New Genes and Functional Innovation

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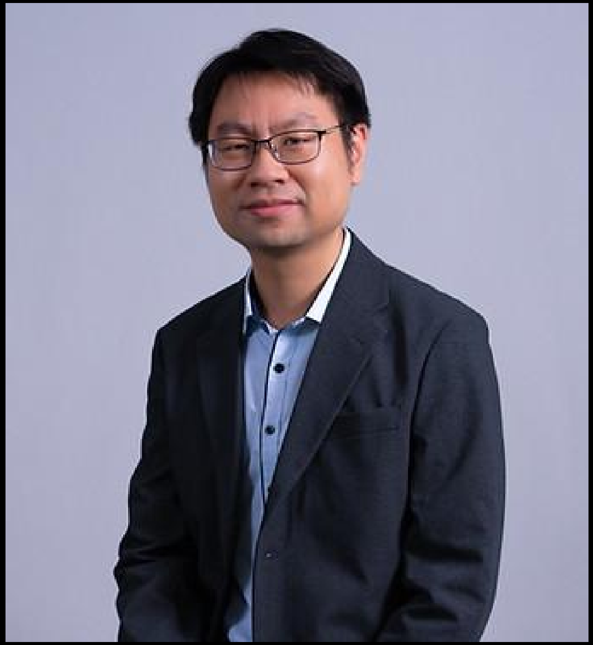
When I think about the Topic…

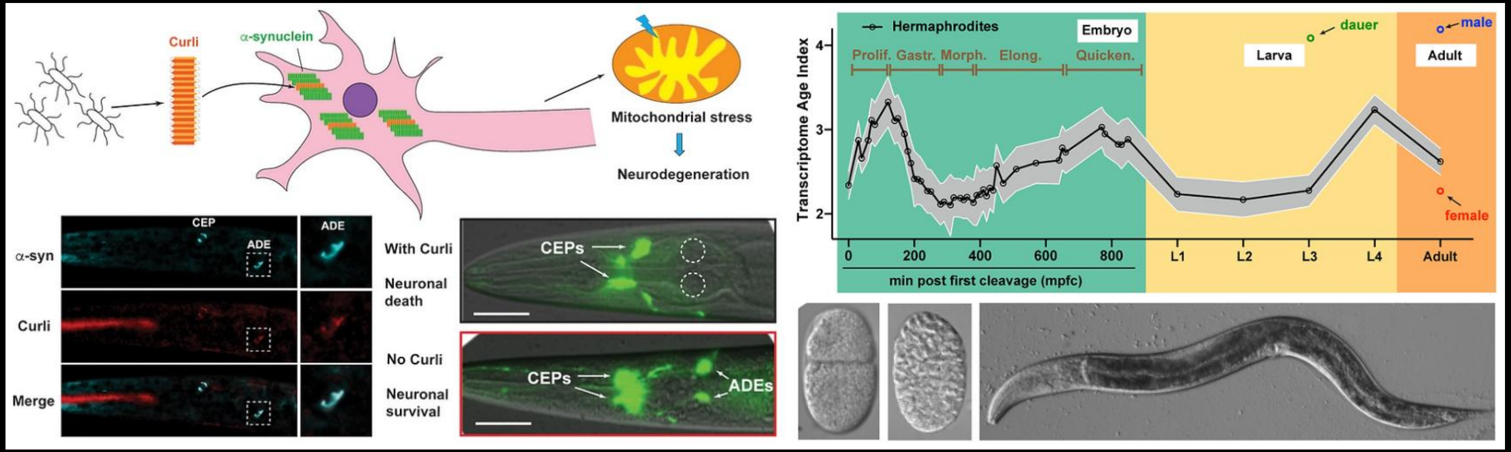
Q1: How does expression of new genes change during the development?

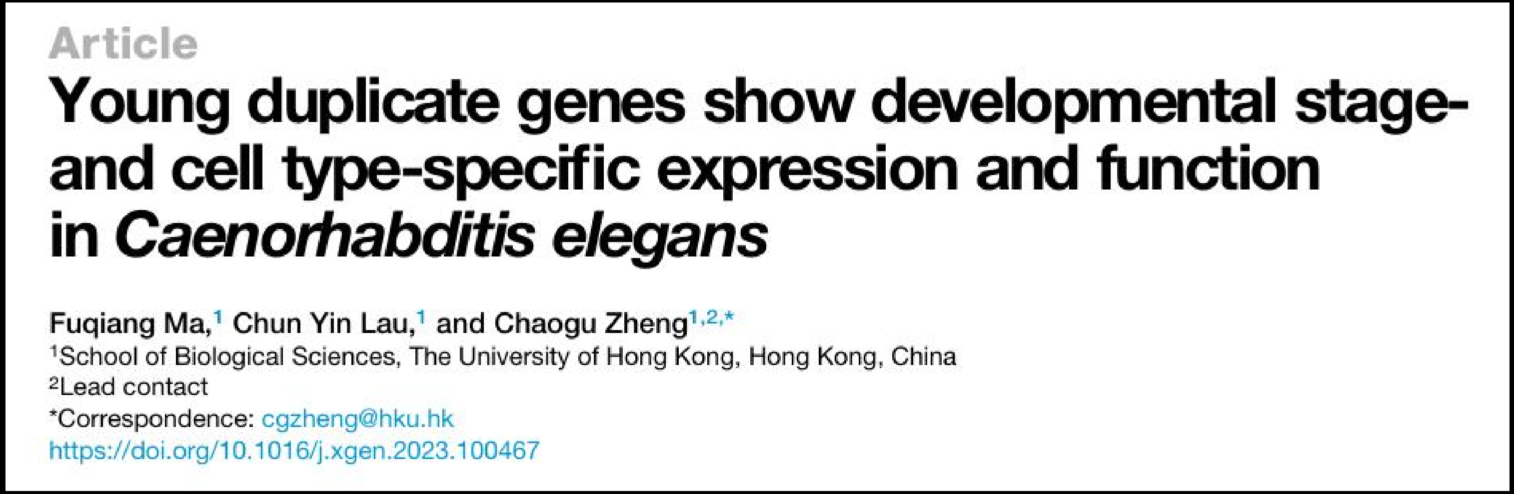
Q2: Are these gene show specific spatial pattern?

Q3: Do they really cause a phenotype innovation during the development?

