Genetic Basis of Growth Under Ocean Acidification in Pacific Oysters

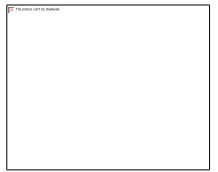
James Dennis-Orr

Supervisors: Dr. Sean Rogers and Dr. Timothy Green

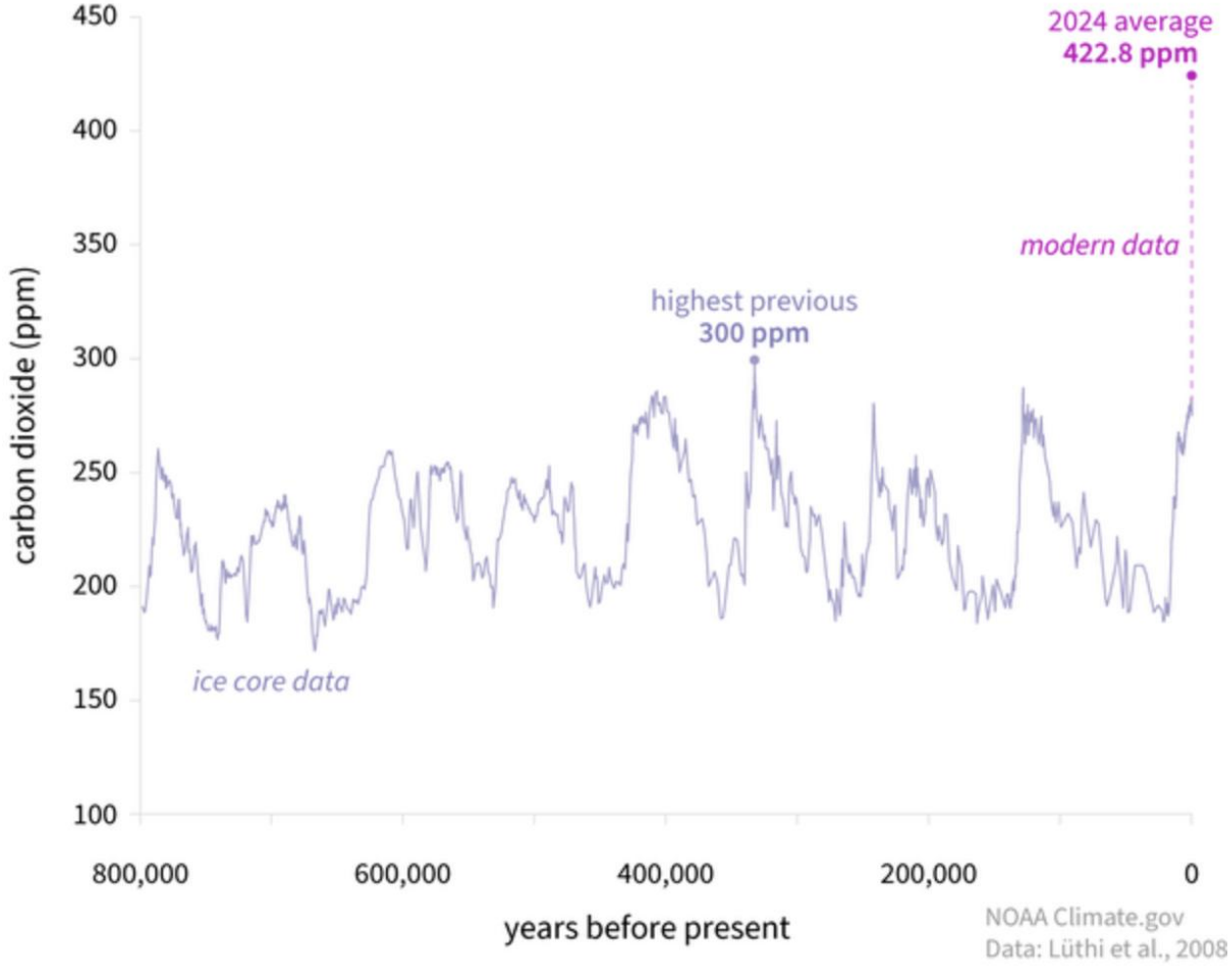
Committee: Chris Pearce and Clara Mackenzie

