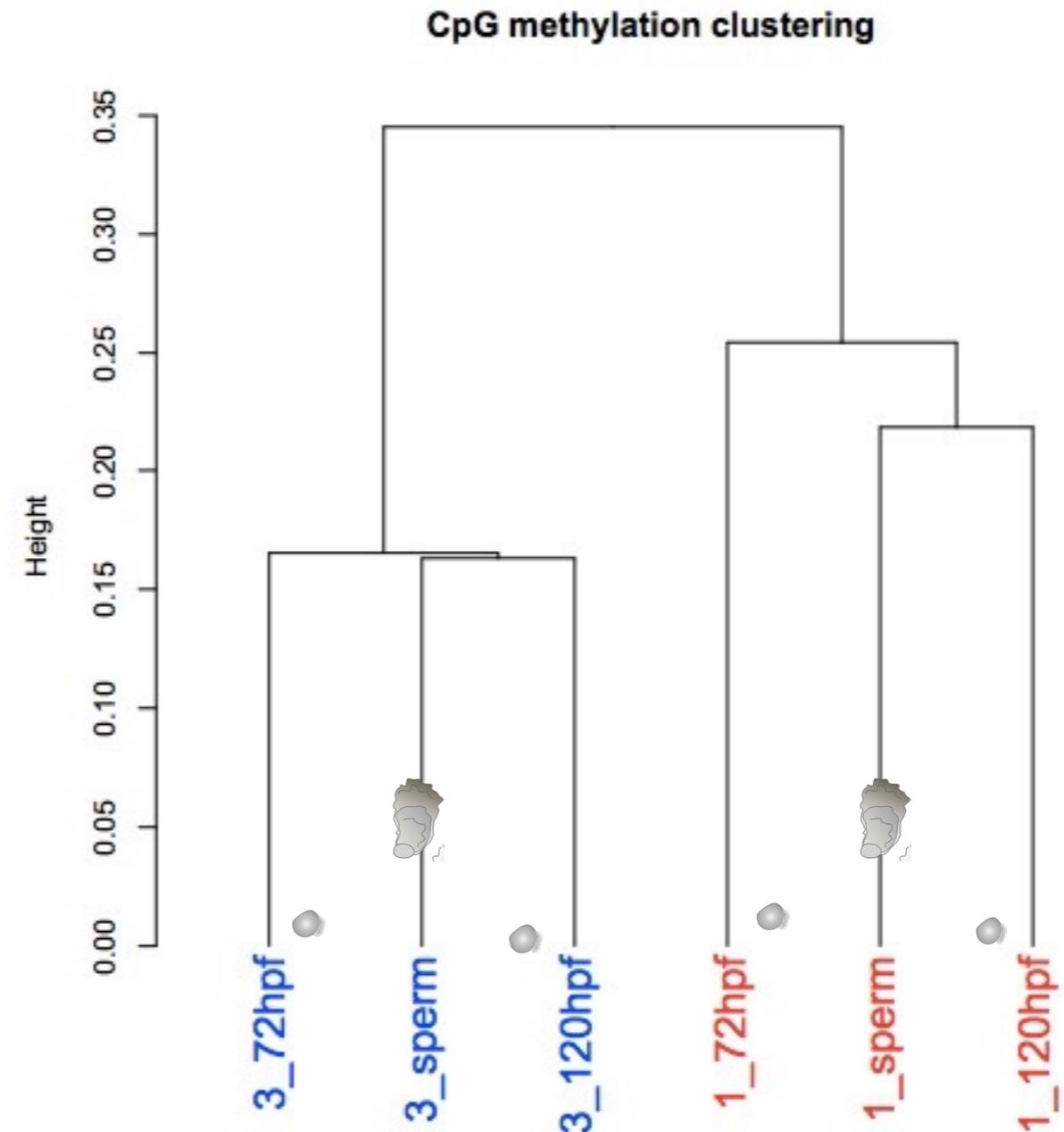
bioRxiv
beta
THE PREPRINT SERVER FOR BIOLOGY

New Results

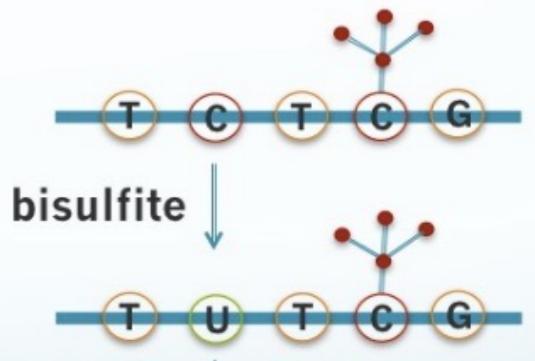
Indication of family-specific DNA methylation patterns in developing oysters

Claire E. Olson , Steven B. Roberts

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



Family and Developmental Variation



Inheritance



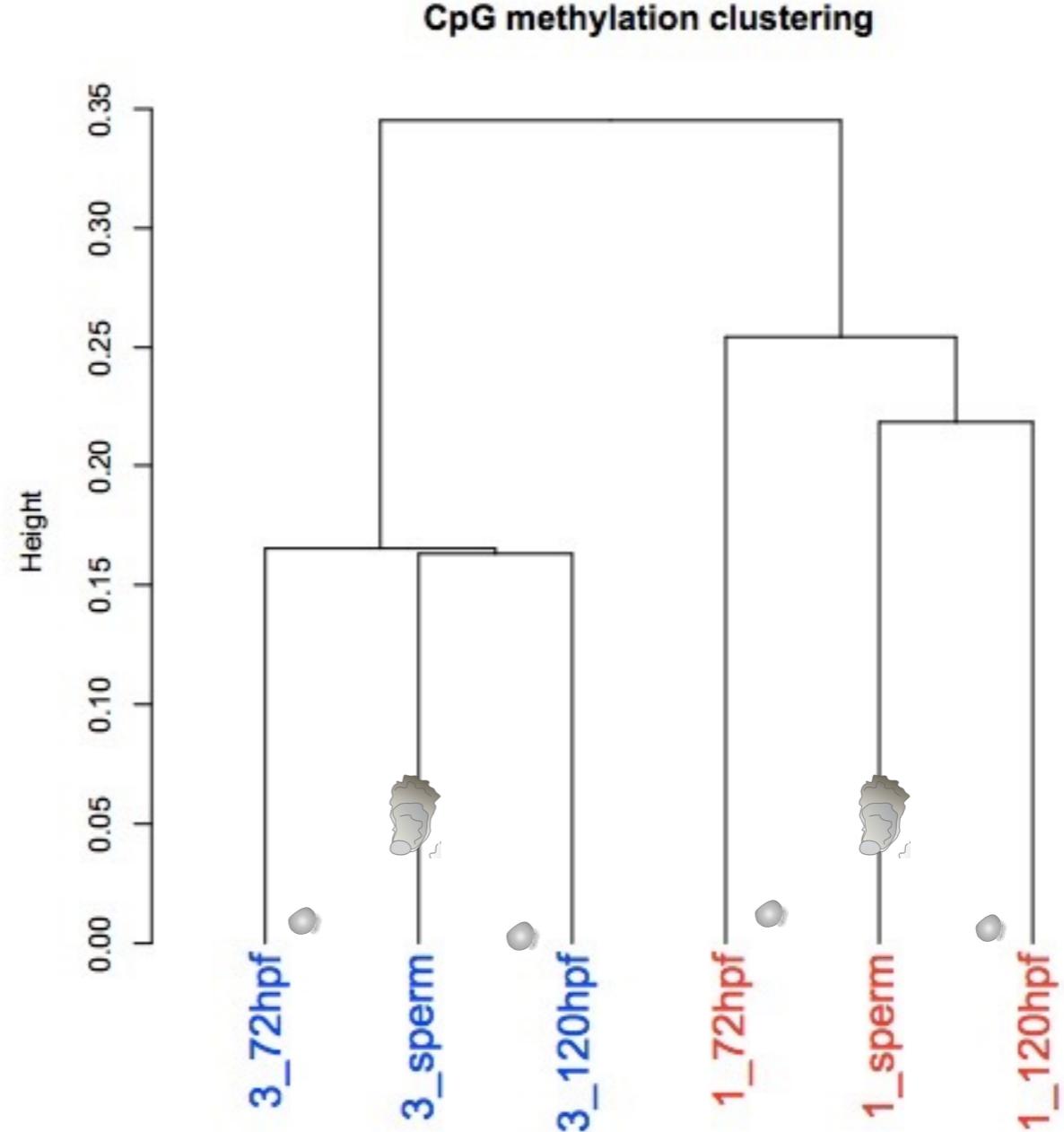
bioRxiv
beta
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New Results

Indication of family-specific DNA methylation patterns in developing oysters

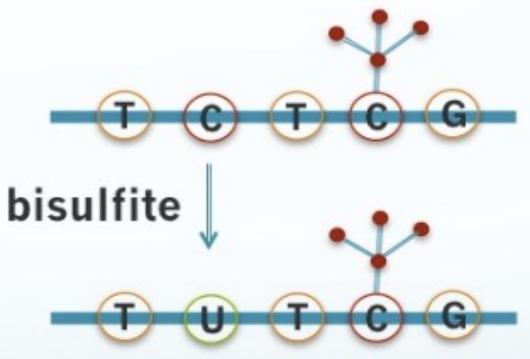
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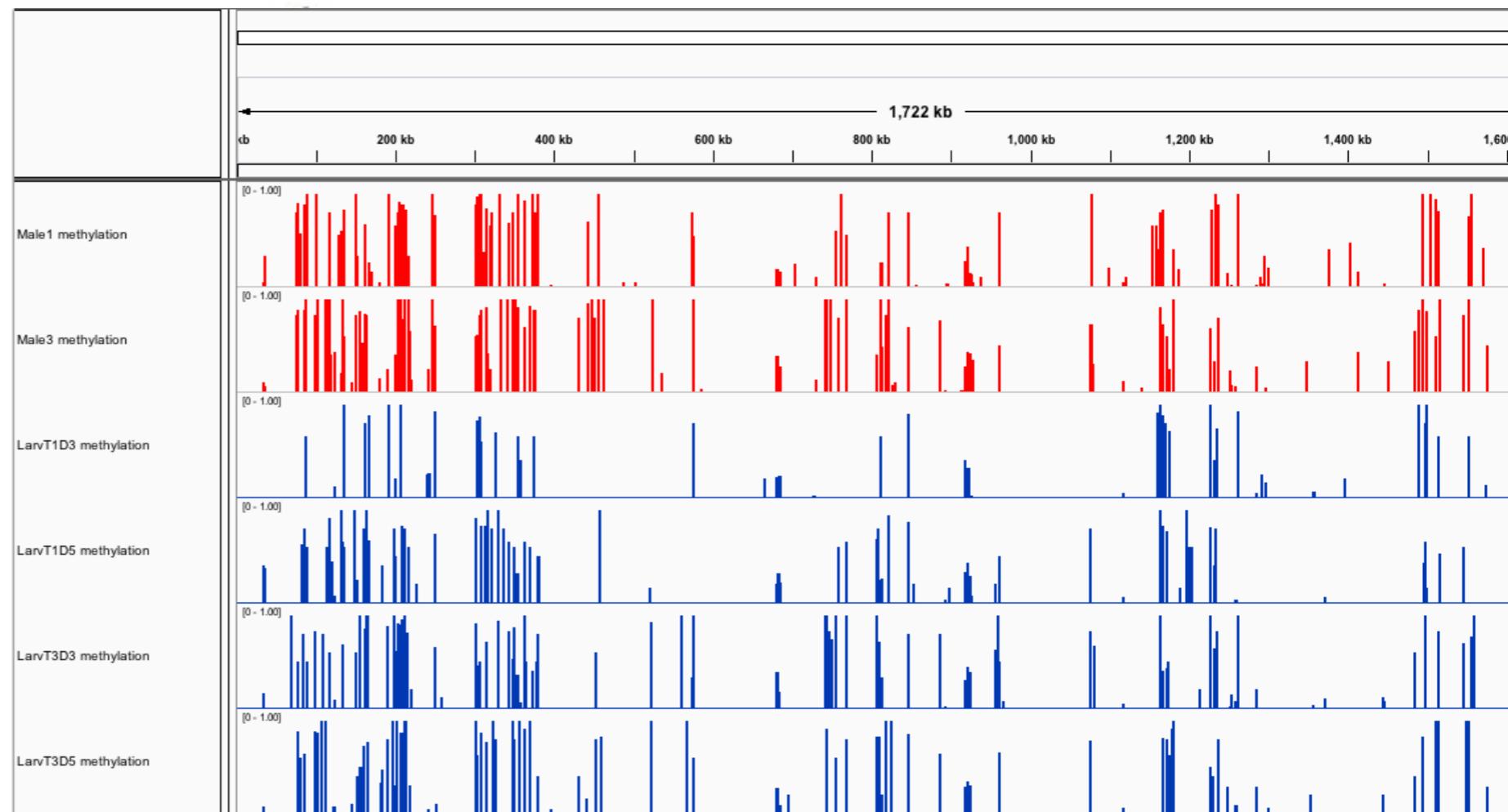