Article Information







Article

Young duplicate genes show developmental stage- and cell type-specific expression and function in *Caenorhabditis elegans*

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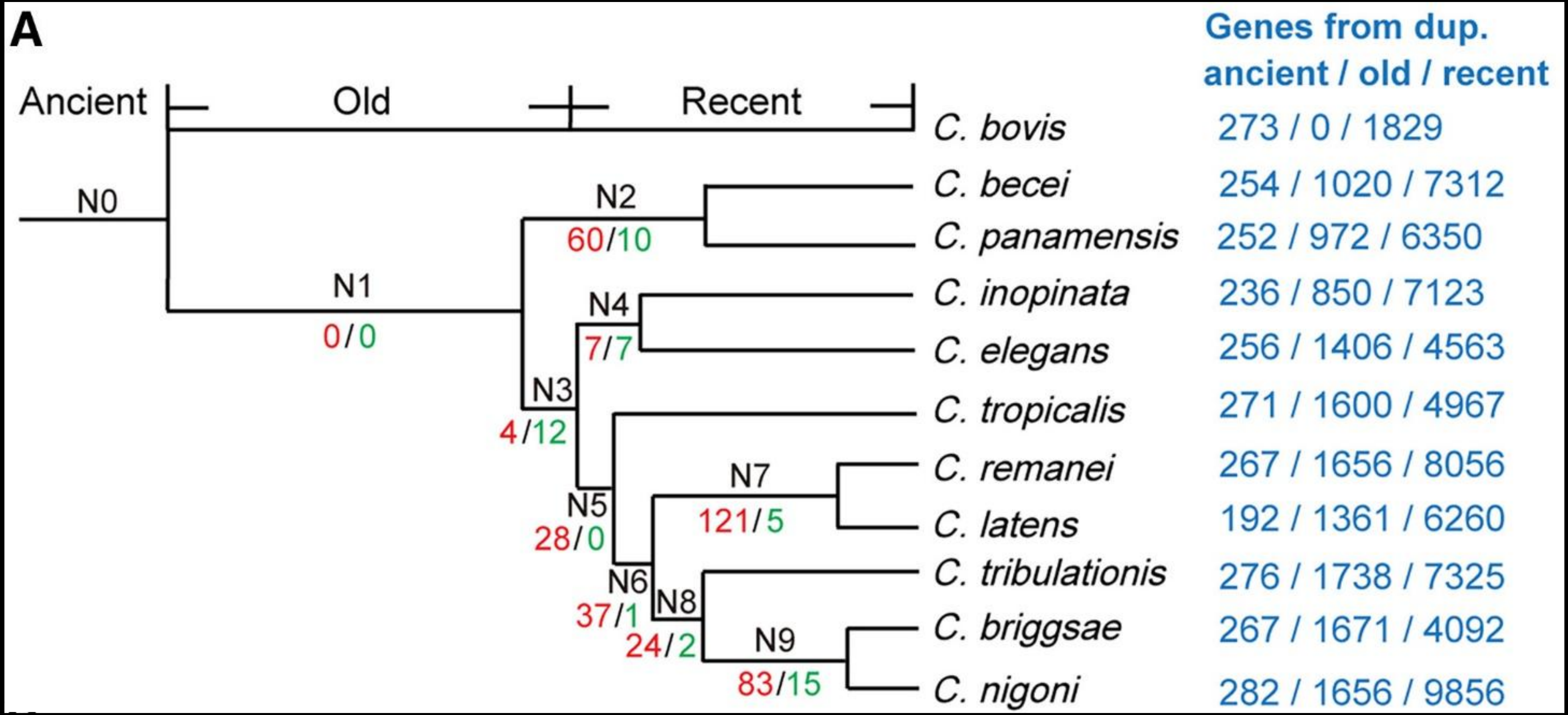
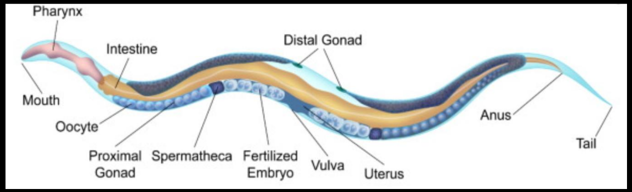
Definition of newly duplicated genes



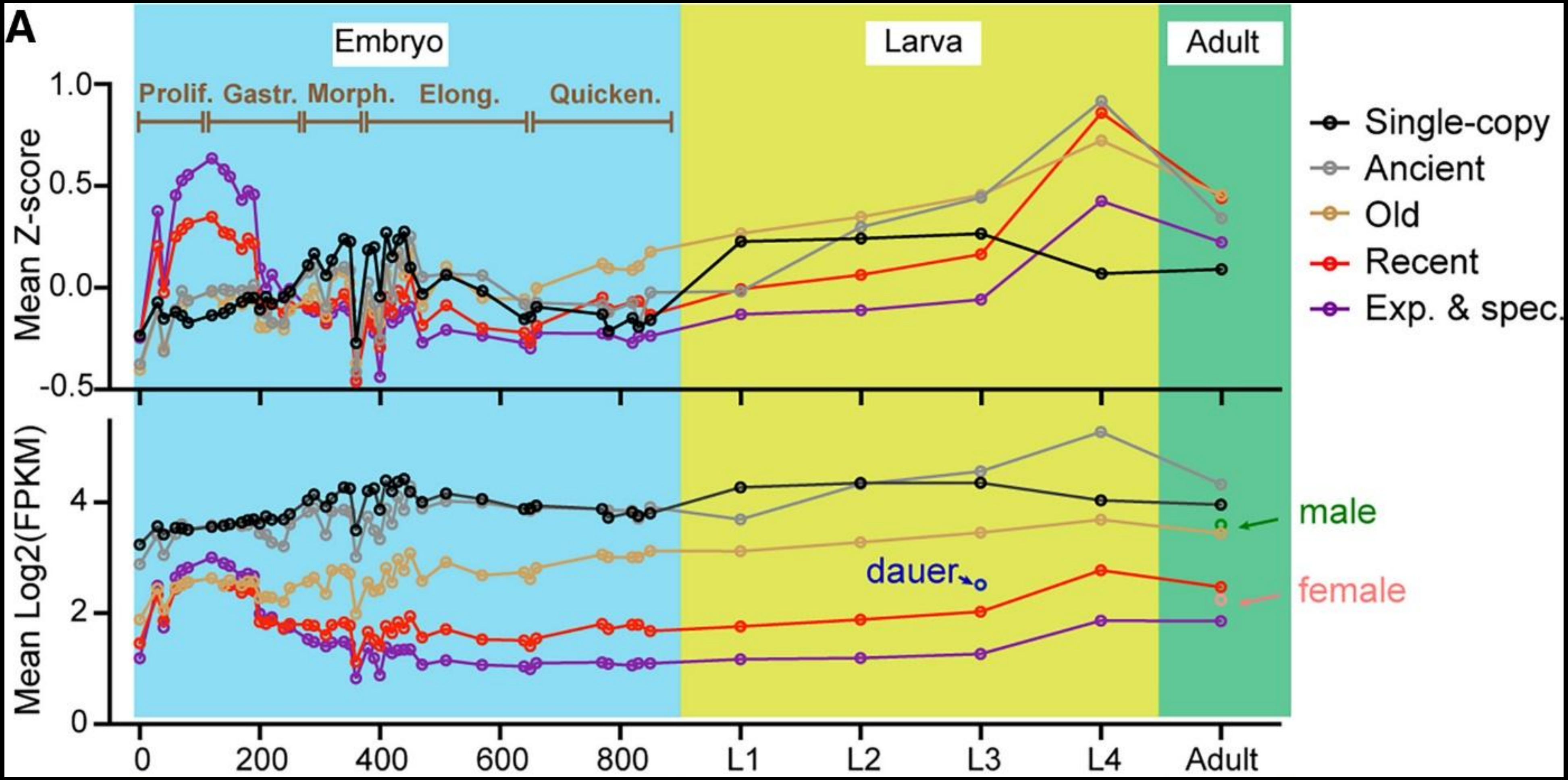
	Genes from dup. ancient / old / recent
C. bovis	273 / 0 / 1829
C. becei	254 / 1020 / 7312
C. panamensis	252 / 972 / 6350
C. inopinata	236 / 850 / 7123
C. elegans	256 / 1406 / 4563
C. tropicalis	271 / 1600 / 4967
C. remanei	267 / 1656 / 8056
C. latens	192 / 1361 / 6260
C. tribulationis	276 / 1738 / 7325
C. briggsae	267 / 1671 / 4092
C. nigoni	282 / 1656 / 9856