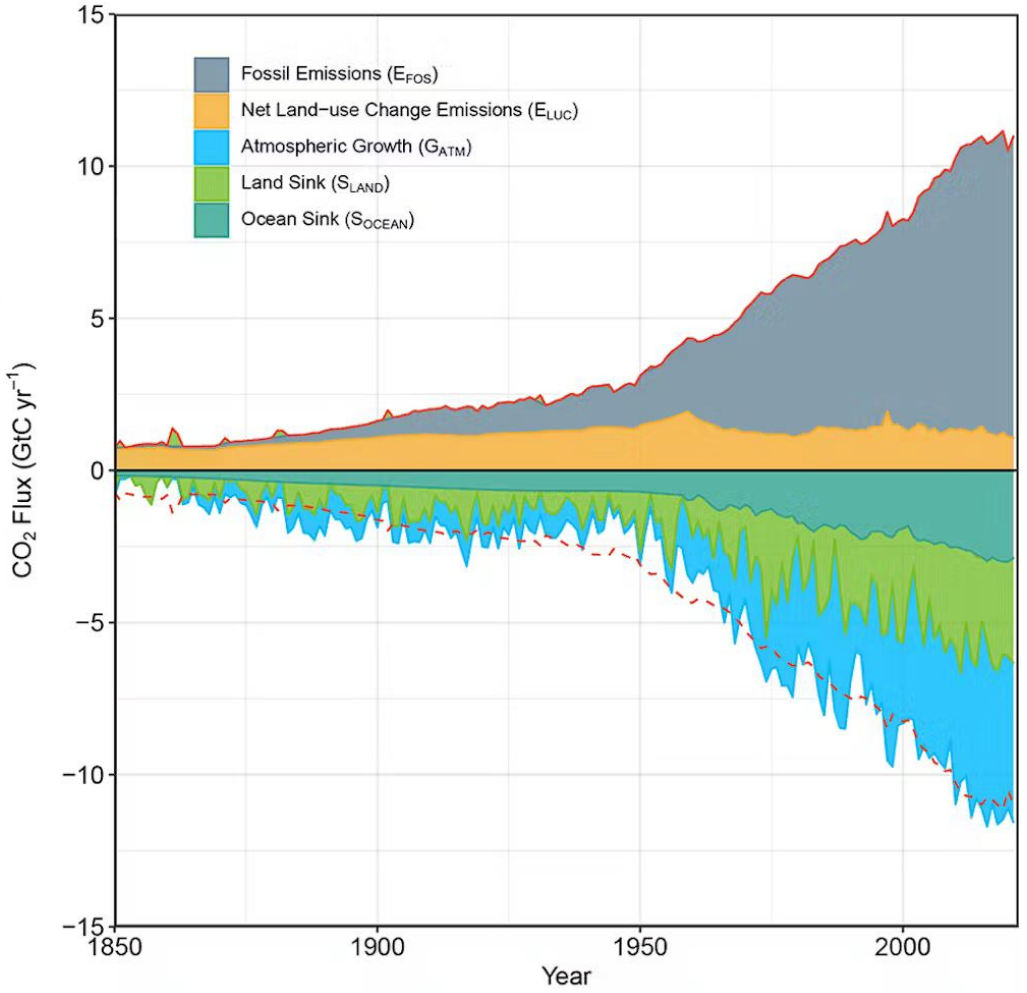
November 12th, 2026



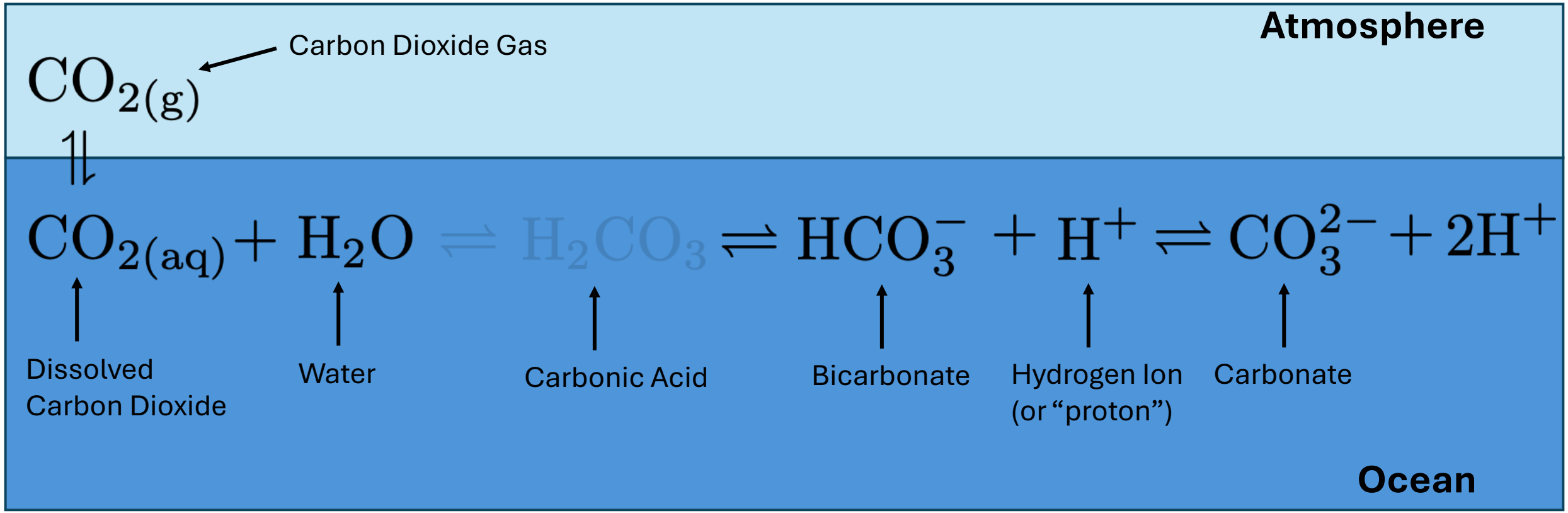




CARBON DIOXIDE OVER 800,000 YEARS



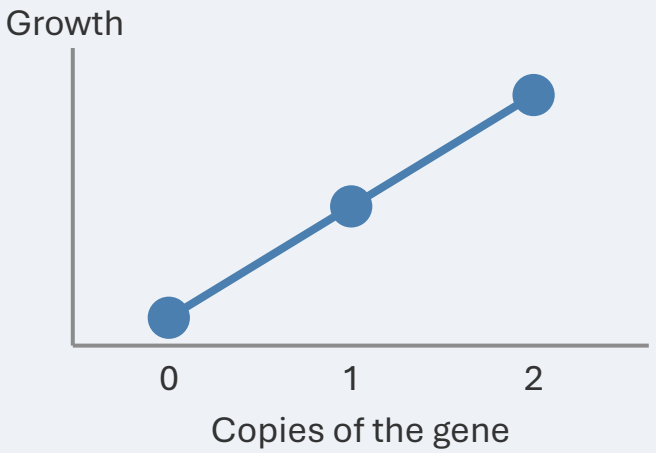


The Issue


Atmosphere
Carbon Dioxide Gas
$CO_{2(g)}$
$\rightleftharpoons$
$CO_{2(aq)} + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_3^{2-} + 2H^+$
Dissolved Carbon Dioxide
Water
Carbonic Acid
Bicarbonate
Hydrogen Ion (or "proton")
Carbonate
Ocean