Epigenetic variation 1

Family and Developmental Variation



Sperm & Larvae (72h & 120h)



DNA methylation level (0-100%) @ cytosines



bioRxiv

THE PREPRINT SERVER FOR BIOLOGY

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>

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

Gene
expression



Epigenetic
variation

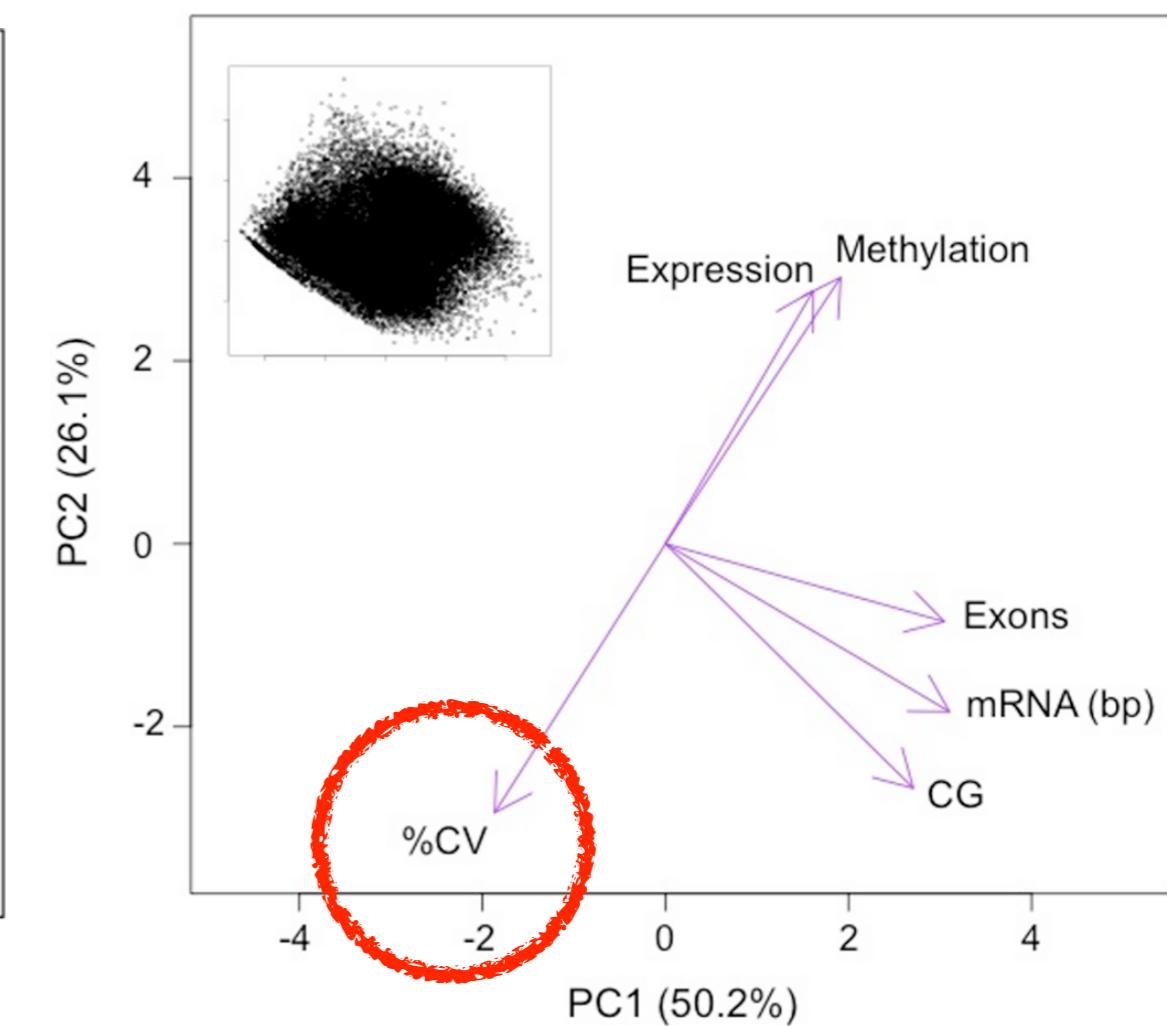
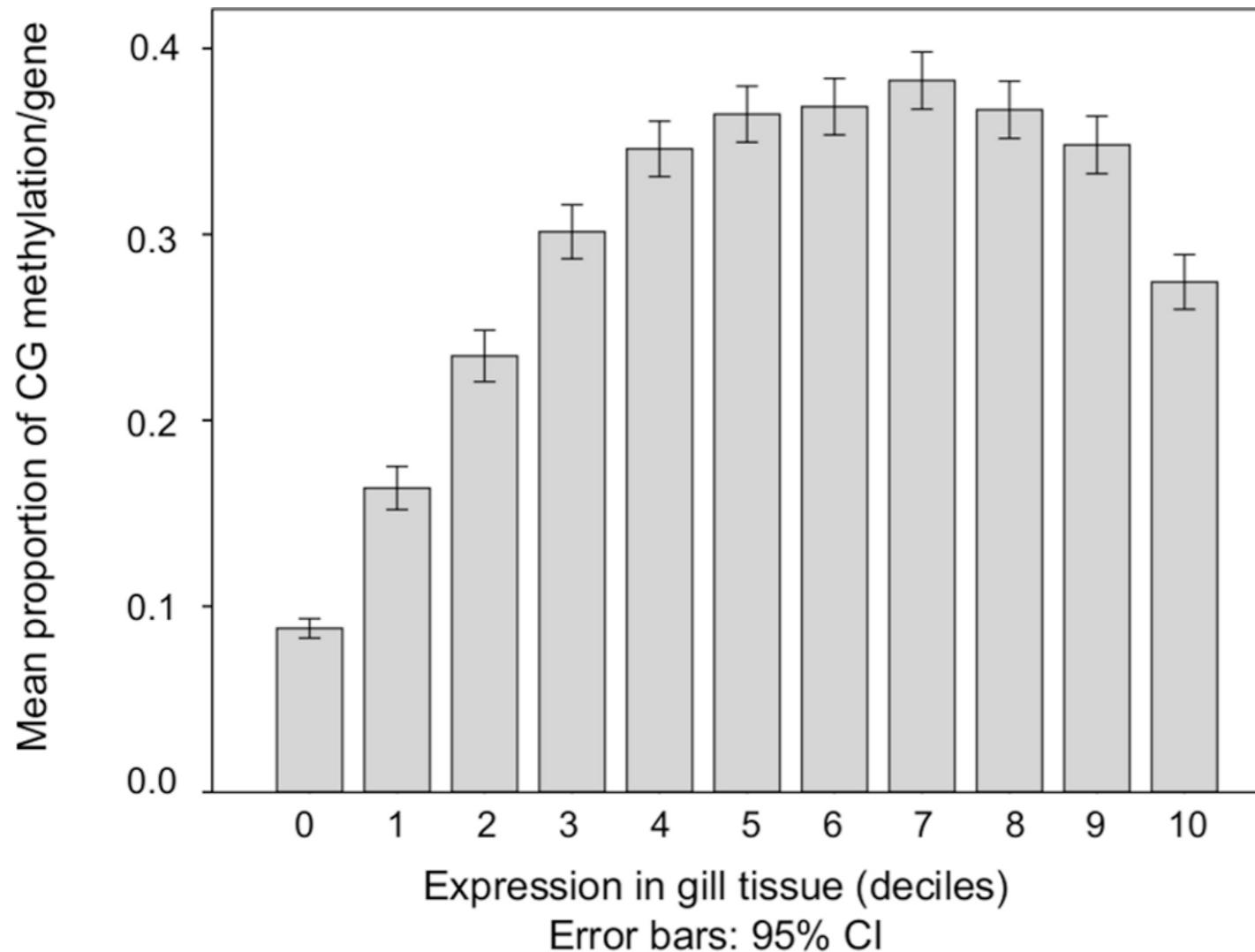
Function?

Gene expression

2

Epigenetic variation

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

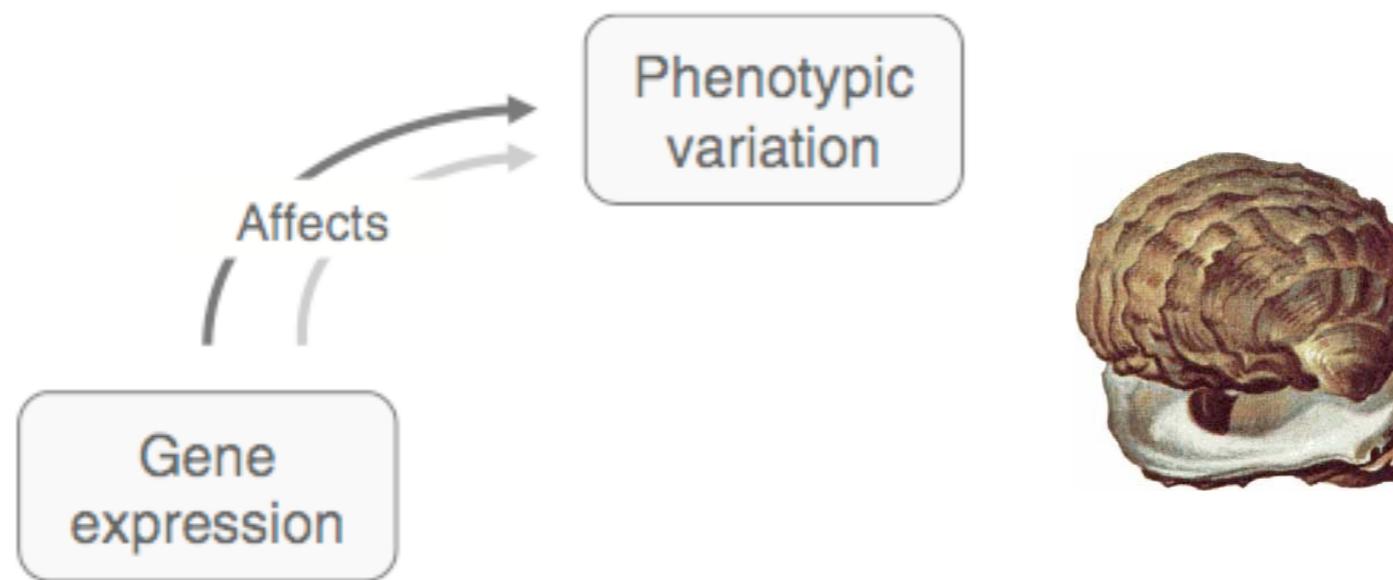




In species that experience a diverse range of environmental conditions, processes have evolved to increase the number of potential phenotypes in a population in order to improve the chances for an individual's survival.