Nematode (线虫)
Caenorhabditis elegans **(秀丽隐杆线虫)**

Comparison of recently duplicated genes and old genes

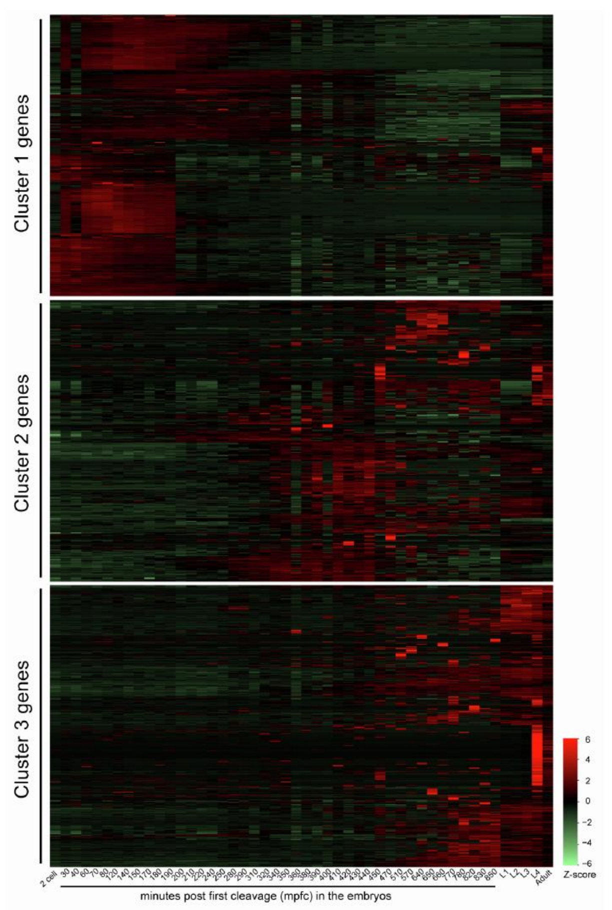
time-specific
expression

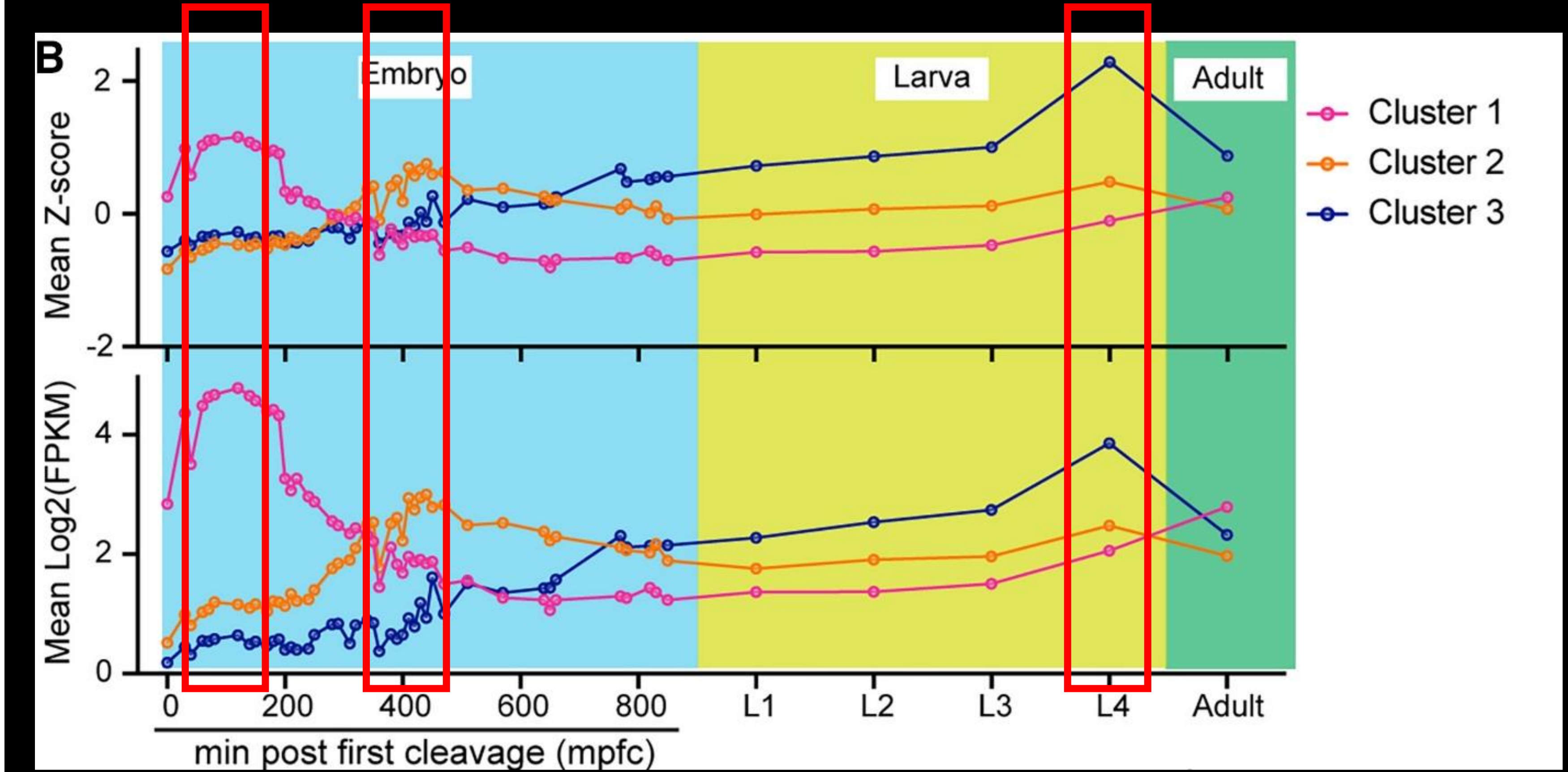


lower
expression

Newly duplicated genes show lower but more time-specific expression dynamics.

