Is There a Perfect Body for Swimming?
A Mathematical Exploration

What does the “perfect swimmer” look like? At first glance, the answer seems biological: long arms, large feet, powerful lungs. But beneath these features lies a deeper question—can mathematics define the ideal human body for moving through water?

Swimming transforms the human body into a moving geometric object interacting with a fluid. In this essay, we explore how geometry, physics, and optimisation theory shape performance—and why a truly perfect swimmer may never exist.

1. The Mathematics of Drag

The dominant resisting force in swimming is drag, which depends on velocity, shape, and surface interaction with water. It is given by:

$$F_D = (1/2)\,\rho\, C_D\, A\, v^2$$

This equation reveals a crucial insight: drag increases with the square of velocity. Doubling speed requires roughly four times the force. Therefore, elite swimmers must optimise not just strength, but shape.

To minimise drag, swimmers aim to reduce frontal area and streamline their bodies. The ideal form resembles a teardrop—wide at the front and tapering smoothly. This reduces turbulent flow and lowers the drag coefficient.

2. Scaling Laws: Size vs Efficiency

Geometry introduces a subtle constraint. If a swimmer scales up by a factor k, their surface area increases as k^2, but their volume—and therefore muscle power—increases as k^3.

This creates a nonlinear trade-off: larger swimmers can generate more force, but also face disproportionately higher drag. Mathematics suggests there is an optimal size, rather than simply ‘bigger is better.’

3. Lever Mechanics and Limb Length

Swimming propulsion depends heavily on rotational motion. The arm acts as a lever, and torque is given by:

$$\tau = r \times F$$

Here, r represents arm length. Longer arms increase torque, allowing swimmers to push more water per stroke. This explains why elite swimmers often have unusually large wingspans.

4. Rhythm, Oscillation, and Efficiency

Swimming is not continuous motion—it is oscillatory. Each stroke introduces acceleration and deceleration. Efficient swimmers minimise these fluctuations, maintaining smoother velocity.

This becomes an optimisation problem: what combination of stroke length and frequency minimises energy loss? Such problems are studied using calculus of variations, a field concerned with finding optimal functions.

5. A Real-World Approximation

Olympian Michael Phelps is often cited as an almost ideal swimmer. His long wingspan increases torque, his large hands enhance propulsion, and his body proportions reduce drag.

From a mathematical perspective, Phelps represents a near-optimal balance of competing variables—geometry, force, and efficiency.

6. Why Perfection May Not Exist

Despite these insights, mathematics suggests that a single perfect swimmer's body is unlikely to exist.

First, swimming is a multivariable optimisation problem. Improving one factor, such as size, may worsen another, such as drag.

Second, different strokes favour different body types. The optimal form for butterfly differs from freestyle or breaststroke.

Finally, water itself behaves unpredictably. Fluid motion is governed by the Navier–Stokes equations, which are highly complex and can exhibit chaotic behaviour. Tiny changes in technique can have large effects.

Conclusion

Mathematics reveals that swimming is not just a sport, but a rich optimisation problem shaped by geometry and physics.

While athletes like Michael Phelps demonstrate how close humans can come to an ideal, the search for perfection ultimately leads to a deeper truth: there is no single perfect body—only a landscape of near-optimal possibilities.

And perhaps that is what makes both mathematics and sport so compelling: not the existence of perfect answers, but the pursuit of them.