Conceptual Models for a functional role of DNA methylation



Stochastic Variation

increased transcriptional opportunities

increased likelihood of suitable phenotype



Gene expression

Epigenetic variation
2

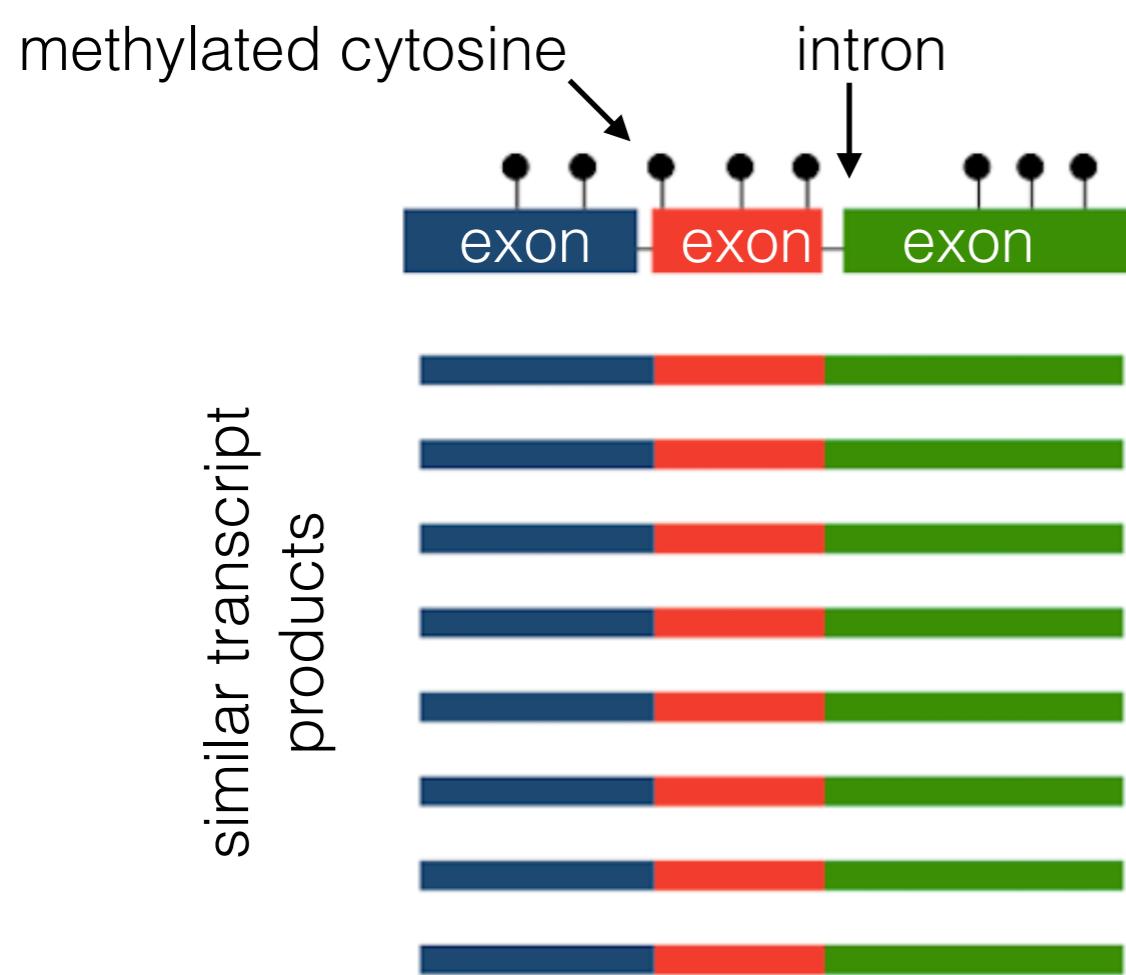


in silico analysis

(modified from Gavery and Roberts 2010)

Predicted degree of DNA methylation

Roberts and Gavery 2012

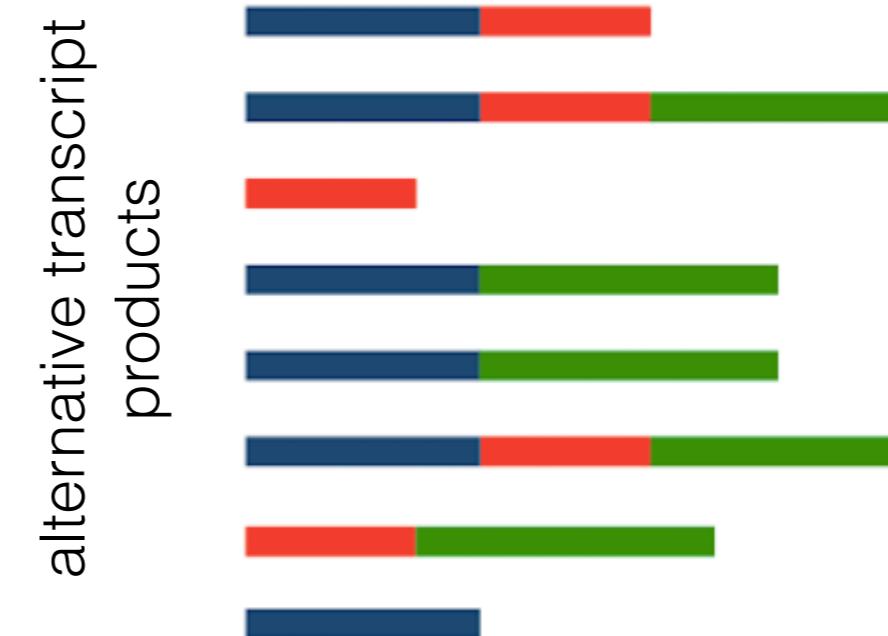


housekeeping

Stochastic Variation

A context dependent role for DNA methylation in bivalves

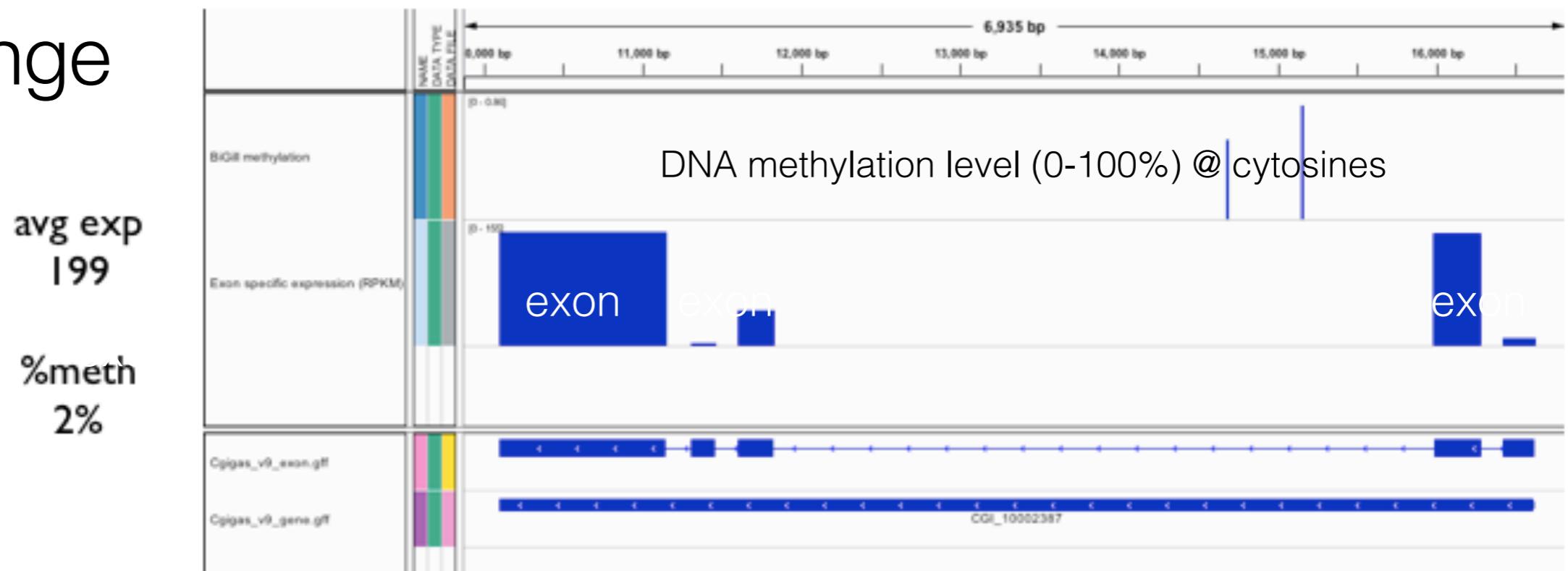
Mackenzie R. Gavery and Steven B. Roberts
Advance Access publication date 7 January 2014