Recently duplicated genes can be divided into 3 clusters

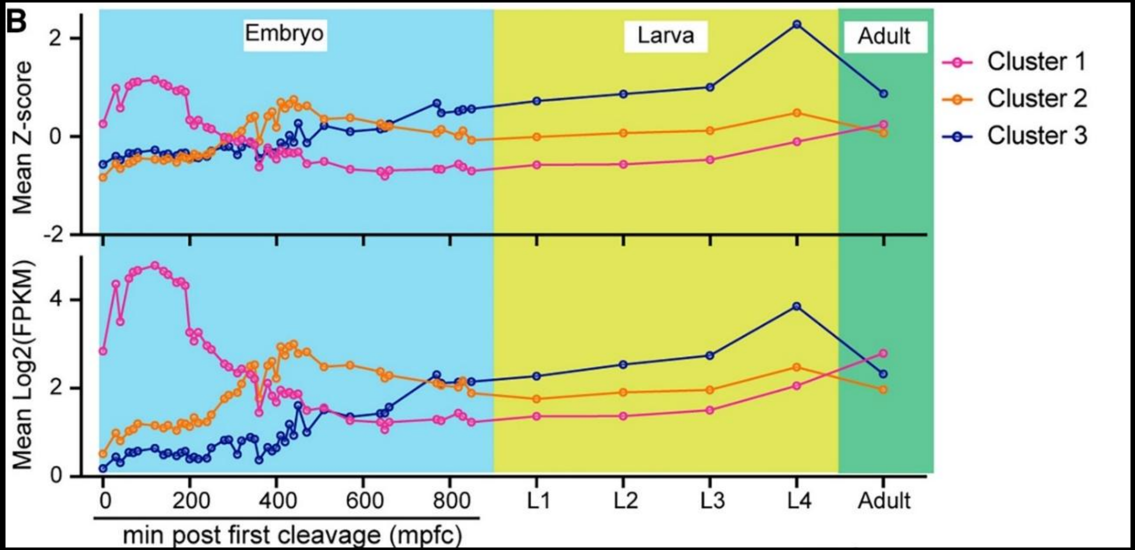


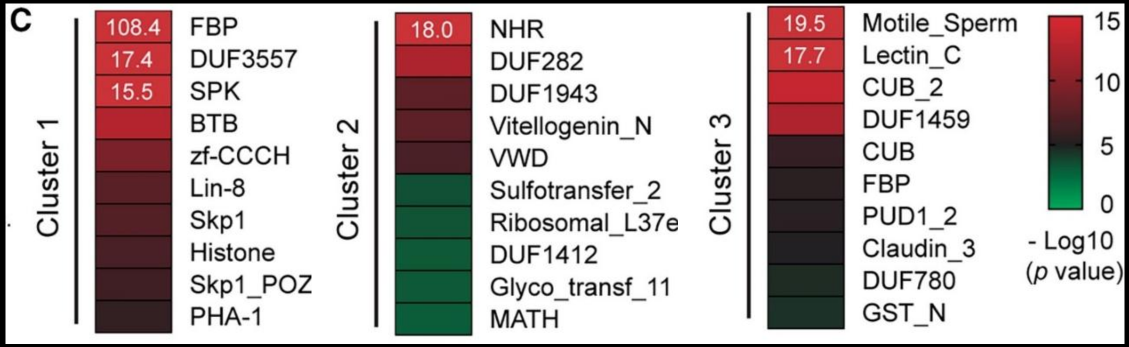


3 clusters respectively reach peak expression at 70 mpfc(min post first cleavage), 440mpfc and L4 stage.

Function and essentiality of recently duplicated genes

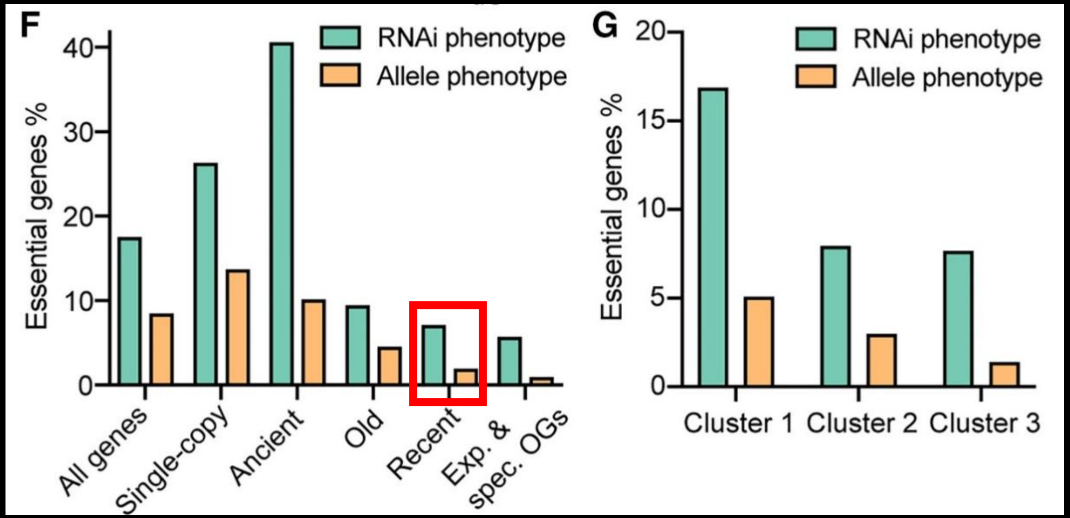
- **Function**



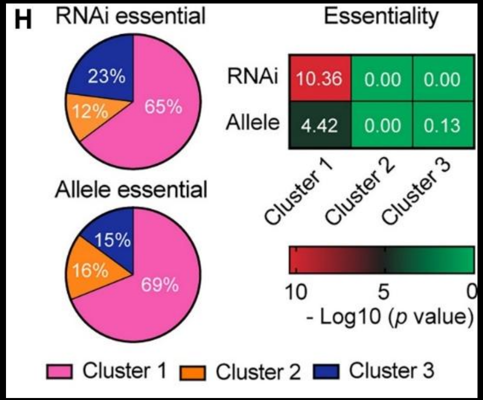


- Cluster1: maternal-to-zygotic transition
- Cluster2: gene expression
- Cluster3: spermatogenesis and immunity

