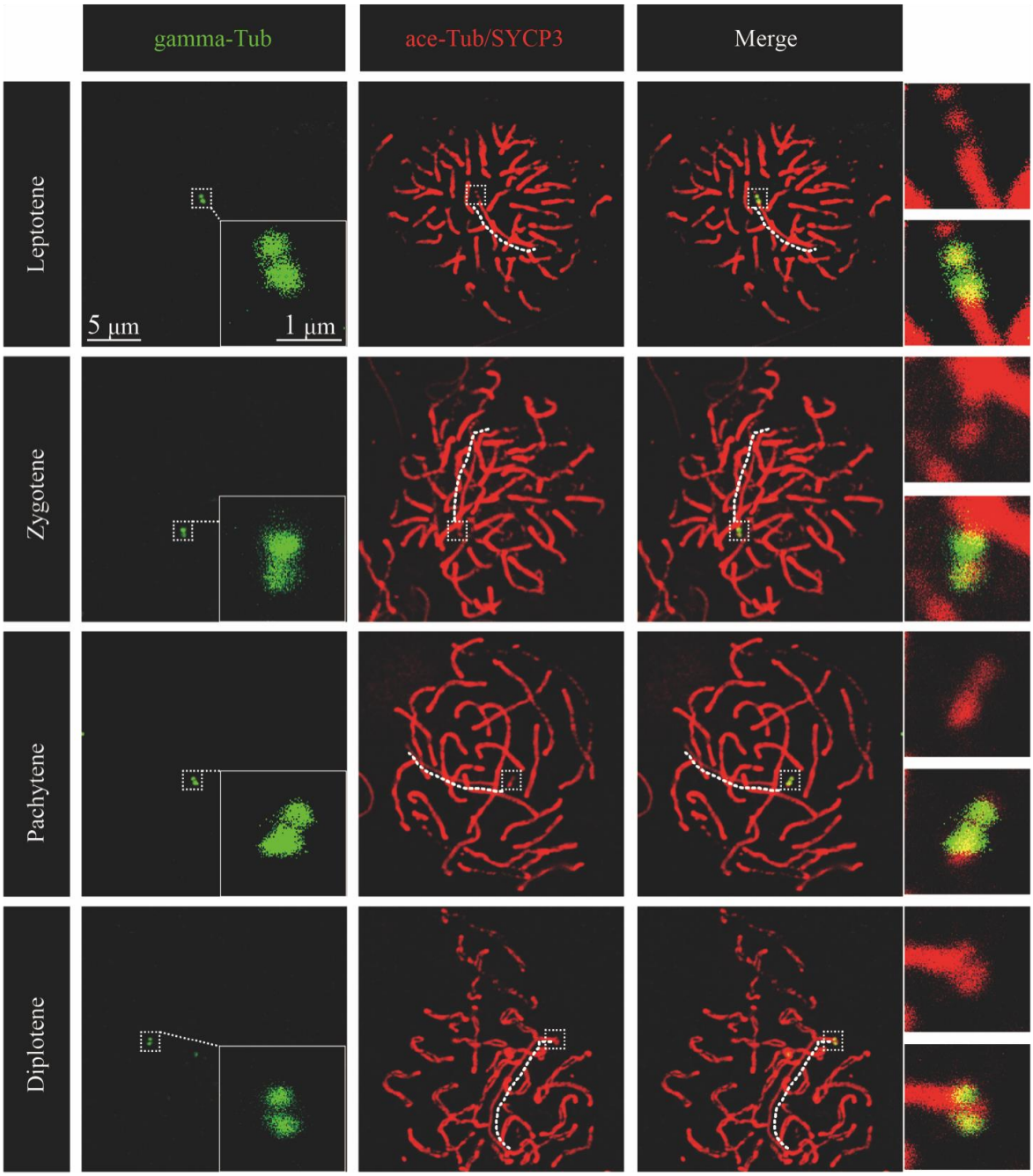
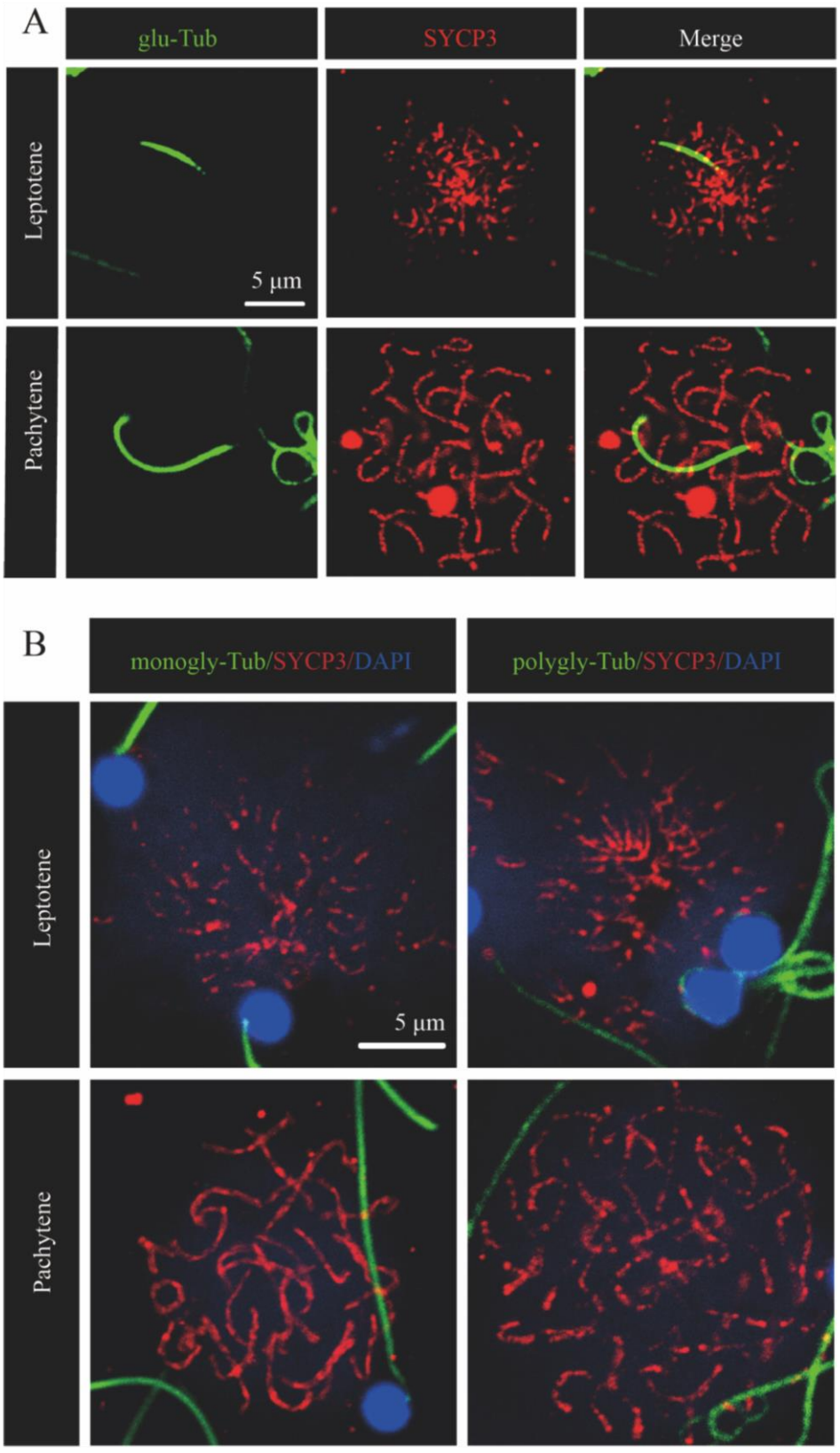
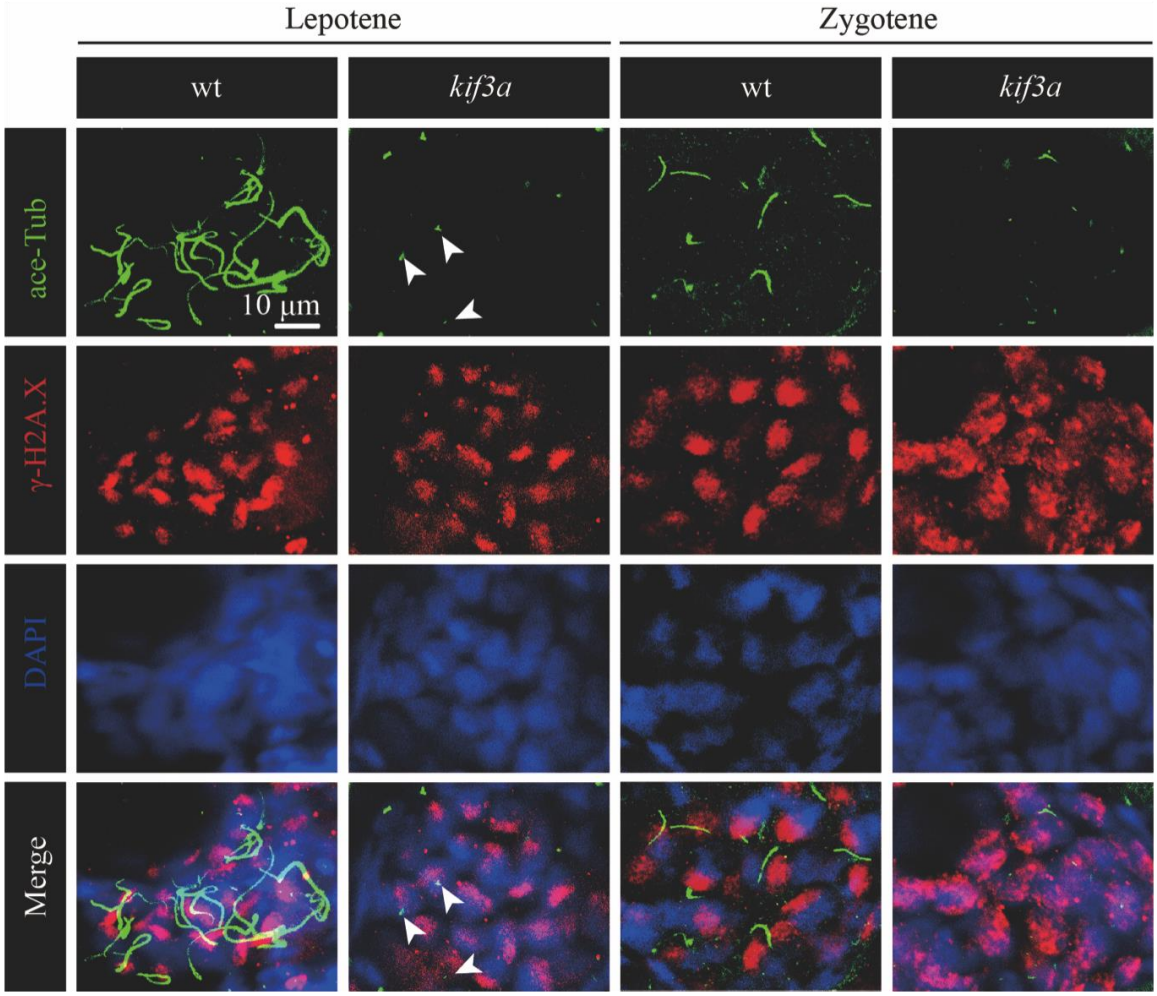
Supplementary material



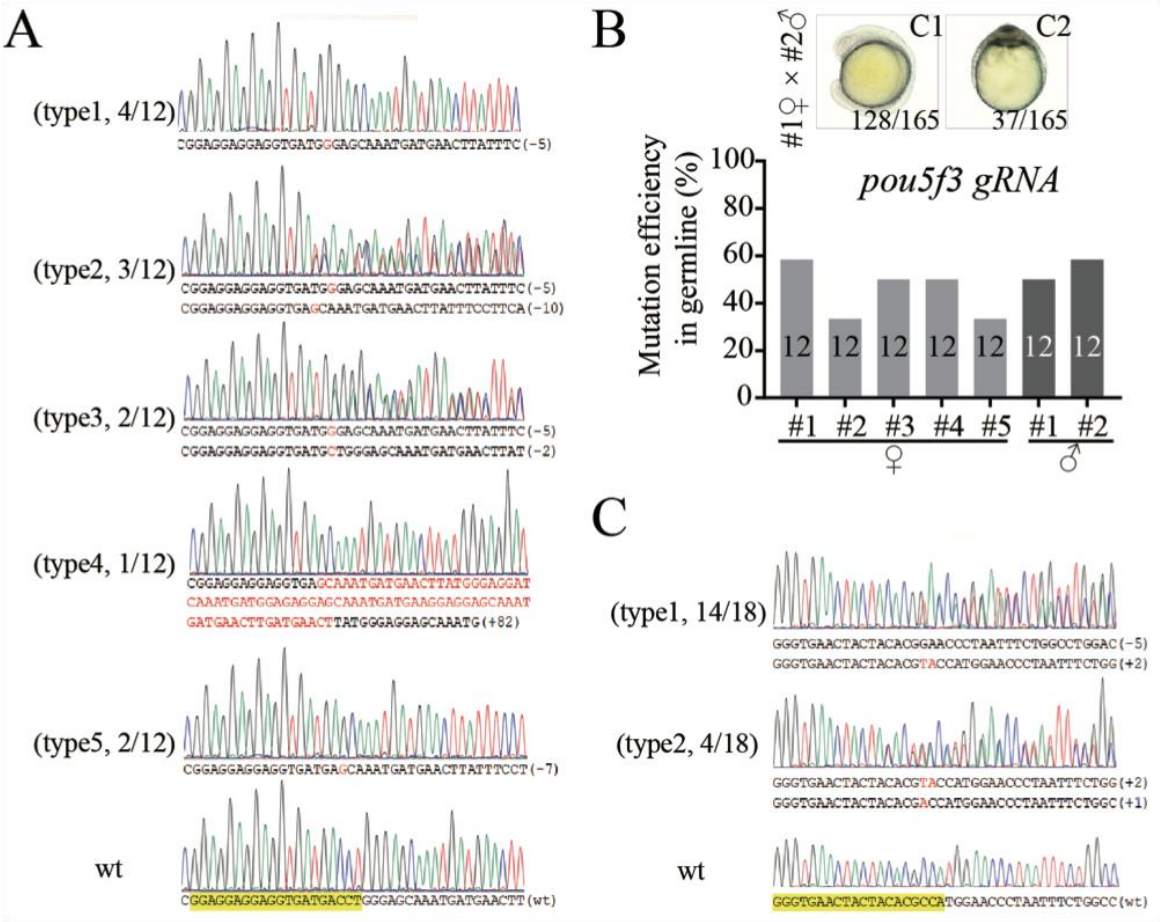
Supplementary Figure S1. Cilia of primary spermatocyte at different stages. Confocal images showing basal bodies and synaptonemal complexes labeled with anti- γ tubulin (green) and anti-SYCP3 (red) antibodies at different stages of primary spermatocytes as indicated. Because both SYCP3 and acetylated-tubulin antibodies were raised in rabbit, spermatocyte cilia were also labeled in red (next