response to
change

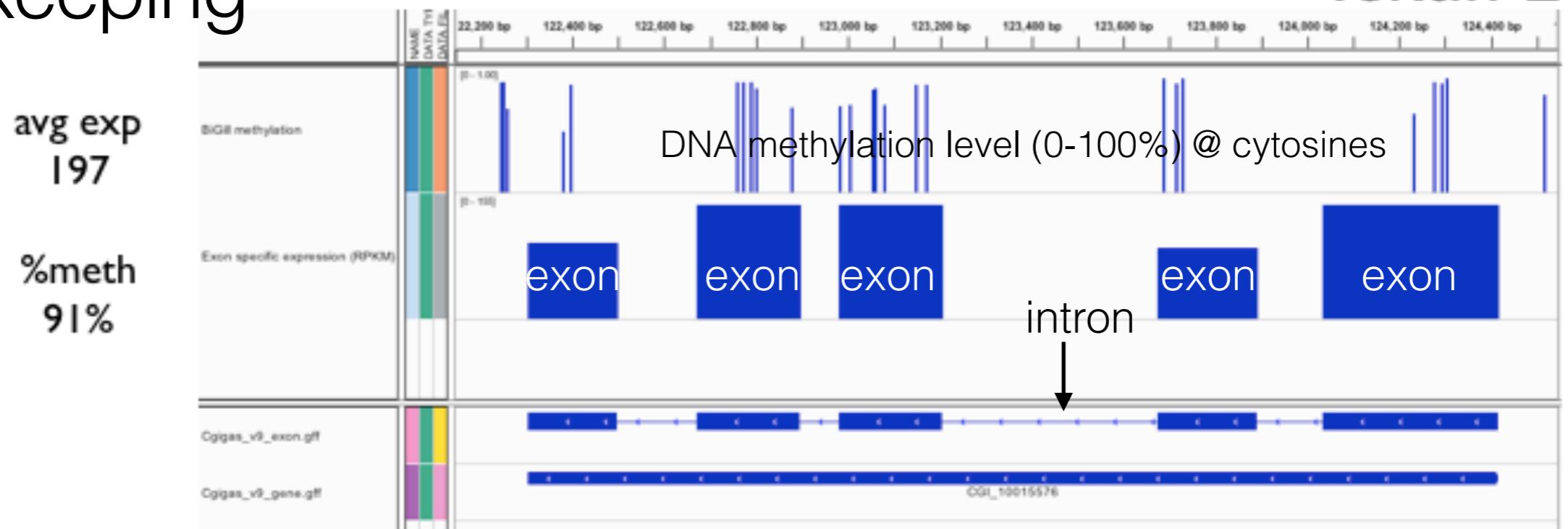
response to
change

Heat shock 70 kDa protein 12A



housekeeping

Tektin-2



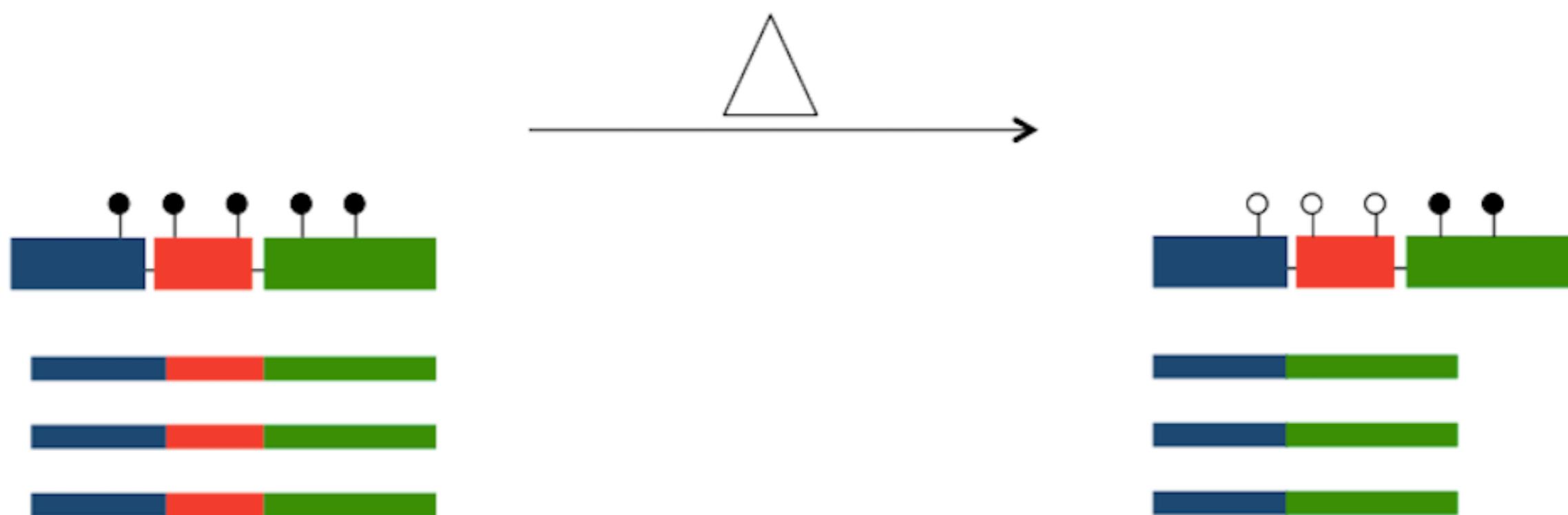


Targeted Regulation

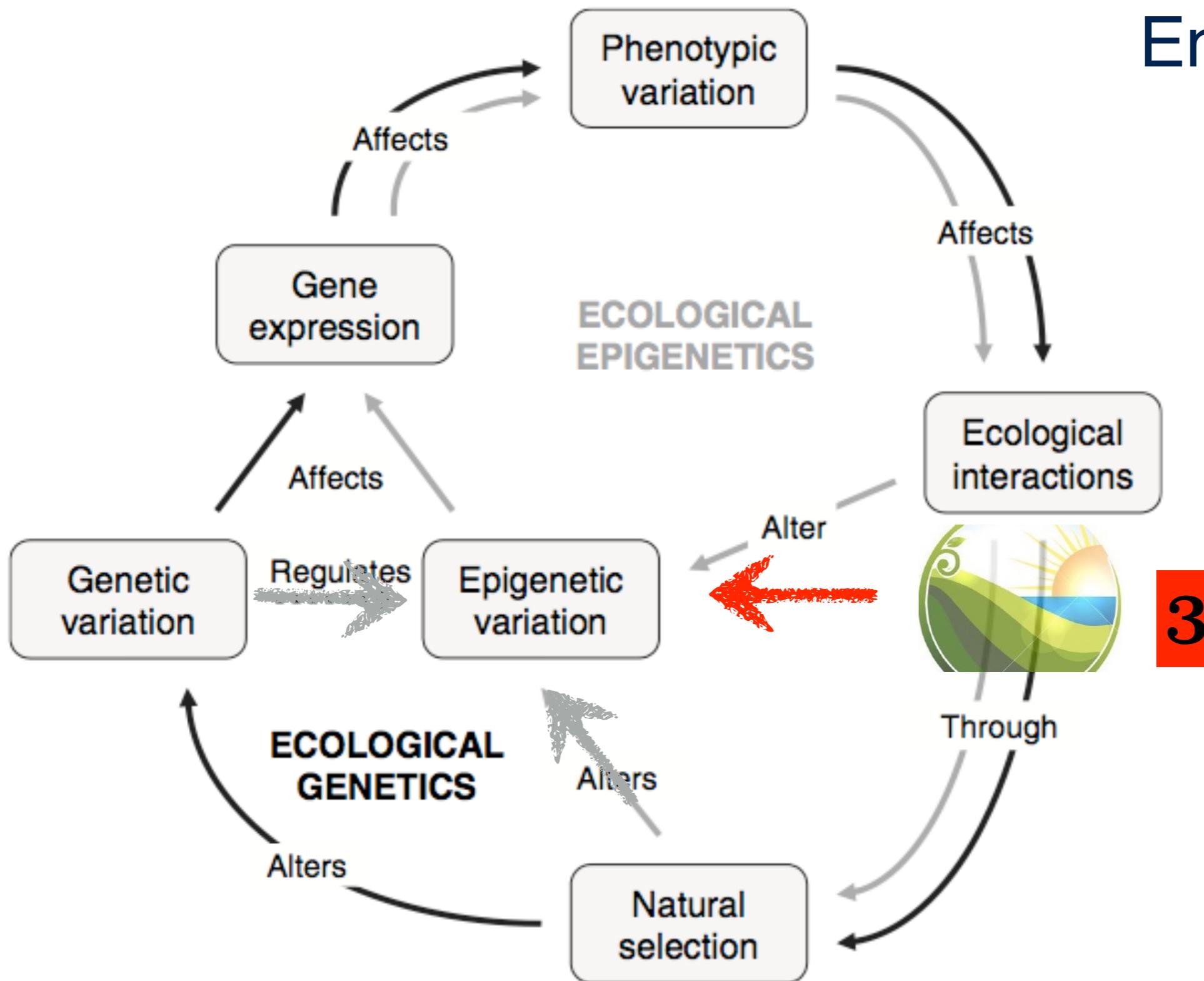
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Environmental Influence



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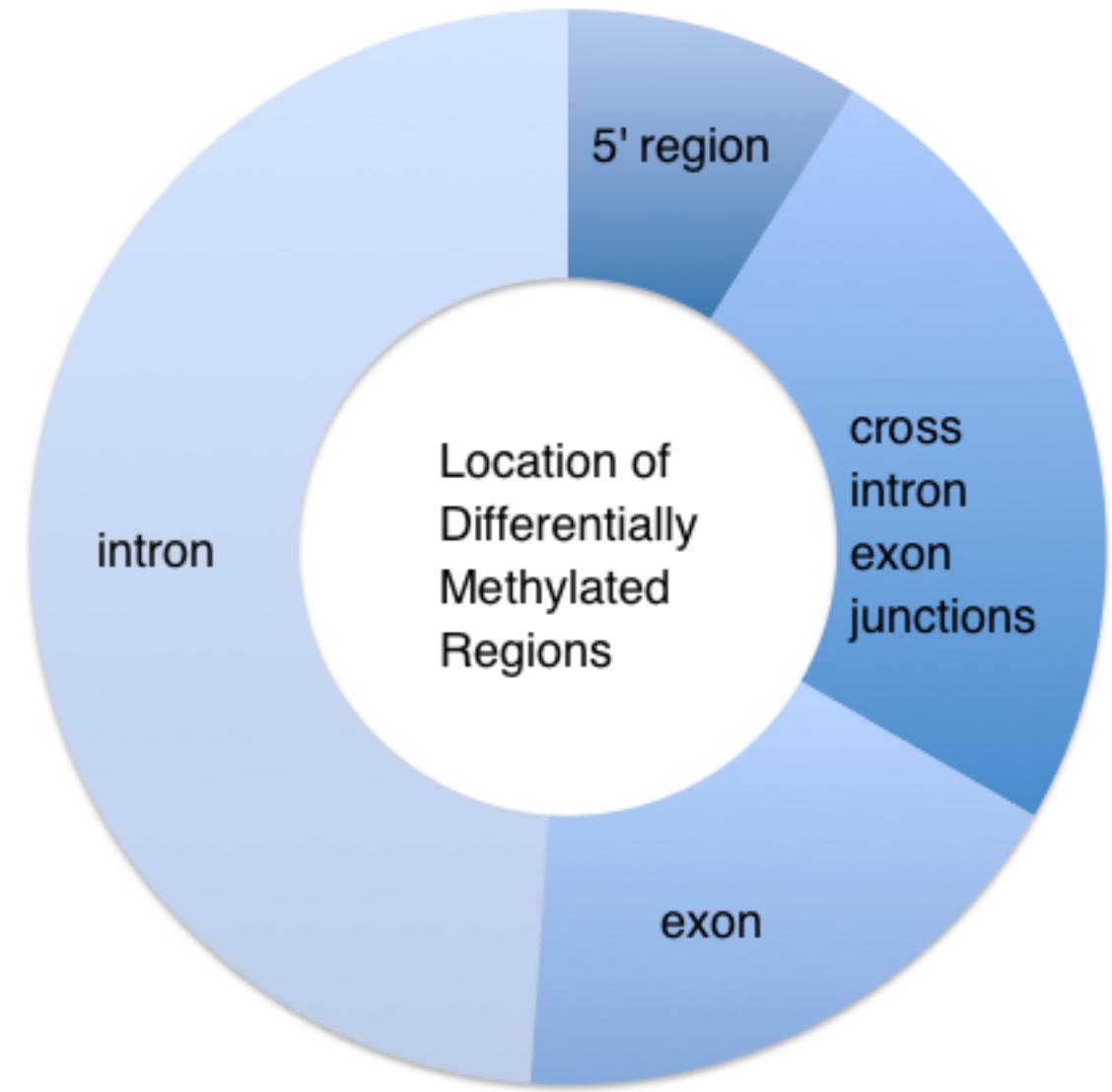
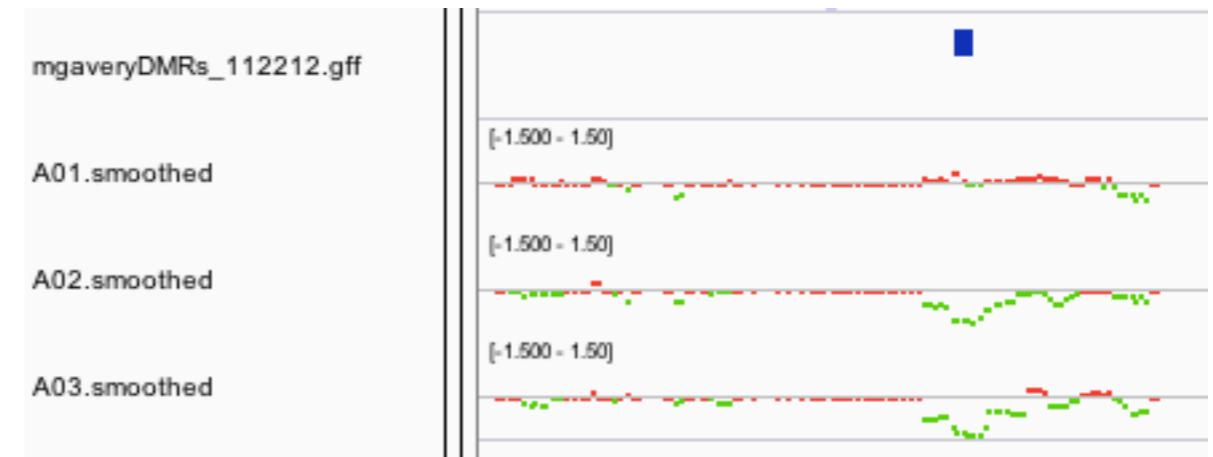
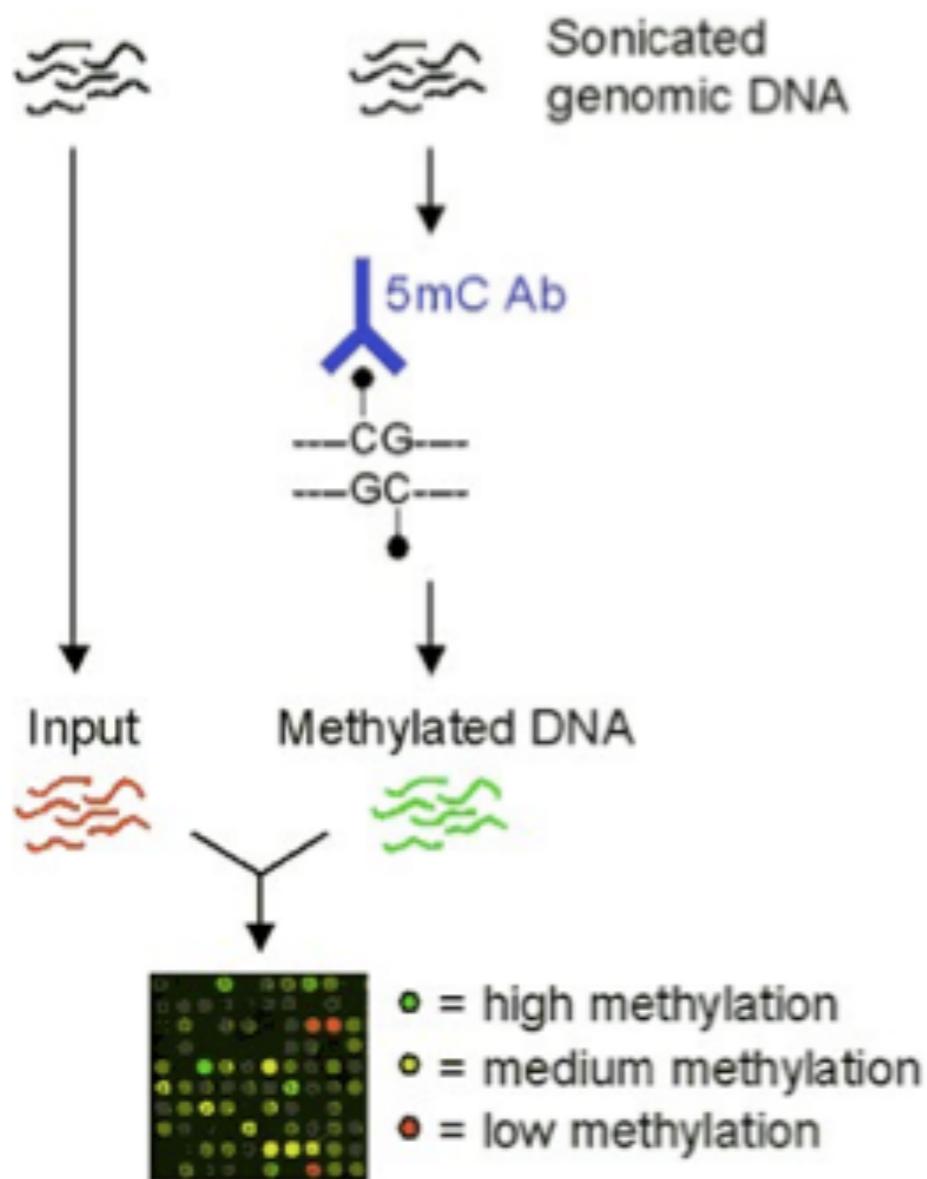
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IDEA AND
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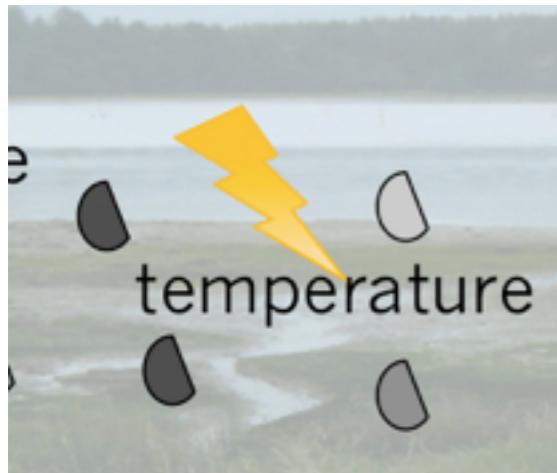
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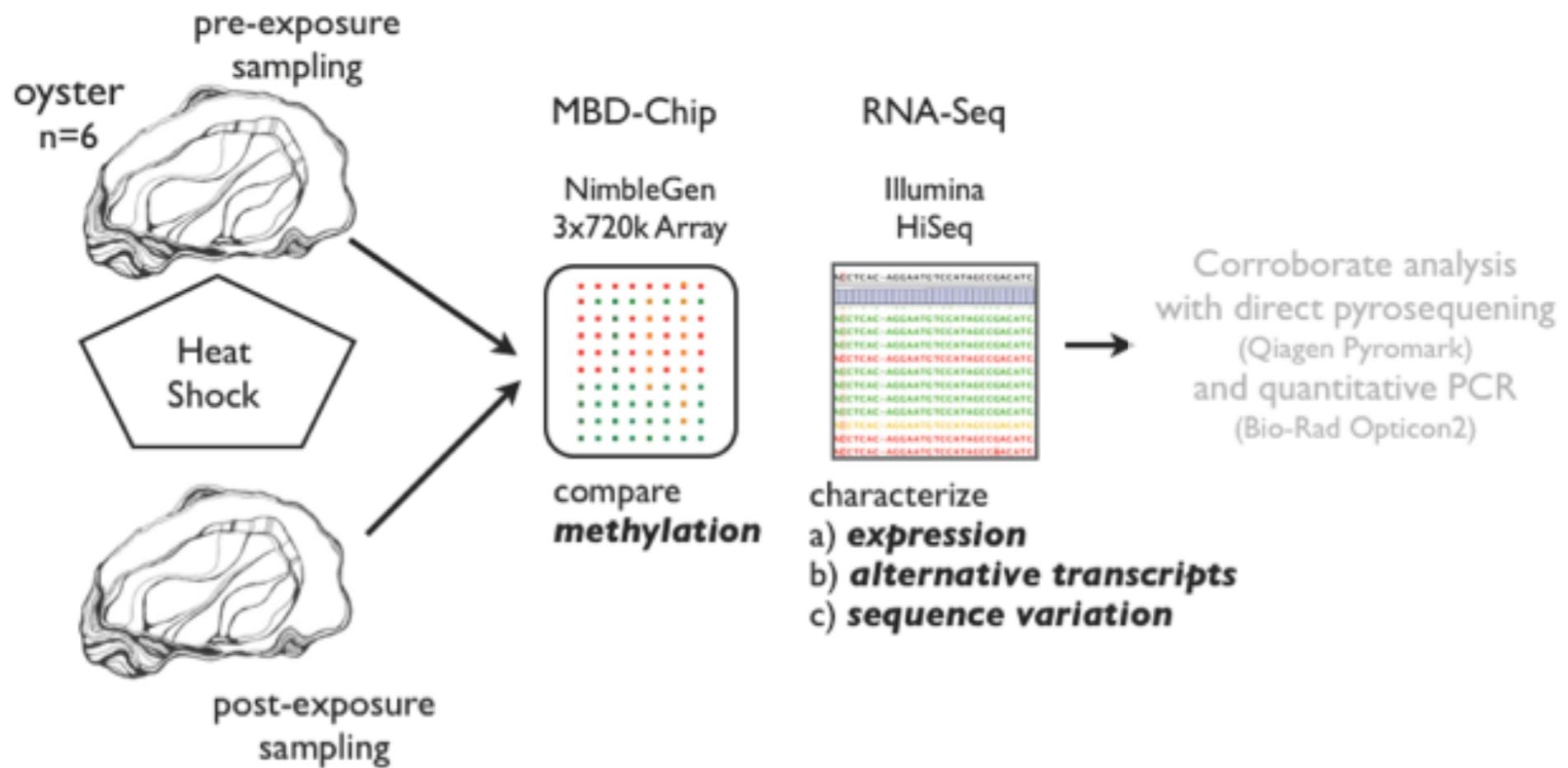
Environmental impact (Estrogens)