Additive, Dominance and Epistasis

Additive



Each copy adds the same

Passes reliably from parent to offspring

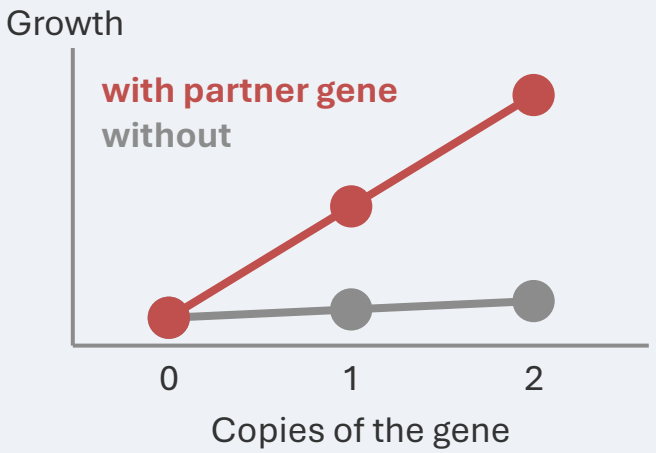
Dominance



One copy does as much as two

Depends on the pair, reshuffled every generation

Epistasis



One gene's effect depends on another

Our oysters: chromosome 6 needs chromosome 9

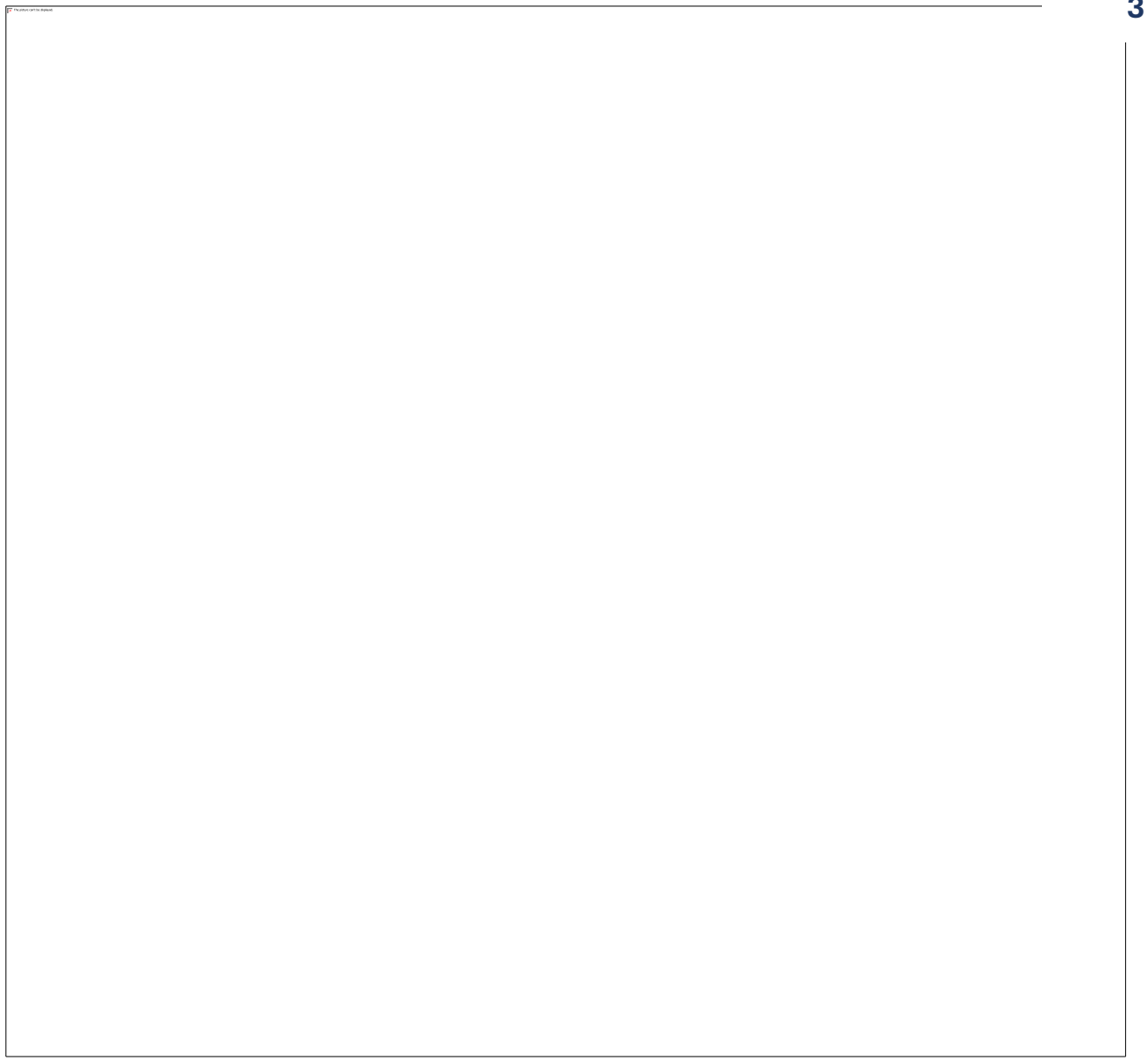
Breeding builds on additive effects. Epistasis is why a marker can help in one family and do nothing in another.

Solution:

Breeding Programs

Marker Assisted Selection

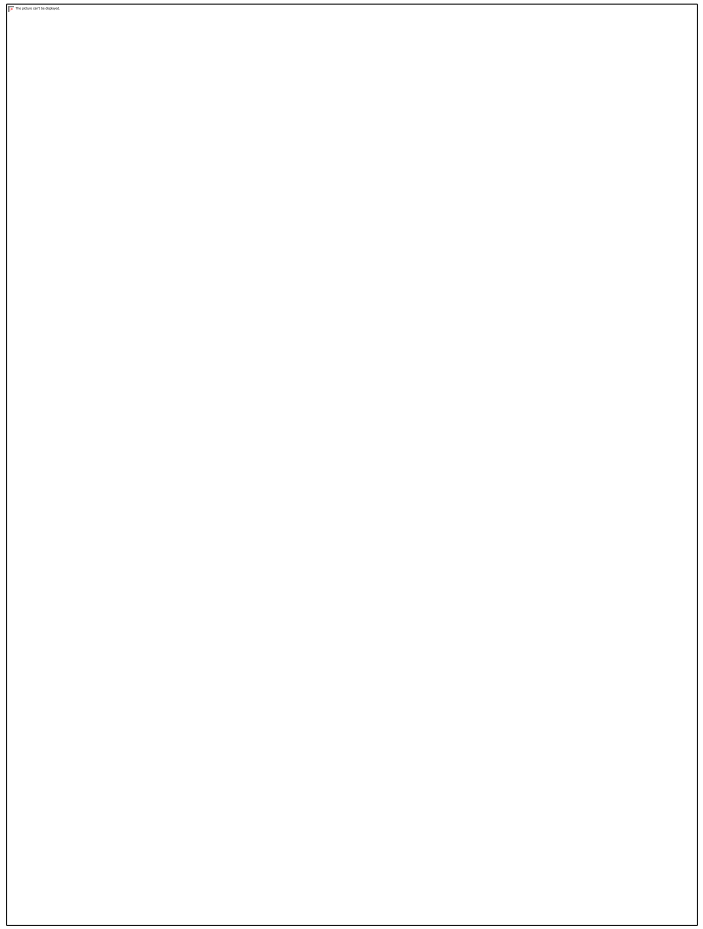
~7–12% growth gain per generation through selective breeding
(Langdon et al. 2003; de Melo et al. 2016)

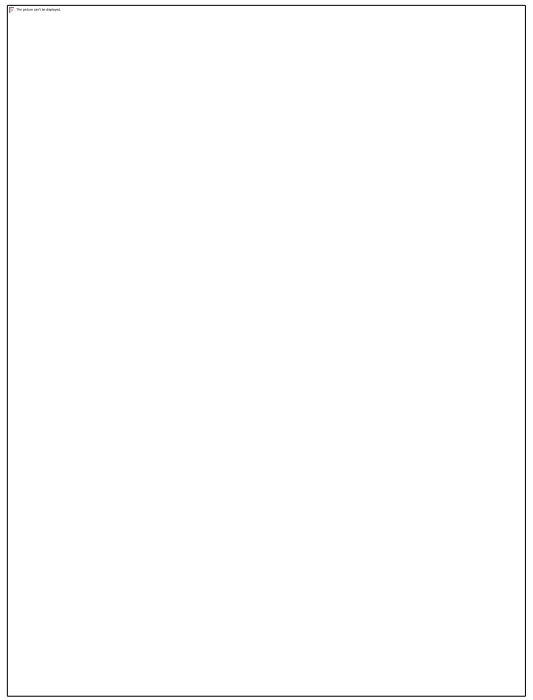


Langdon et al. 2003, Aquaculture 220: 227–244 de Melo et al. 2016, Aquaculture 460: 105–115

The Experiment







19 families, about 25 oysters each, 90 days in control or high pCO_2

A 22% Cost to Growth



What we saw

- Growth fell by about a fifth under high CO_2
- Almost every family grew less
- Some families grew four times faster than others