to white dotted line). The spermatocyte cilia can be distinguished by the basal colocalization with anti-γ tubulin antibodies.



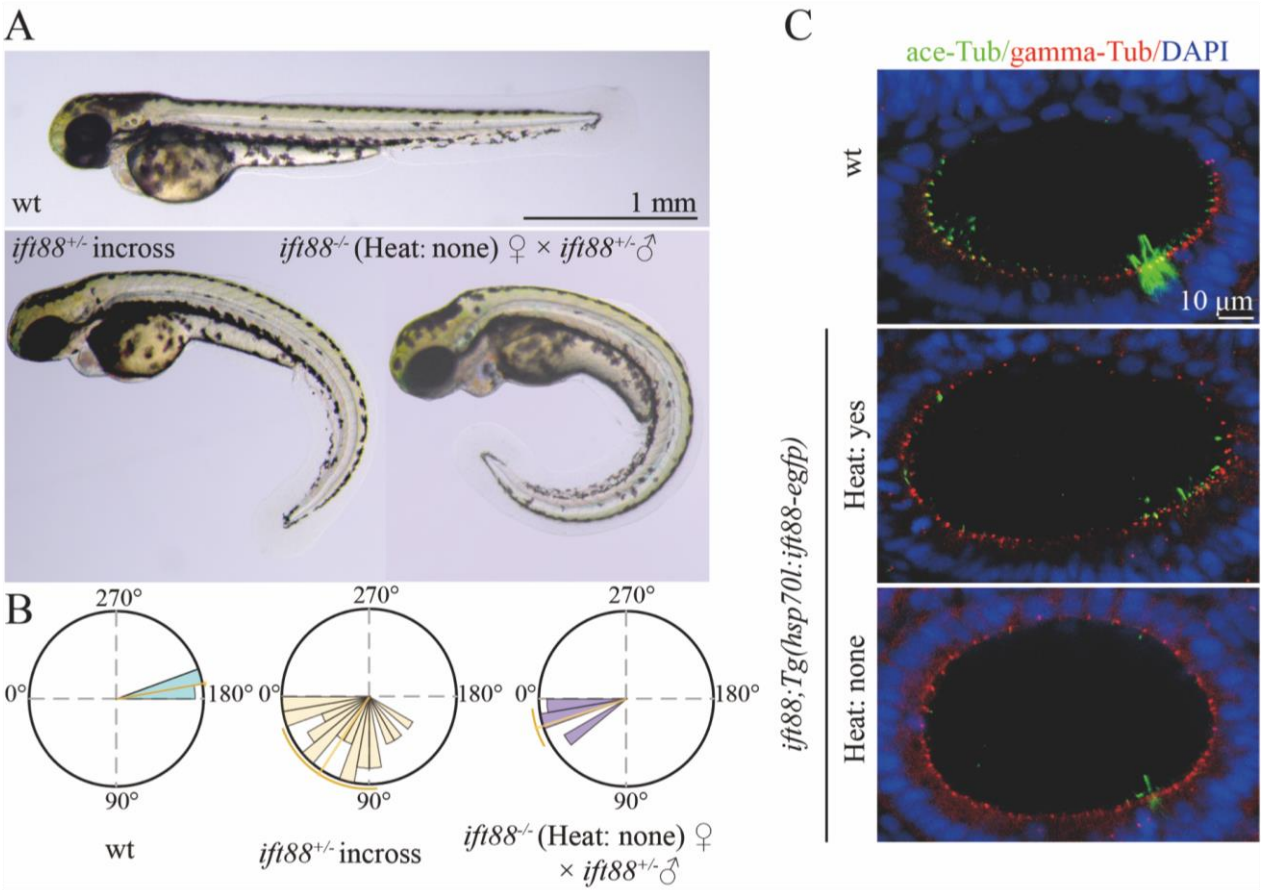
Supplementary Figure S2. Tubulin modification inside spermatocyte cilia. (**A**) Confocal images showing cilia and synaptonemal complexes labeled with anti- glutamylated-tubulin (glu-Tub, green) and anti-SYCP3 (SYCP3, red) antibodies. (**B**) Confocal images showing staining of mono-glycylated (monogly-Tub, green) or poly-glycylated (polygly-Tub, green) tubulin antibodies. The sperm flagella, but not spermatocyte cilia, can be labeled with these antibodies.