- **Essentiality**

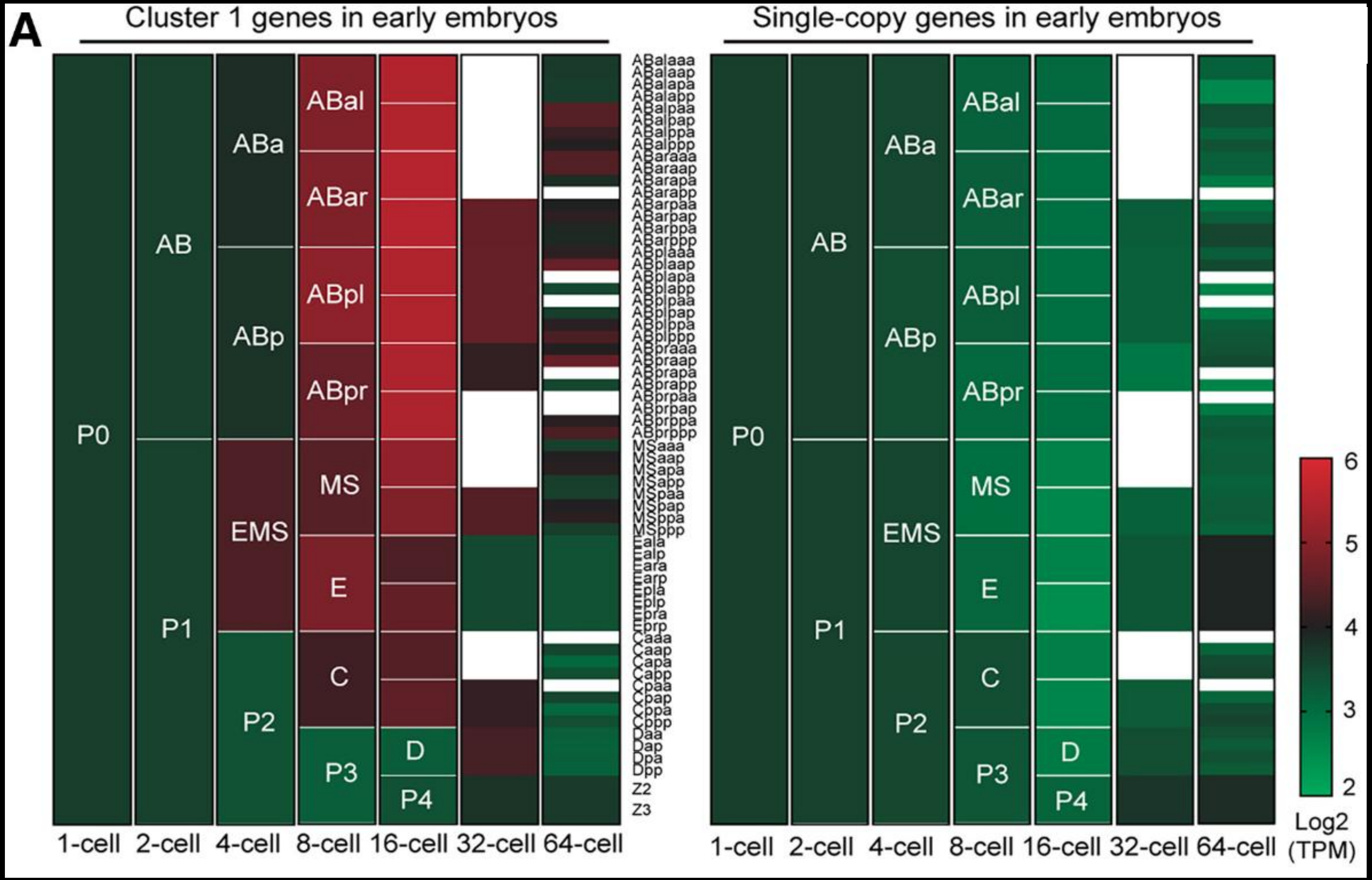


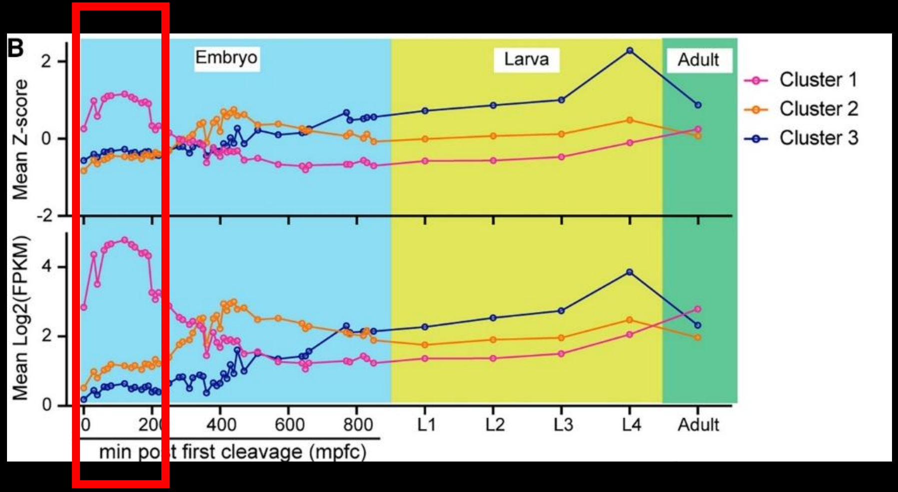
🟩 *RNAi* for knockdown
🟧 *Allele* for knockout

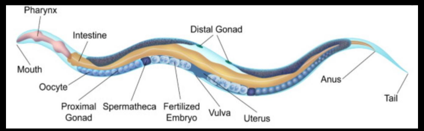


- Young genes show low essentiality
- Cluster1 genes have *relatively high essentiality*