Growth = weight gained per day
over the 90-day trial

Fast Families Stayed Fast



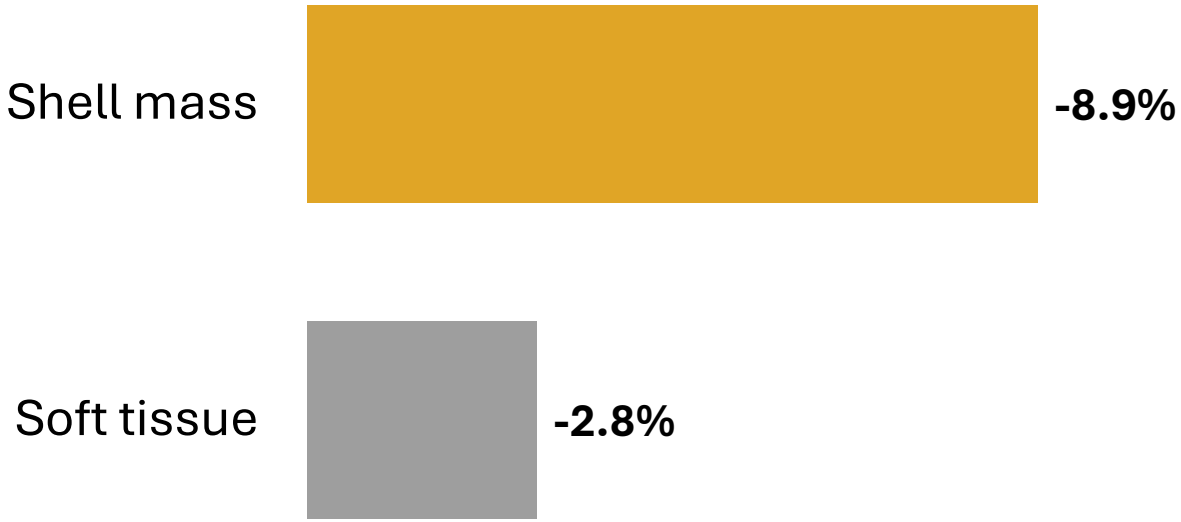
Starting size held equal

- The fastest families in normal water were also the fastest under high CO_2
- Almost the same order in both waters
- No family coped better than the rest

So the target is simply growth

The Cost Lands on Shell

How much lower under high pCO_2



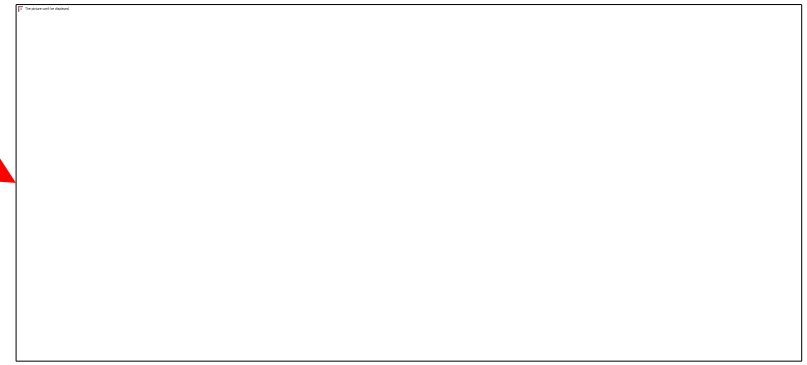
Shell shrinks, soft tissue barely moves

- Shell 8.9% lower ($p < 10^{-6}$)
- Soft tissue 2.8% lower, not significant
- At the same tissue mass: 7.4% less shell
- End-point weights only: says nothing about thickness

Allometric model on 938 oysters: log(shell) ~ log(tissue) × treatment + (1 | family), tissue centred, so the treatment term is the difference at average tissue mass.

Imputing to 36,000 Markers

Parental Data
High Density



Low Density Data
~1,100 markers

High Density Data → Imputed
~36,000 markers

Cheap panel on all animals, dense data on the parents

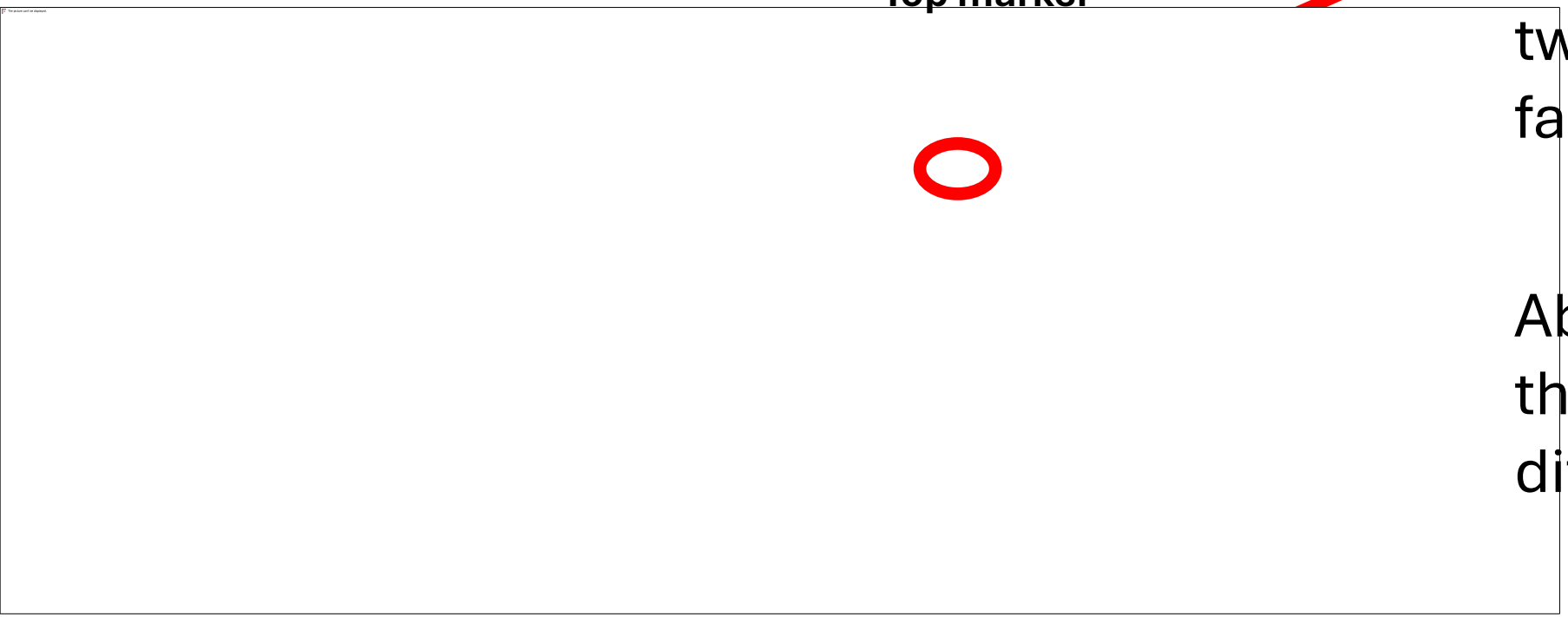
The families fill the gaps. Then a GWAS tests each marker.

