# Transcriptomic Analysis Reveals the Growth Regulatory Mechanisms in Diploid, Triploid, and Tetraploid Pacific Oyster (*Crassostrea gigas*)

Yuting Meng [1, 2, †], Yousen Zhang [1, †], Weijun Wang [1, 2, 3, *], Yancheng Zhao [1], Daowen Qiu [1], Zan Li [1, 3], Guohua Sun [1, 3], Cuiju Cui [1, 3], Qiang Wang [1, 3], Zhongyi Liu [4] and Jianmin Yang [1, 3, *]

[1] School of Fisheries, Ludong University, Yantai 264025, China
[2] College of Fisheries and Life Science, Shanghai Ocean University, Shanghai 201306, China
[3] Yantai Haiyu Marine Technology Co., Ltd., Yantai 264000, China
[4] 1.8 Meters Marine Technology (Zhejiang) Co., Ltd., Hangzhou 311100, China

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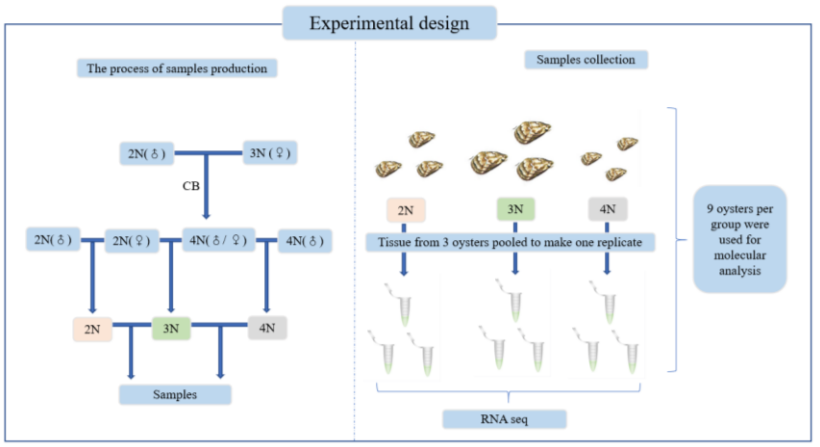
## Abstract

Ploidy level exerts profound influences on the phenotypic and physiological traits of *Crassostrea gigas*. Compared to diploids, triploids exhibit desirable characteristics such as sterility, a faster growth rate, and improved meat quality. In contrast, tetraploids often suffer from slow growth, yet the mechanisms underlying these polyploid-associated traits remain unclear. This study aimed to elucidate these mechanisms by comparing differences in growth-related phenotypes and gene expression among diploid, triploid, and tetraploid oysters. Through trend analysis, we clustered genes with similar expression changes across ploidy levels and conducted functional enrichment analysis on these gene clusters. The results revealed that genes associated with the innate immune response were significantly up-regulated in tetraploids, whereas genes related to biomineralization and metabolism were markedly up-regulated in triploids.

These findings suggest that tetraploid oysters may mount a stronger innate immune response compared to diploids and triploids, while triploids demonstrate superior growth performance. This study provides valuable resources for investigating the functional aspects of genes related to polyploid phenotype differences.




## Results

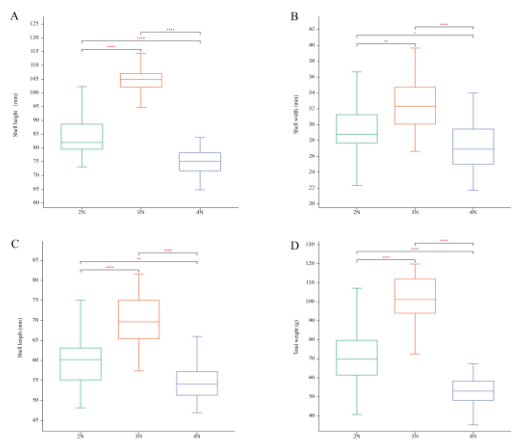



Figure 1. Analysis of phenotypes in *C. gigas* between 2N (diploid), 3N (triploid), and 4N (tetraploid) oysters. (A) Shell height; (B) Shell width; (C) Shell length; (D) Total weight. The symbol "*" indicates a difference among the three groups at the $p < 0.05$ level; "**" indicates a significant difference among the three groups at the $p < 0.01$ level; "****" indicates a significant difference at the $p < 0.0001$ level.

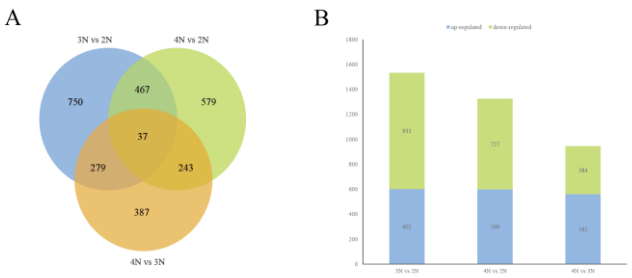



Figure 2. Venn diagram and histogram of the number of DEGs. (A) Venn diagram of the number of DEGs. (B) Histogram showing the number of DEGs that were up- or down-regulated between different groups.