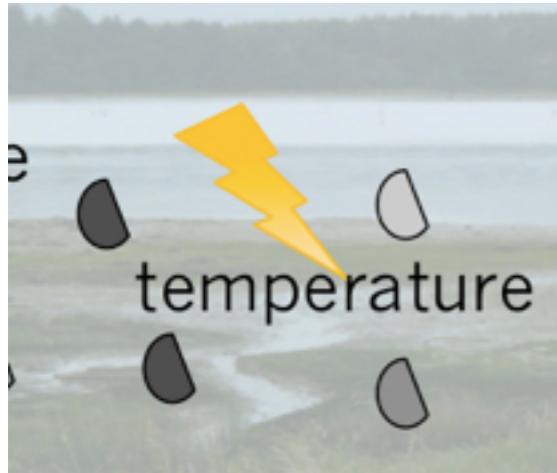
Environment and gene expression



stochastic or targeted?



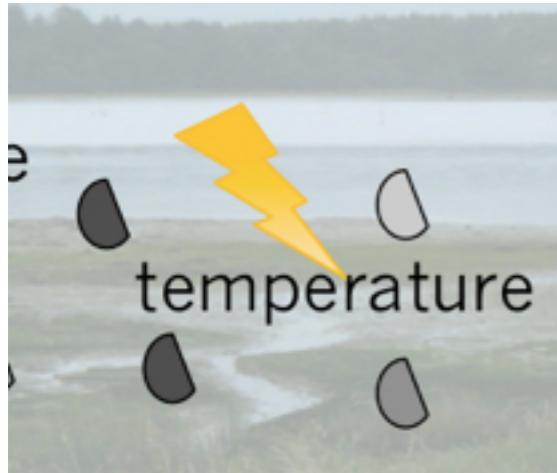
Environment and gene expression



stochastic or targeted?

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

Environment and gene expression

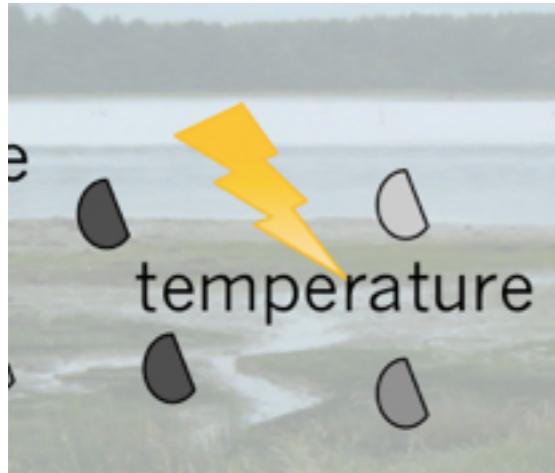


stochastic or targeted?

Oyster	Hypo-methylated	Hyper-methylated
2	7224	2803
4	6560	3587
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No obvious association
with genome feature
including *differentially*
expressed
genes