Chromosome 6 Stands Out

One region on chromosome 6

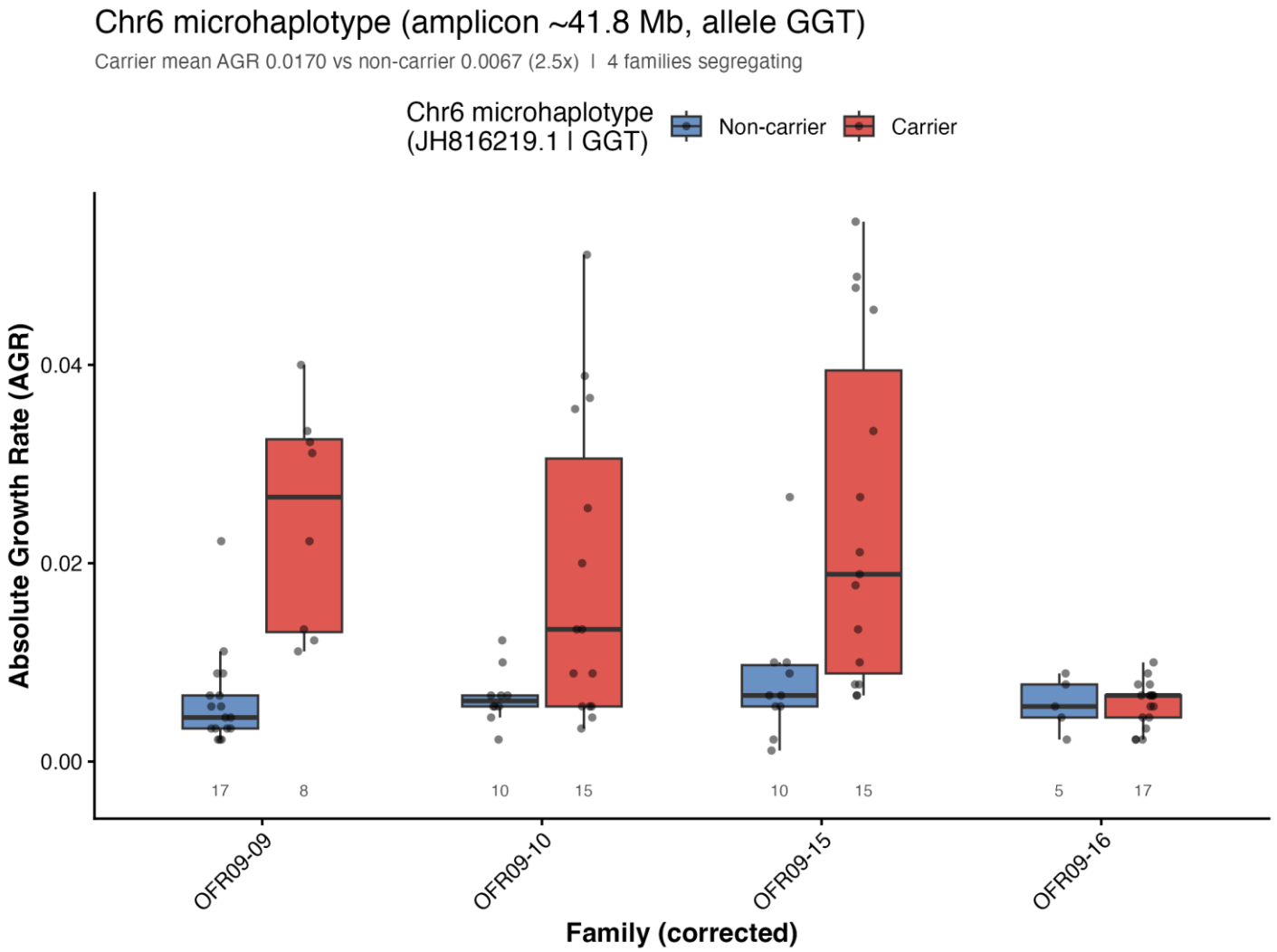
Carriers grew about two and a half times faster