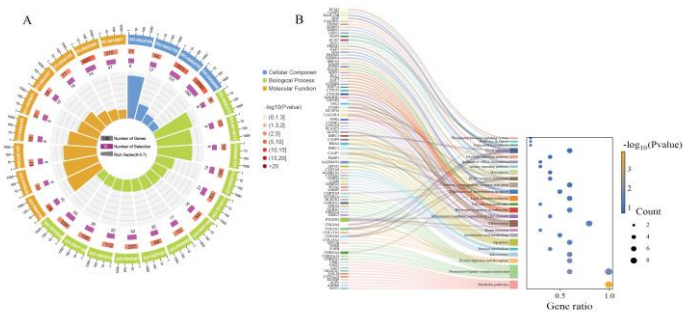



Figure 3. The GO (A) and KEGG (B) enrichment of DEGs.

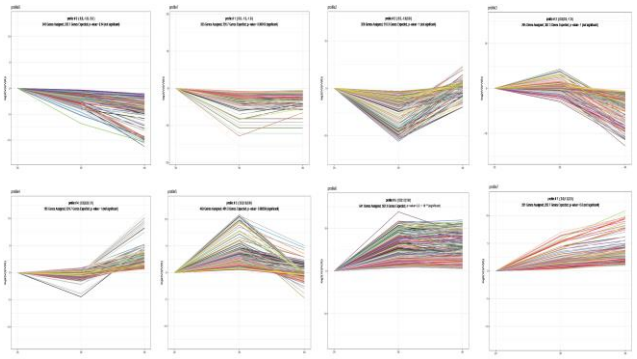


Figure 4. Series Test of Cluster. The lines in different colors represent distinct genes. The number of genes and *p*-values for different ploidy gene expression patterns are shown in the figure.

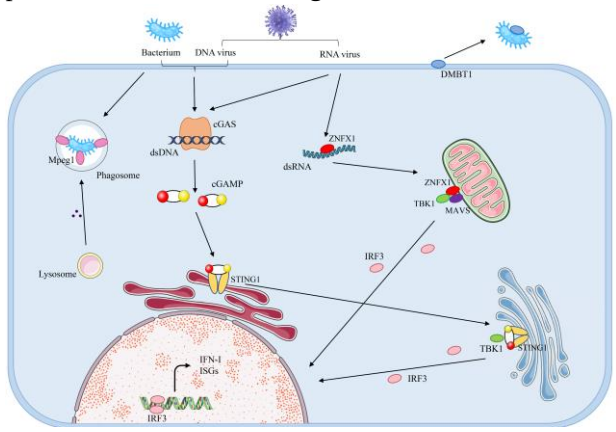



Figure 6. Molecular mechanisms associated with innate immunity in tetraploid oysters

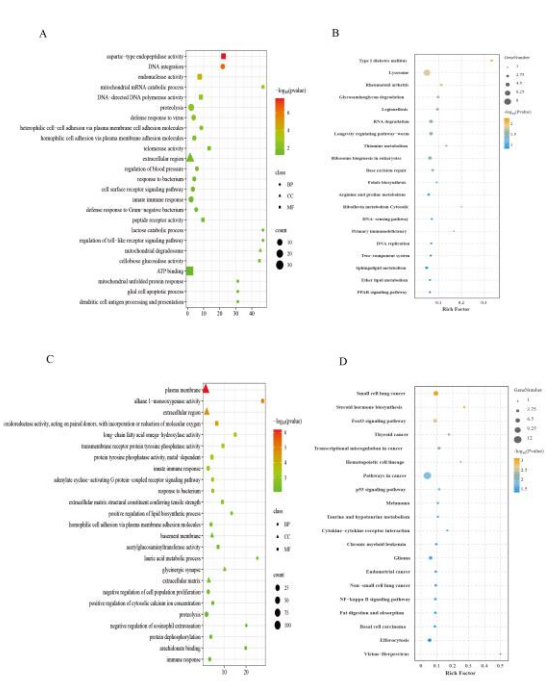



Figure 5. GO and KEGG Bubble plots. GO (A) and KEGG(B) bubble plots of DEGs in profile 2 and profile 4. GO (C) and KEGG (D) bubble plots of DEGs in profile 3 and profile 5.

## Conclusions

1. Tetraploid oysters exhibited marked overexpression of genes related to innate immunity (STING1, ZNFX1, Mpeg1, etc.). This hyperactivation of the innate immune response appears to demand diversion of energy resources away from growth and metabolism toward immune defense. Although this response may enhance pathogen resistance, the associated energetic cost is likely a primary contributor to the observed growth retardation in tetraploids.
2. Triploid oysters achieve enhanced growth performance through a coordinated multi-mechanism strategy: Overexpression of genes involved in steroid hormone biosynthesis (CYP17A1, CYP7B1) disrupts reproductive development, resulting in functional sterility and redirecting energy toward somatic growth; elevated expression of taurine synthesis-related genes (CDO1, FMO5) enhances antioxidant capacity and osmoregulatory function, thereby improving environmental stress tolerance; upregulated expression of biomineralization genes such as BMP3 and BMP7 promotes shell formation, directly accelerating growth rates.