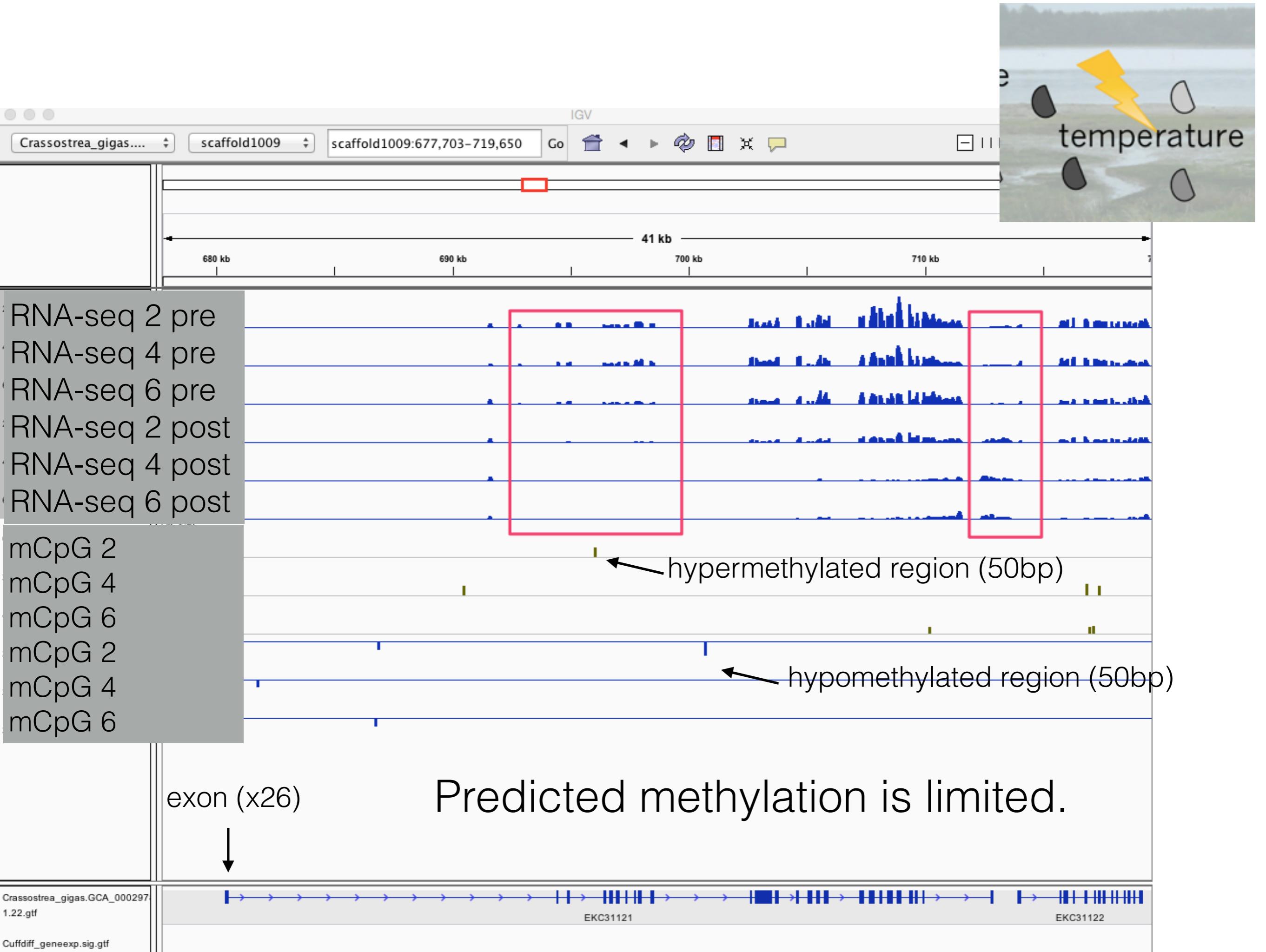
Environment and gene expression



*stochastic or targeted
or ..?*

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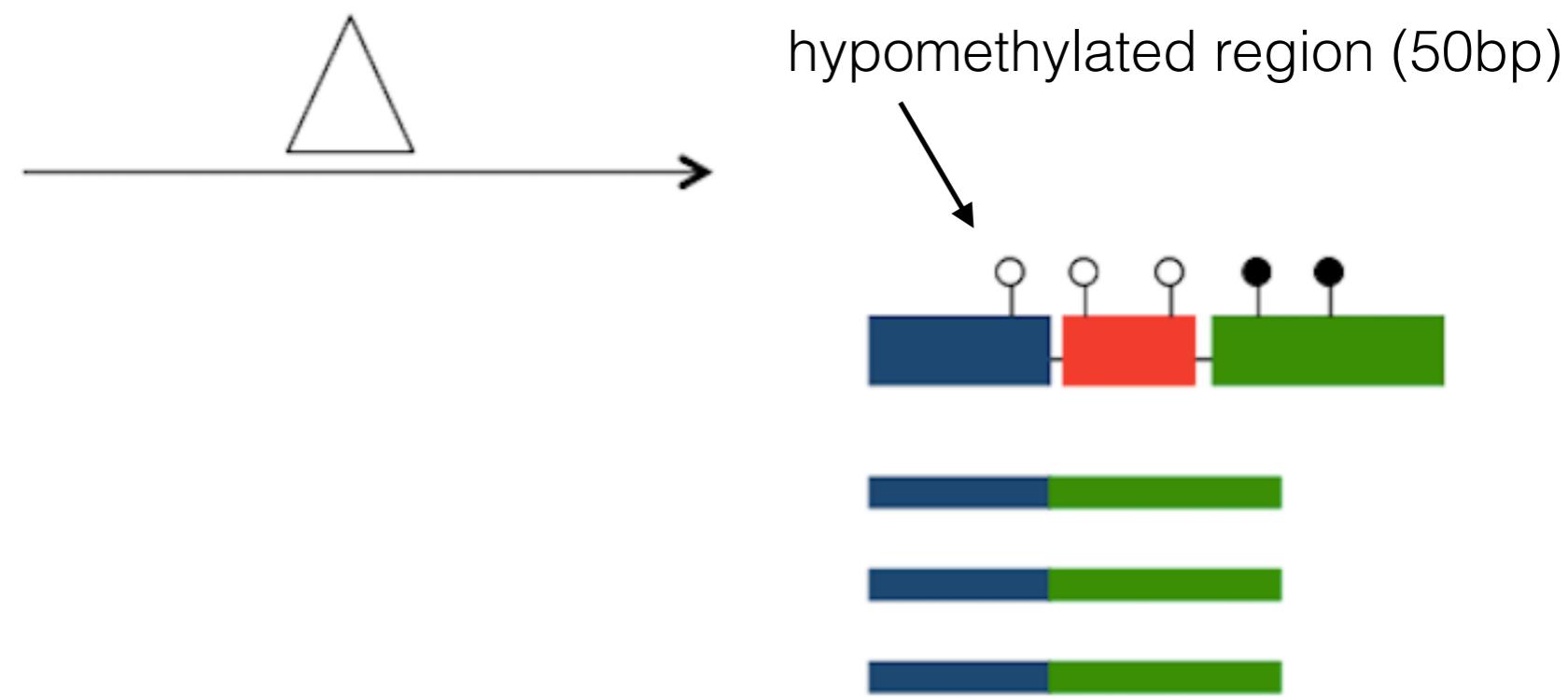
Changes in methylation (either direction) are more prevalent in introns, repeats, and transposable elements.



Gene
expression

2

Epigenetic
variation



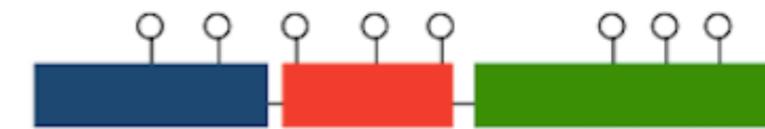
not in this experiment

not even consistent methylation changes at loci level

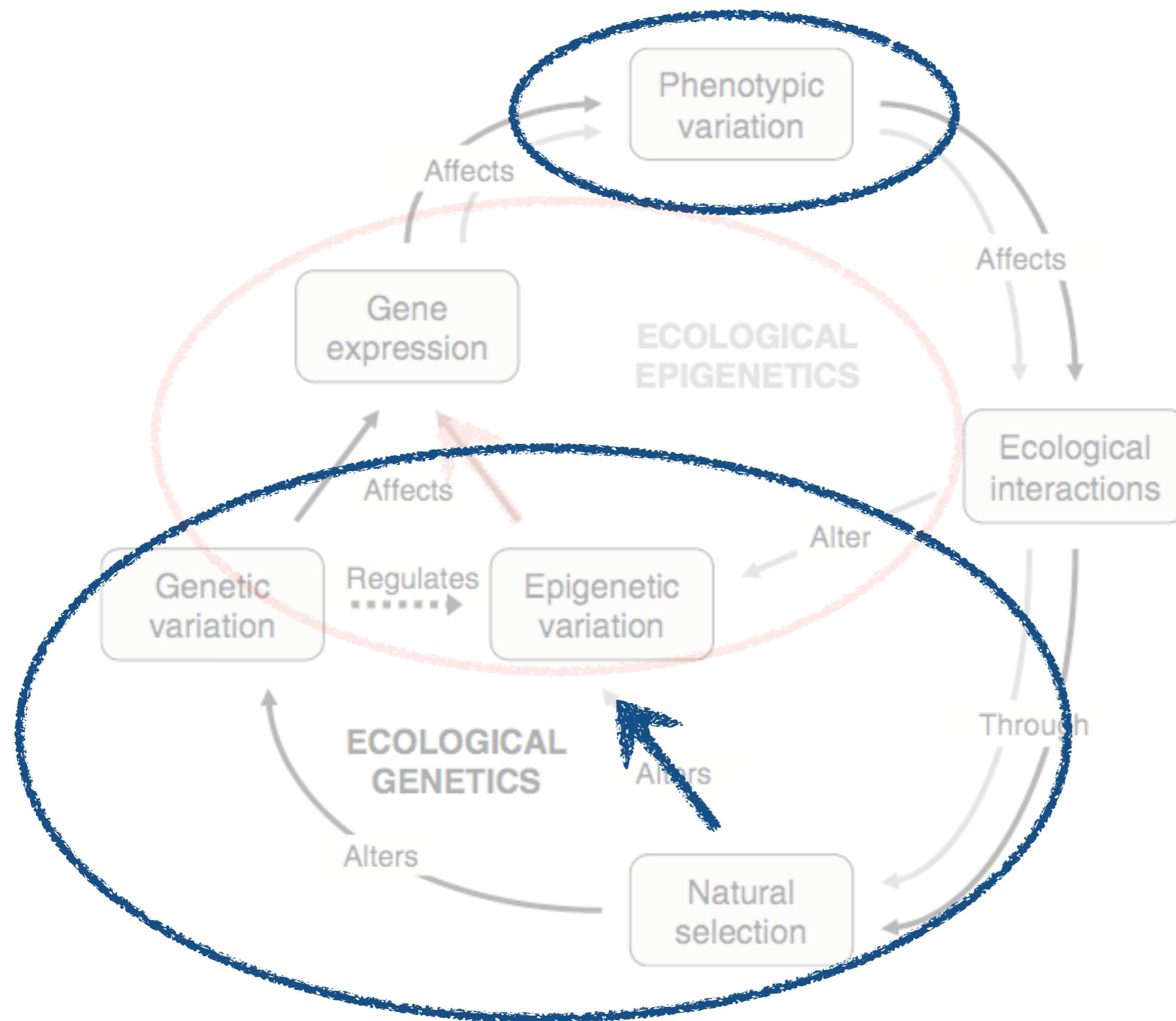
Gene
expression

2

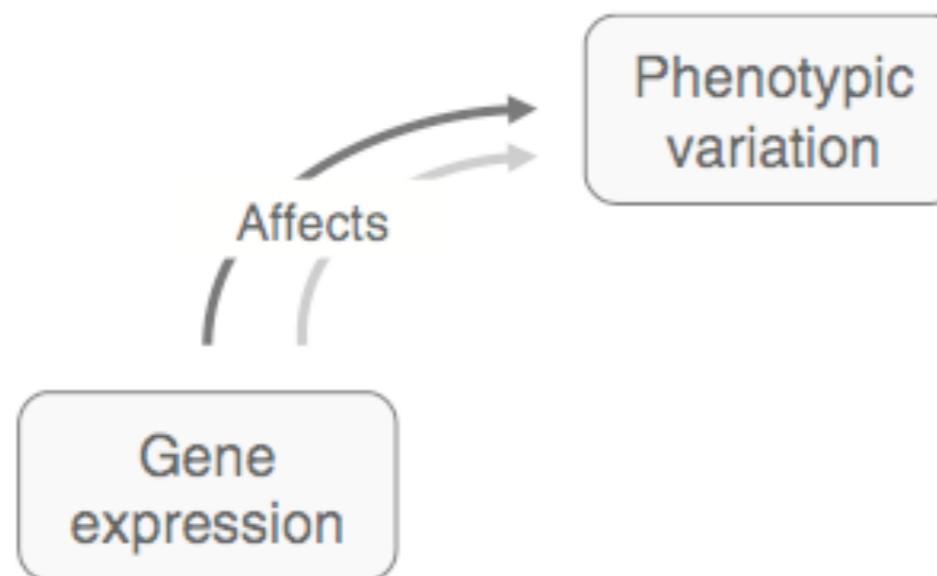
Epigenetic
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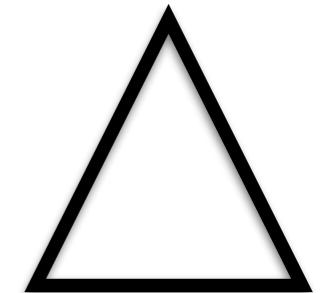
more questions....
interesting but what is controlling?

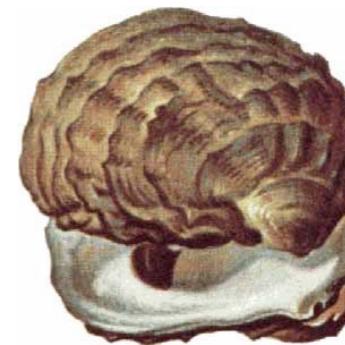
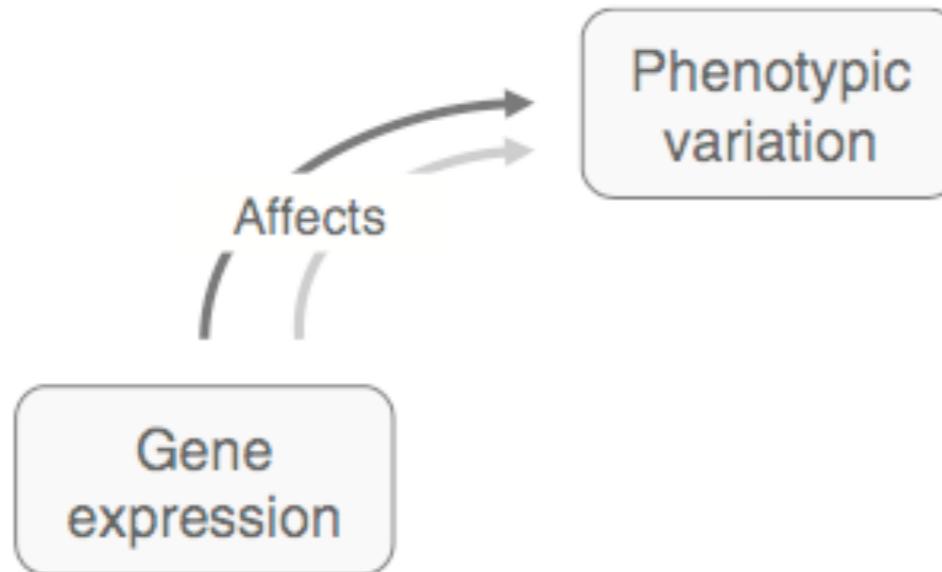


Conceptual Models for a functional role of DNA methylation



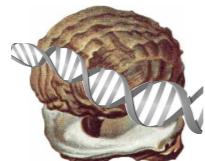
Mystery - Natural Epigenetic Variation Exists