About an eighth of the growth differences



The signal covers a broad region of chromosome 6

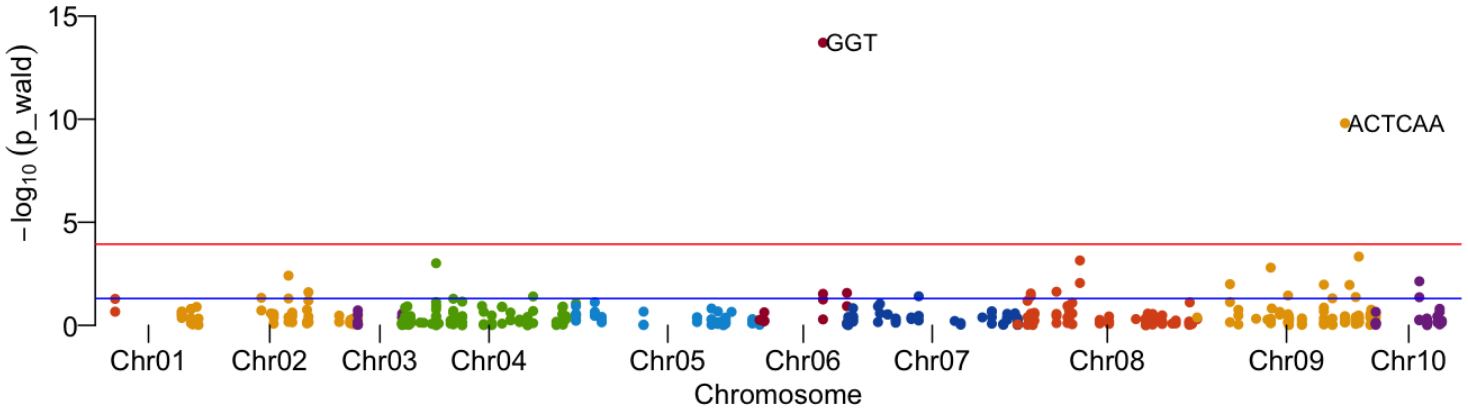
OFR09-16: A Natural Control



- 17 chromosome 6 carriers, no chromosome 9 allele in the family
- Carriers 0.00575 vs non-carriers 0.00578 g/day (p = 0.985)

Same allele, no partner, no effect

A Second Marker, and a Puzzle



Chromosome 6 again, and chromosome 9 as well

- Chr 6 GGT: $p = 1.9 \times 10^{-14}$
- Chr 9 ACTCAA: $p = 1.6 \times 10^{-10}$

But on its own, chromosome 9 does nothing

- Carriers without the Chr 6 allele: 0.0069 vs 0.0067 g/day

The Effect Is Conditional

Chromosome 9 was found by reading short stretches of DNA whole



- Neither marker: baseline
- Chromosome 9 alone: no change
- Chromosome 6 alone: a small lift
- Both together: about four times faster

Far more than the two added together

- Seen within families, not just between them
- In all three families that carry both

Two Markers, Four Times the Growth

What we found

Two regions of the genome that work as a team

Together, oysters grew about four times faster

The first time this has been tested in Pacific oysters

For the VIU program

Fast families stayed fast under acidification

Marker-assisted selection could work here

Select on both markers together

Thank you!

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