

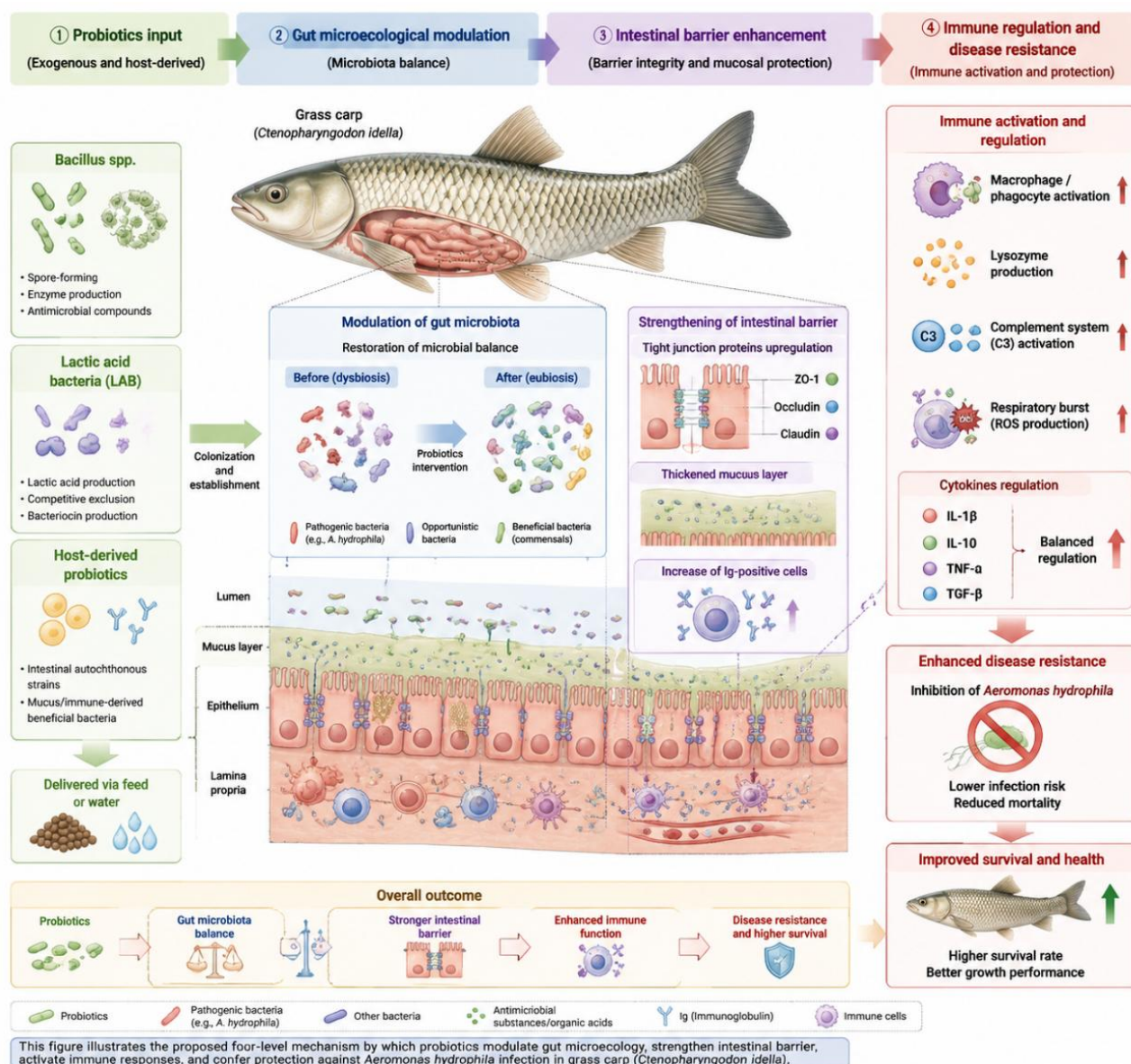


Figure 1 Mechanisms of probiotic-mediated immune enhancement and disease resistance in grass carp (*Ctenopharyngodon idella*)

The productivity benefit is not limited to one probiotic type or one production stage. In fingerling grass carp, diets containing *Bacillus coagulans*, *Rhodopseudomonas palustris*, or *Lactobacillus acidophilus* all increased final weight, daily weight gain, and relative growth rate compared with the control, although differences among the three probiotic treatments were not significant. Likewise, probiotic-fed groups in a comparative feeding study outperformed controls in weight gain and specific growth rate, and the probiotic treatment also improved protein efficiency and food conversion indices, which are directly relevant to aquaculture productivity and cost control (Abdallah et al., 2022).

3.3 Species, dose, and duration

Growth responses depend strongly on probiotic species and dosage, and the best-performing level is often intermediate rather than maximal. With *Bacillus natto*, fish in the Bn3-Bn5 groups showed better growth and lower feed conversion ratio than lower-dose groups and controls, suggesting a threshold concentration is needed before performance gains become clear. However, the response is not indefinitely linear: in grass carp fed host-derived *Bacillus velezensis* LH023, growth improved overall, but after week 5 the 10^8 group grew more slowly than the 10^7 group, indicating that excessive probiotic concentration can reduce the benefit (Liu et al., 2025).