Gene expression spatial comparison



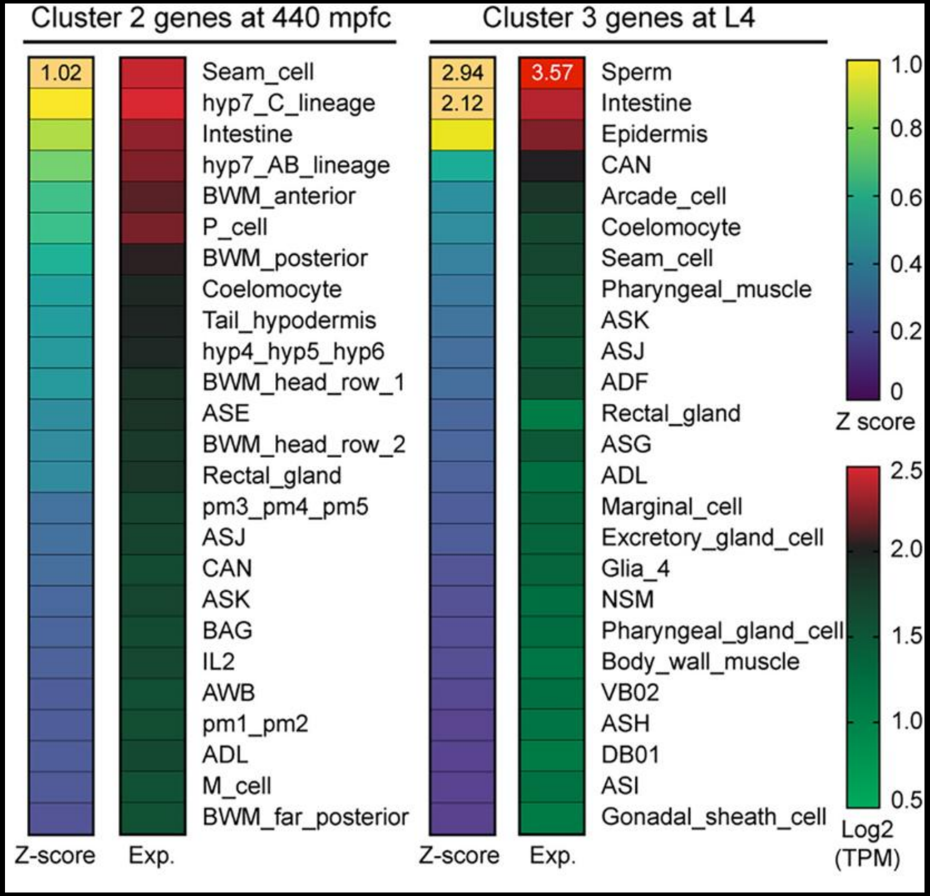


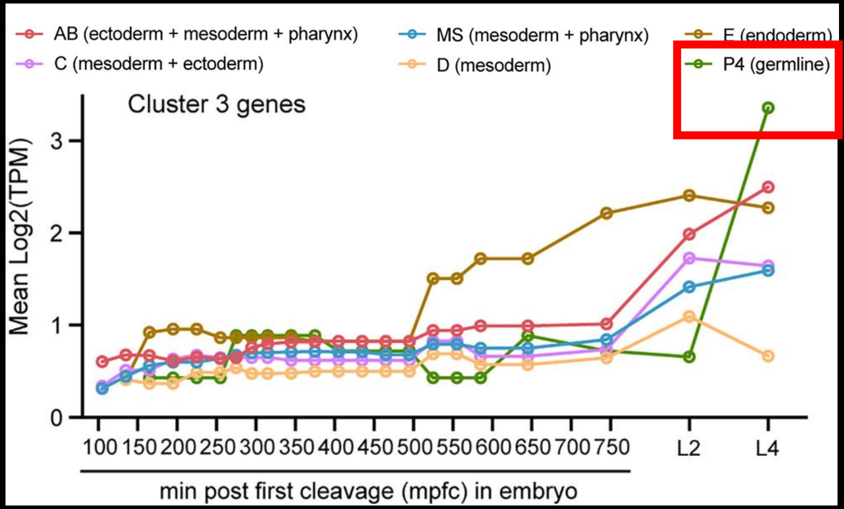


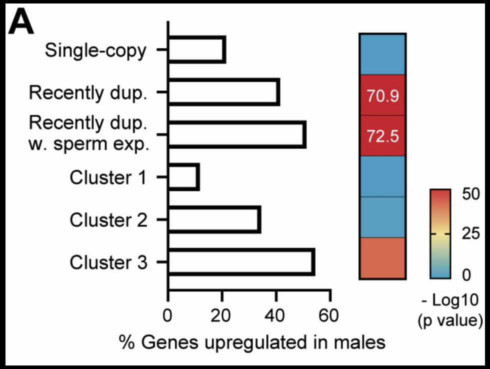
- ➢ AB
  - ➢ ectoderm [外胚层], mesoderm[中胚层], pharynx [咽]
- ➢ EMS
  - ➢ MS -> mesoderm [中胚层], pharynx [咽]
  - ➢ E -> endoderm [内胚层]
- ➢ P2
  - ➢ C -> mesoderm [中胚层], ectoderm [外胚层]
  - ➢ P3 -> **germline cells**

- Cluster1 gene show highest expression in AB lineage, 16-cell stage, while the expression of Cluster1 in **germline cells** is the **lowest**.

Gene expression spatial comparison







Male vs. hermaphrodites

‘**out of testis**’ pattern

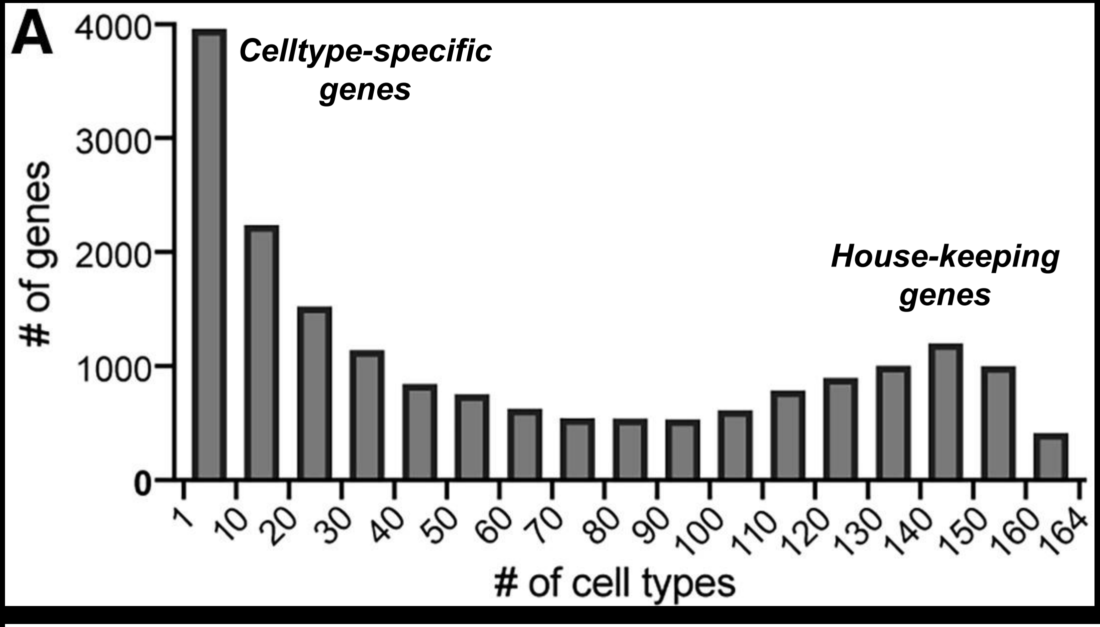
majority of new genes exhibit testis expression