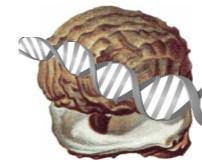


Conceptual Models for a functional role of DNA methylation

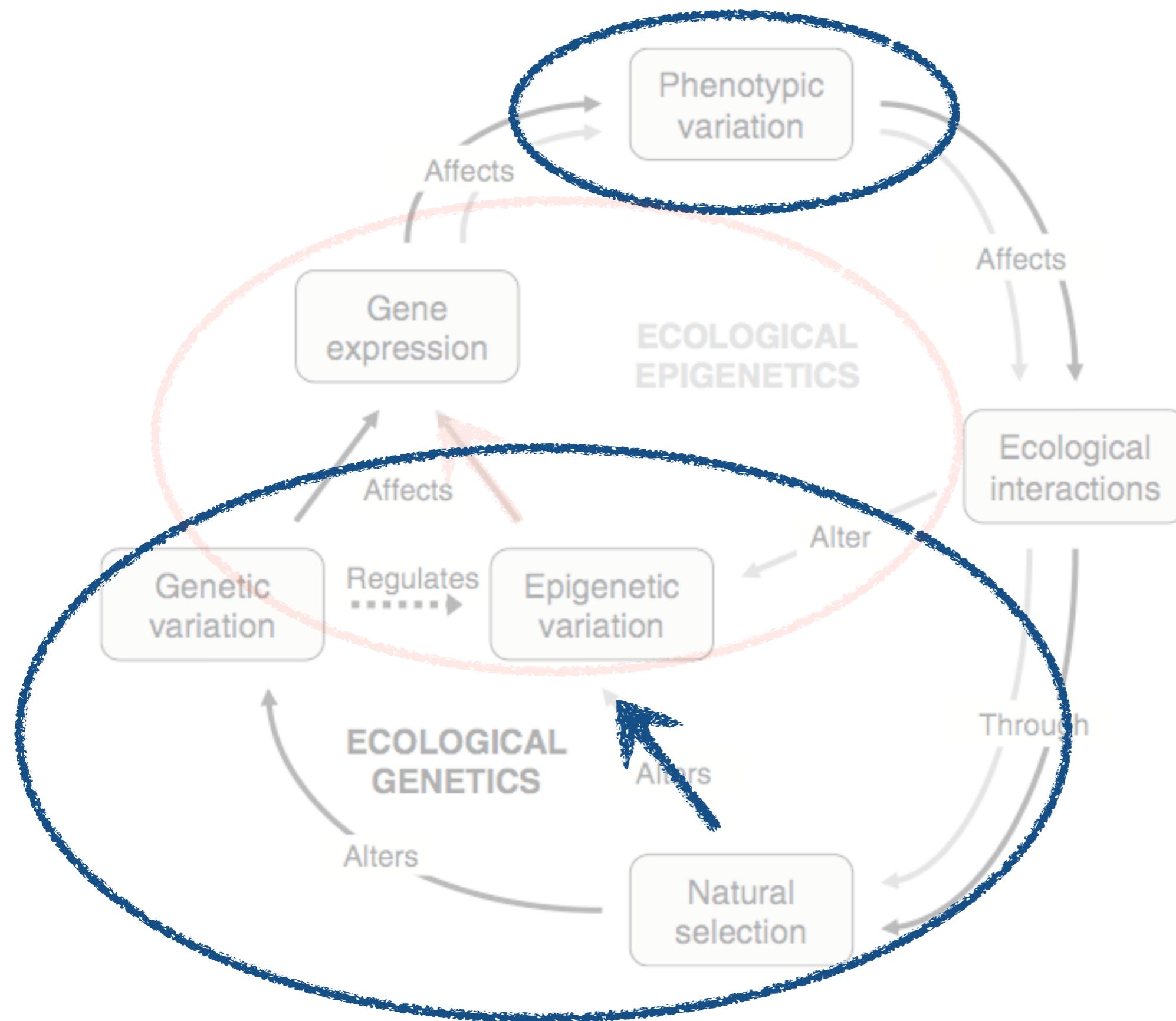
Mystery - Natural Epigenetic Variation Exists



Biological Scale?
Population



*



Population studies

Ostrea lurida

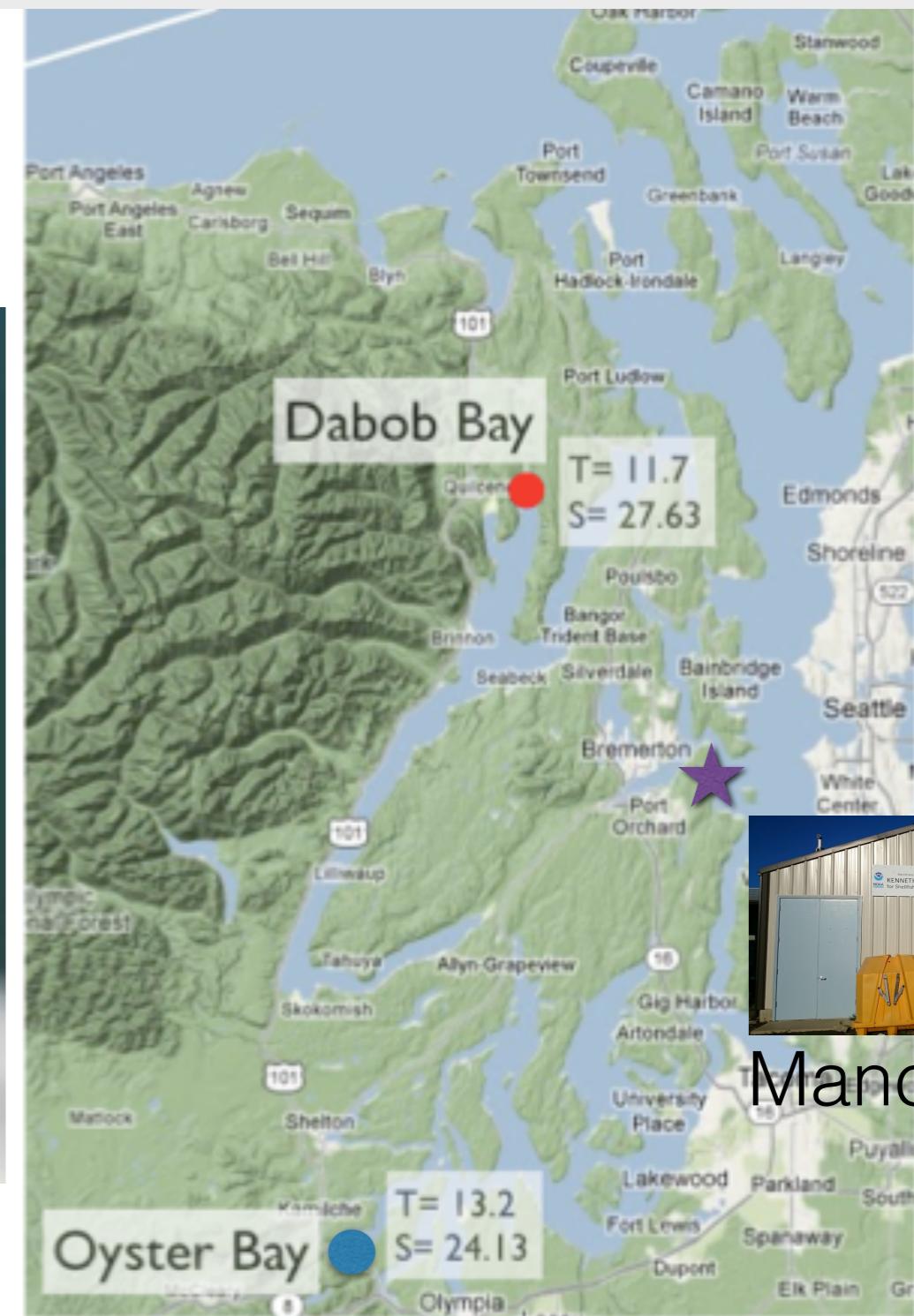


Population studies

Ostrea lurida



Reciprocal Transplant Experiment



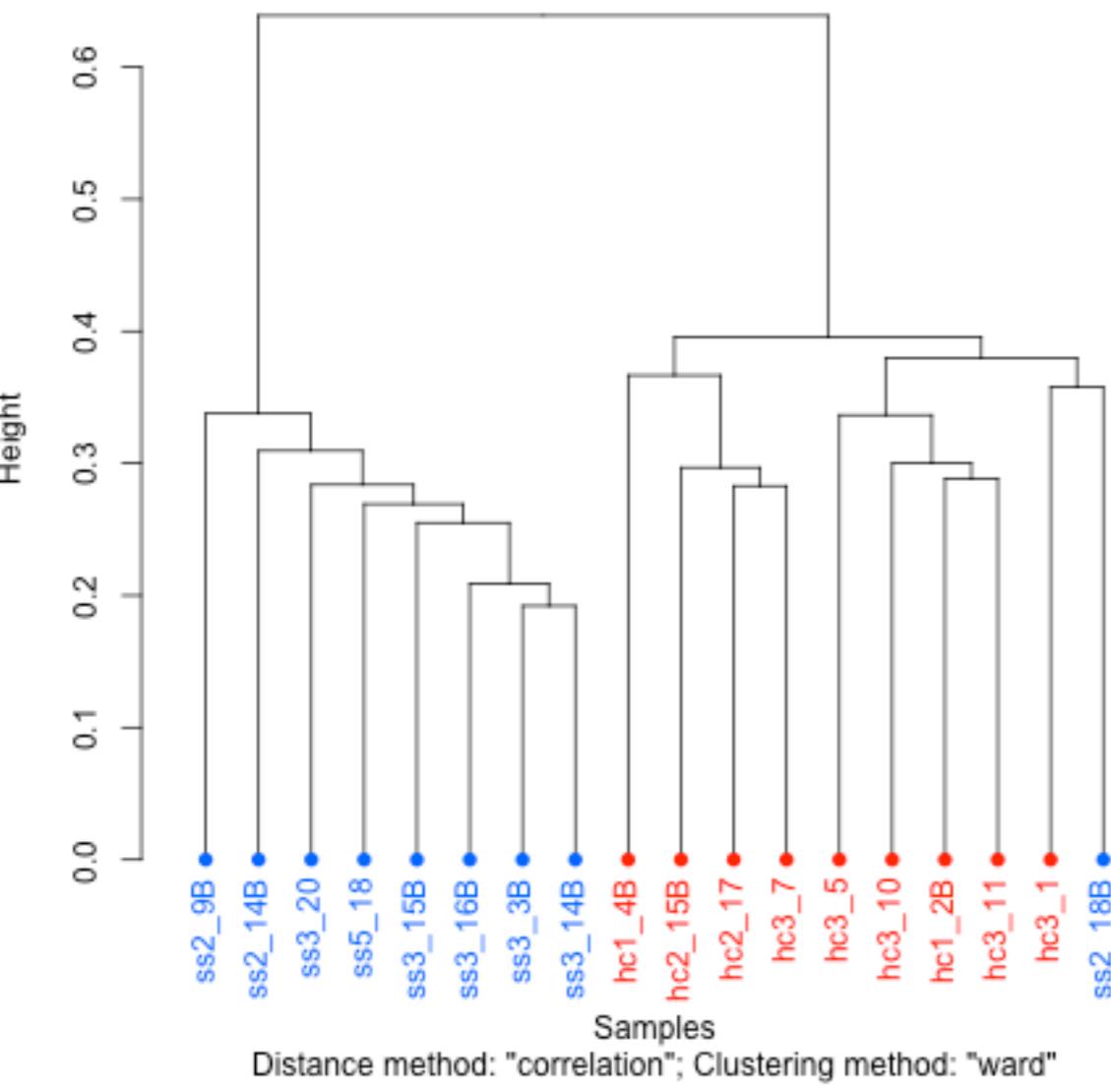
Manchester

Population studies



Reciprocal Transplant Experiment

CpG methylation clustering



Manchester

Very new data

Selection

Ocean Acidification

Panopea generosa



Very new data

Selection

Ocean Acidification

Day 10

Control: Random Mortality

~42% ACGCTGATCGT
~38% ACGCTAATCGT

Day 1

Proportion of sequences in pooled
larvae sample with given allele (G vs A)

~42% ACGCTGATCGT
~38% ACGCTAATCGT

Day 10

High $p\text{CO}_2$: Non-random
Mortality

~80% ACGCTGATCGT
~20% ACGCTAATCGT

Day 1

Ambient $p\text{CO}_2$
Ambient temperature

High $p\text{CO}_2$
Ambient temperature

High $p\text{CO}_2$
High temperature

Ambient $p\text{CO}_2$
High temperature

Ambient $p\text{CO}_2$
Ambient temperature

Evidence of allele beneficial (G) to survival
under High $p\text{CO}_2$ conditions

→

Very new data

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Day 1

Ambient $p\text{CO}_2$
Ambient temperature

Day 10

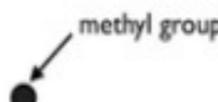
Control: Random Mortality

~44% ACGCTGATCGT
~56% ACGCTAATCGT

Day 1

Proportion of sequences in pooled
larvae sample with given allele (methylated
cytosine vs unmethylated cytosine)