Supplementary Figure S3. Cilia were present in primary oocytes. Staining of γ-H2A.X (red) and acetylated tubulin (green) in the oocytes of wild type and *Tg(kop:cas9-UTRnanos3; U6:3xsgRNA-kif3a)* double transgenic fish. Arrowheads indicate basal bodies left in the mutant oocytes.



Supplementary Figure S4. Generation of maternal-zygotic mutants via PGC-specific Cas9 transgenic line. (**A**) The genotype results of 12 MZ*tcf7l1a* embryos showing C2 phenotype in Fig 2C. The genotype results showed that these embryos showing C2 phenotype were either homozygous mutants (type 1, type 4 and type 5) or containing two different mutant alleles (type 2 and type 3). (**B**) Mutation efficiencies of gametes and the phenotypes of offspring of *pou5f3* sgRNA injected *Tg(kop:cas9-UTRnanos3)* fish. C1 shows the WT like phenotype, C2 shows the phenotype of MZ*pou5f3*. The mutation efficiencies were calculated by the number of mutated heterozygotic embryos from crossing between F0 and wild type fish. A total of 12 embryos were genotyped from each cross and the mutation efficiency was calculated. (**C**) The genotype results of 18 MZ*pou5f3* embryos showing C2 phenotype in panel B. The genotype results showed that all these embryos showing C2 phenotype contained two different mutant alleles.



Supplementary Figure S5. Phenotypes of *ift88* mutants. (**A**) External phenotypes of wild type and *ift88* mutants generated from different crosses as indicated. (**B**) Statistical analysis of the angles of body curvature in wild type and *ift88* mutants as indicated. (**C**) Confocal images showing cilia in otic vesicle of 18-somite stage wild type and *ift88* mutants as indicated.