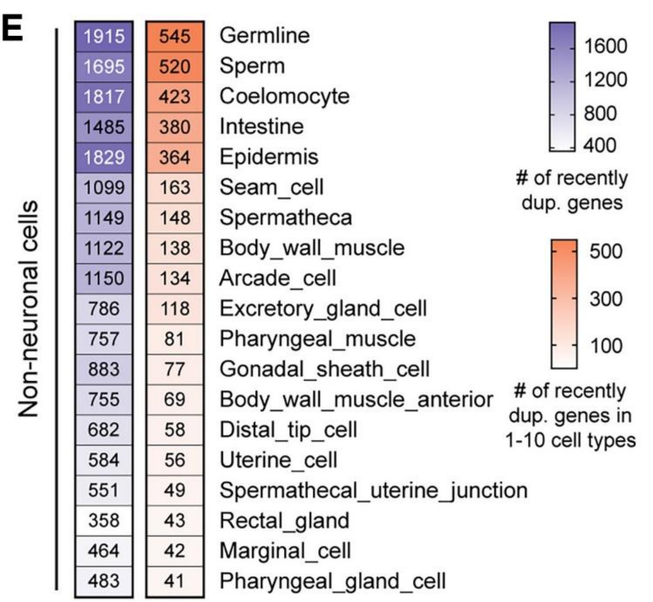
Drosophila

Human

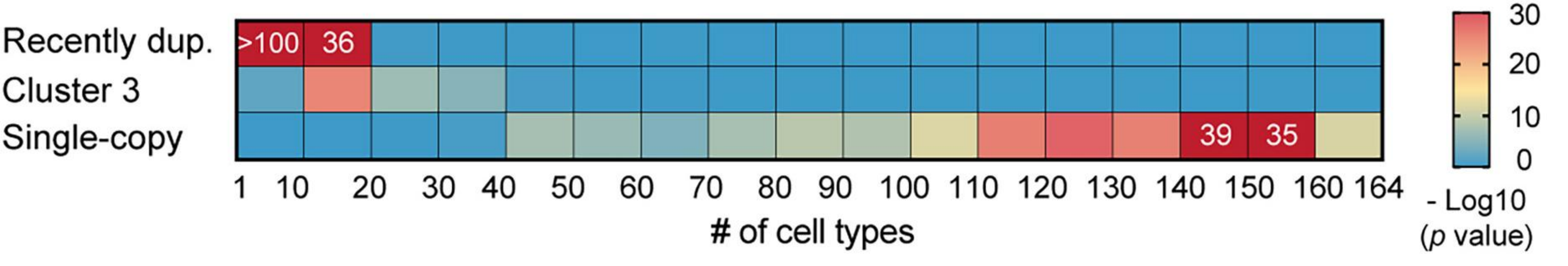
- Cluster2 and Cluster3 genes are enriched in *specific cell types* at the single-cell level
- Recently duplicate gene, especially Cluster3 gene show male-biased expression, which supports out-of-testis theory

Expression of young duplicate genes is highly restricted among differentiated cell types

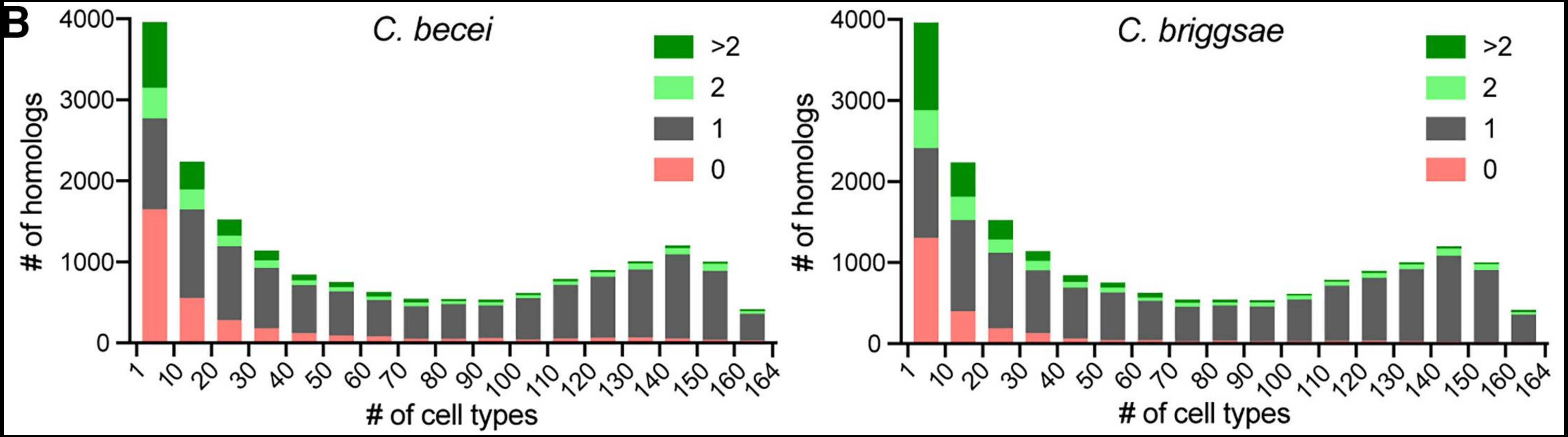




1915	545	Germline
1695	520	Sperm
1817	423	Coelomocyte
1485	380	Intestine
1829	364	Epidermis
1099	163	Seam_cell
1149	148	Spermatheca
1122	138	Body_wall_muscle
1150	134	Arcade_cell
786	118	Excretory_gland_cell
757	81	Pharyngeal_muscle
883	77	Gonadal_sheath_cell
755	69	Body_wall_muscle_anterior
682	58	Distal_tip_cell
584	56	Uterine_cell
551	49	Spermathecal_uterine_junction
358	43	Rectal_gland
464	42	Marginal_cell
483	41	Pharyngeal_gland_cell