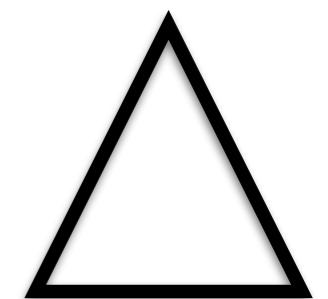
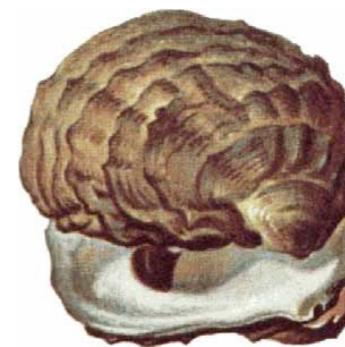
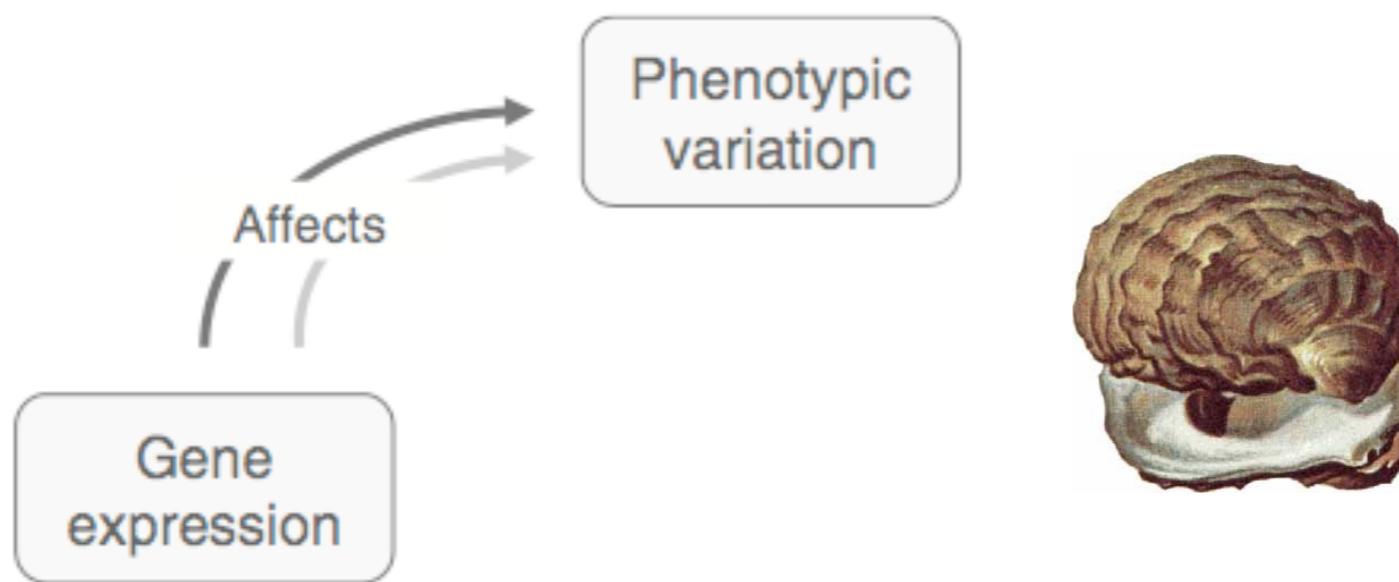
~44% ACGCTGATCGT
~56% ACGCTAATCGT



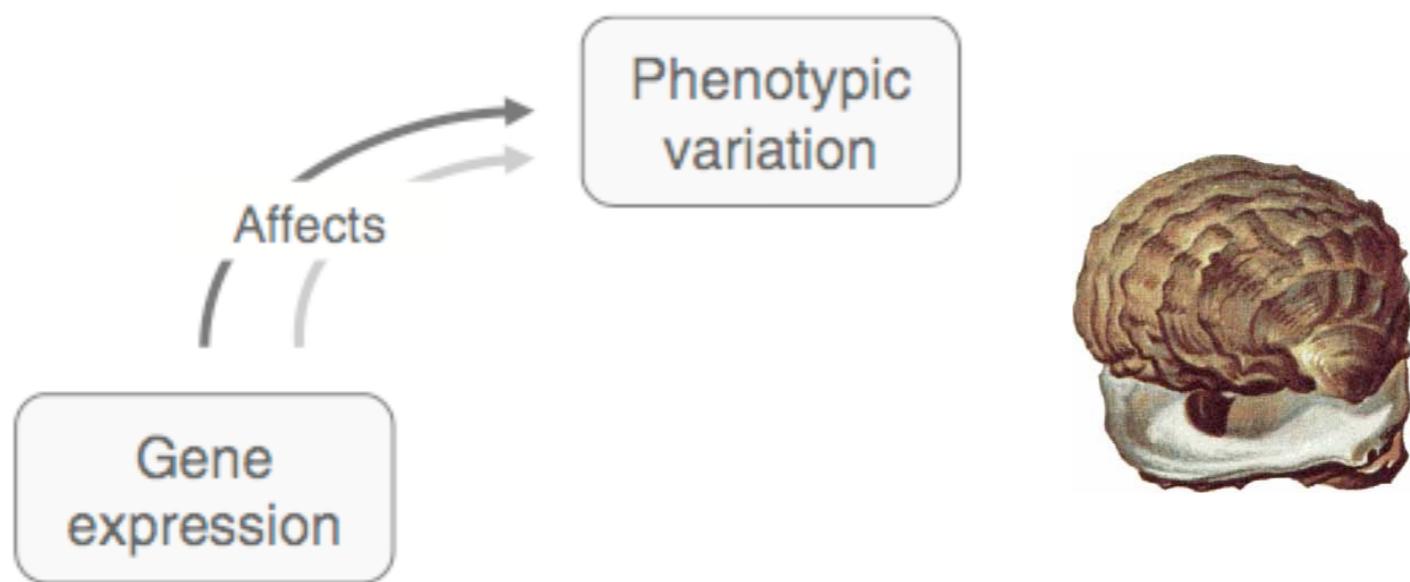
Evidence of epiallele (methylated cytosine)
beneficial to survival
under High $p\text{CO}_2$ conditions

High $p\text{CO}_2$: Non-random
Mortality

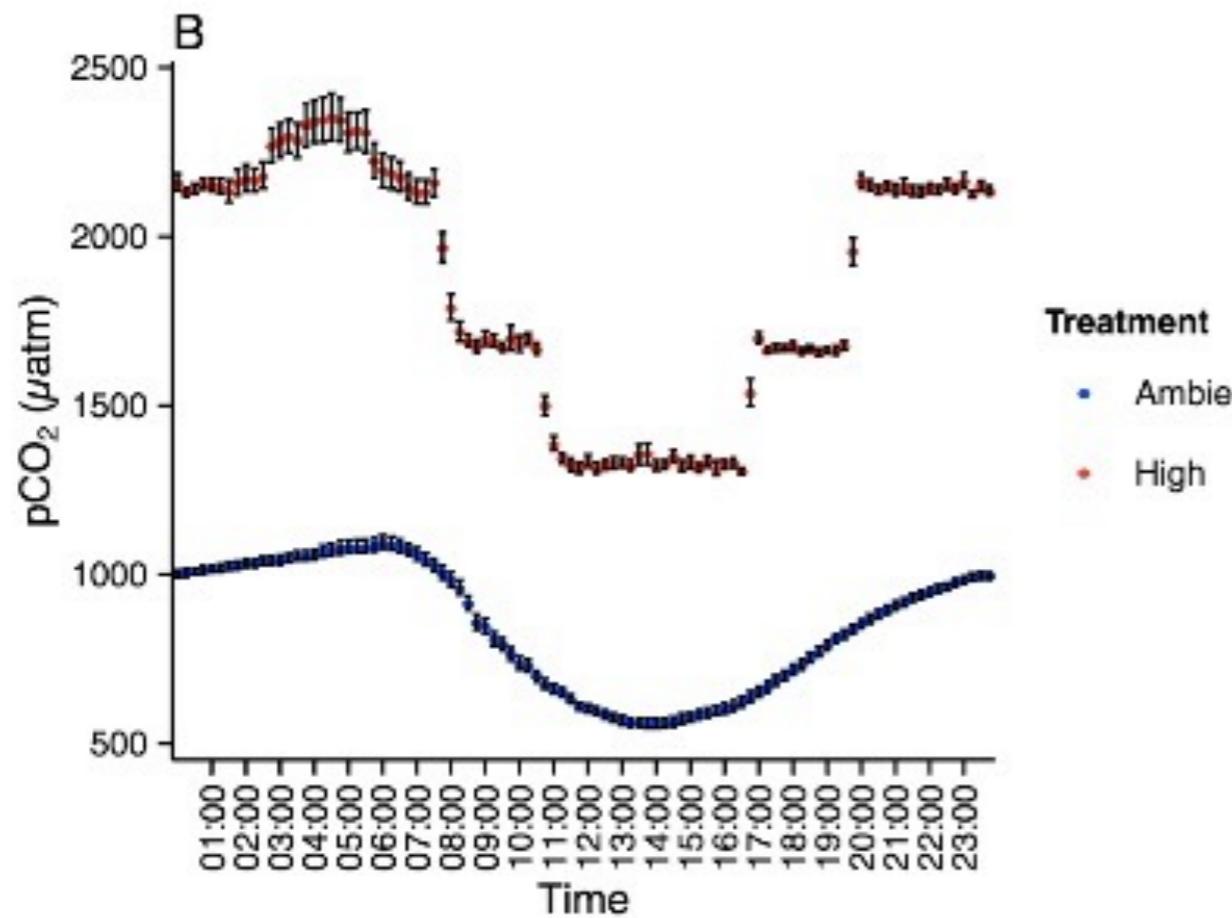
~81% ACGCTGATCGT
~19% ACGCTAATCGT



*



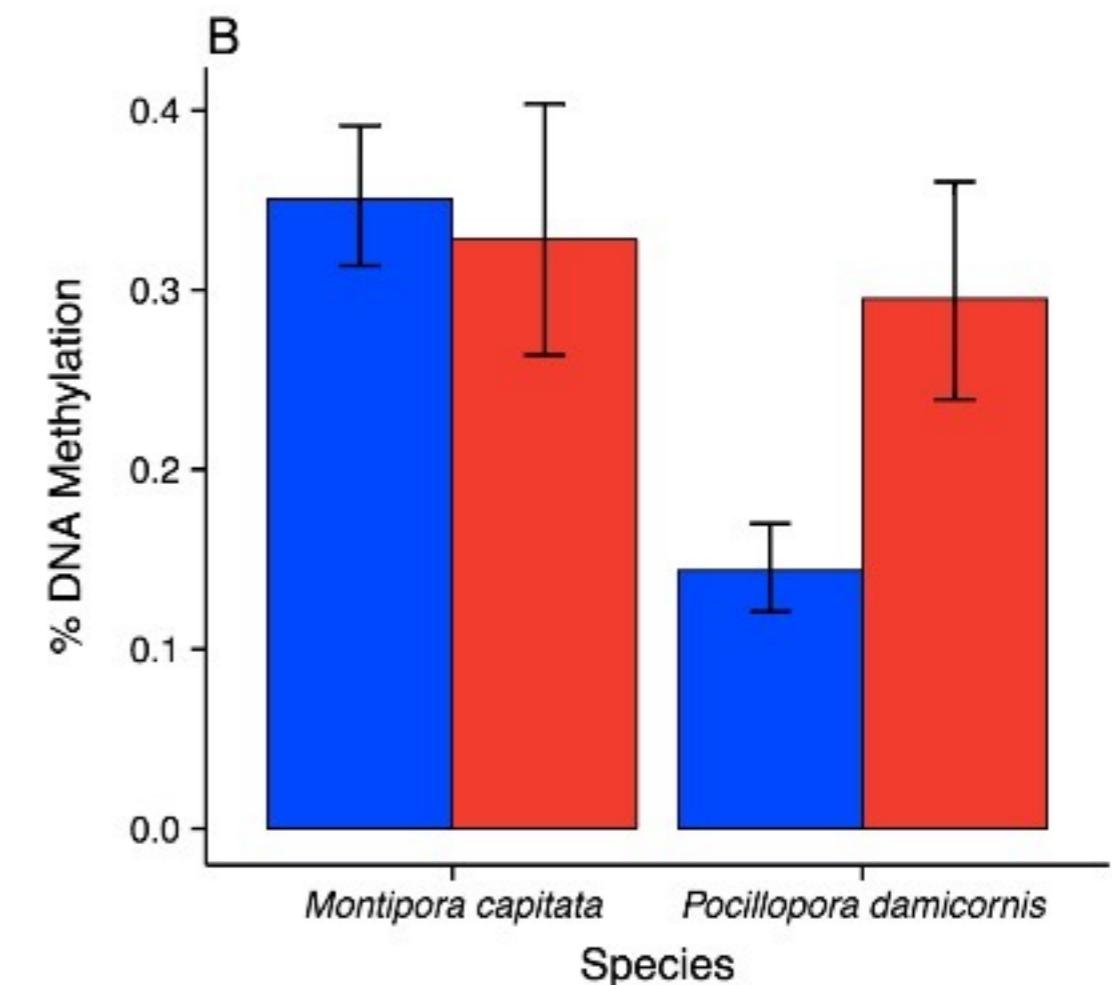
*



Treatment

• Ambient

• High



Evolutionary Applications.
Putnam HM, Davidson JM, and Gates RD. Ocean acidification influences host DNA methylation and phenotypic plasticity in environmentally susceptible corals

Acknowledgements

Mackenzie Gavery

Claire Olson

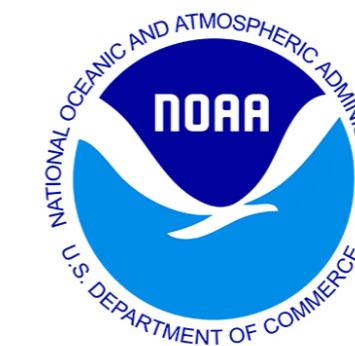
Sam White

Brent Vadopalas

Jake Heare

Jay Dimond

Katherine Silliman



Hollie Putnam
Laura Spencer

slides, data & more @
github.com/sr320/talk-Chicago-eed-2016