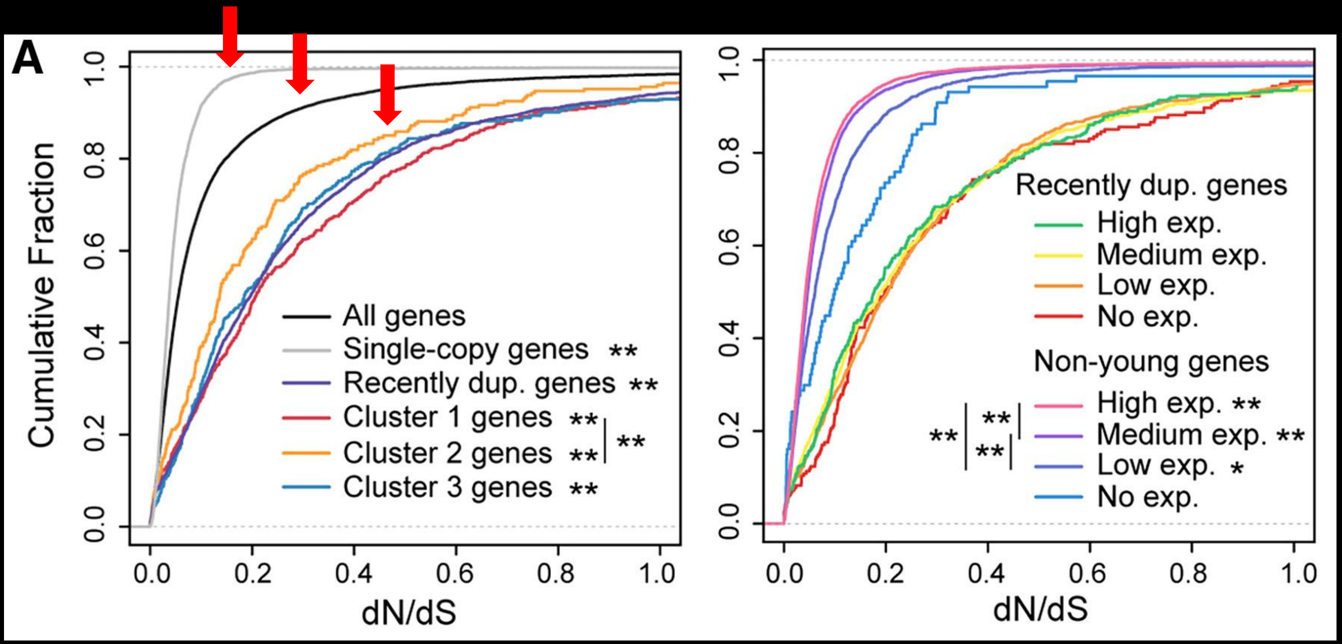


Cell type specific genes are more likely to gain or loss

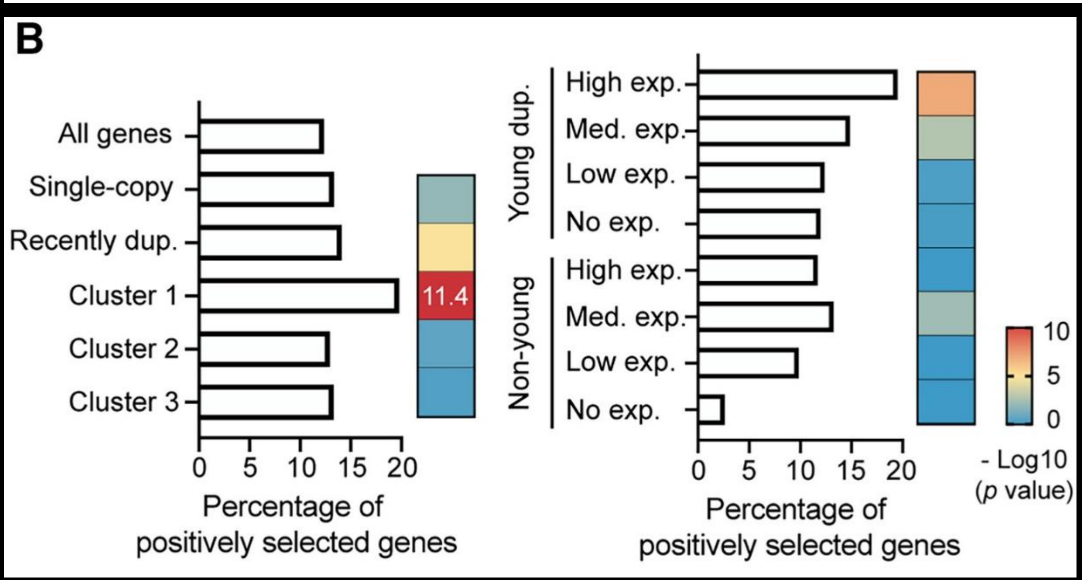


Young duplicate genes are subjected to weak purifying selection and show rapid evolution signal

- **Weak purifying selection**



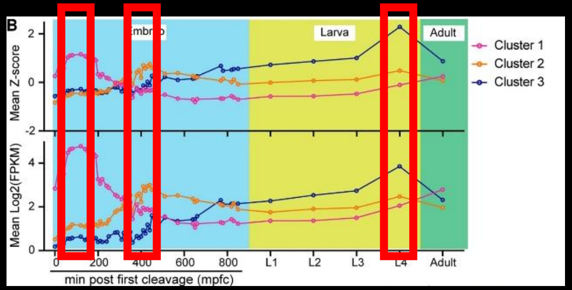
- **Positive selection**



- Older
  - higher expression
  - with purifying selection
- Younger
  - relaxed (weak purifying selection) or positive selection

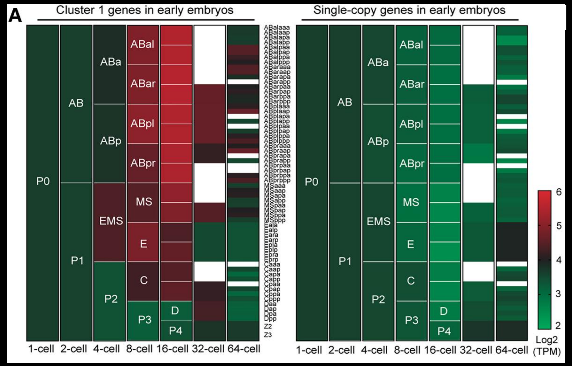
Summary

Q1: How does expression of new genes change during the development?



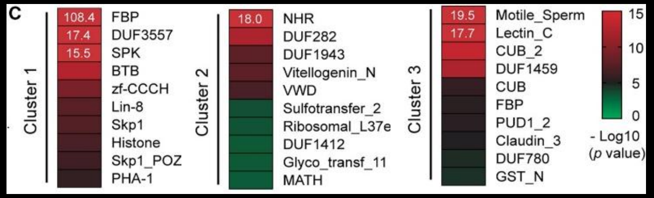
A1: In *C. elegans* new genes can be divided into 3 clusters by specific expression dynamics. Three different clusters respectively express in early-embryos, mid-embryos and late larvae stage.

Q2: Are these gene show specific spatial pattern?



A1: 3 clusters showed specific spatial pattern in different developmental stages. Cluster 1 does no express in germline while cluster 3 highly expresses in germline. And cluster 3 also enriched in immunity organ.

Q3: Do they really cause a phenotype innovation during the development?



A1: This paper still not directly prove the causal relationship between new genes and phenotype innovation. But it shows some relation between new genes and innate immunity.

Limitations of the study

1. lacks experimental data to support his opinion, only data analysis
2. only consider newly duplicated genes

This paper give us a new method to explore the function of new gene

1. Identifying new gene, not only recently duplicated genes, but all kinds of new genes
2. Using spatial transcription or single cell transcription at different developmental stage
3. Tracing the new gene expression, especially with the known new structure in the species.

Thanks for your attention!

Zijian Huang
2025-04-25