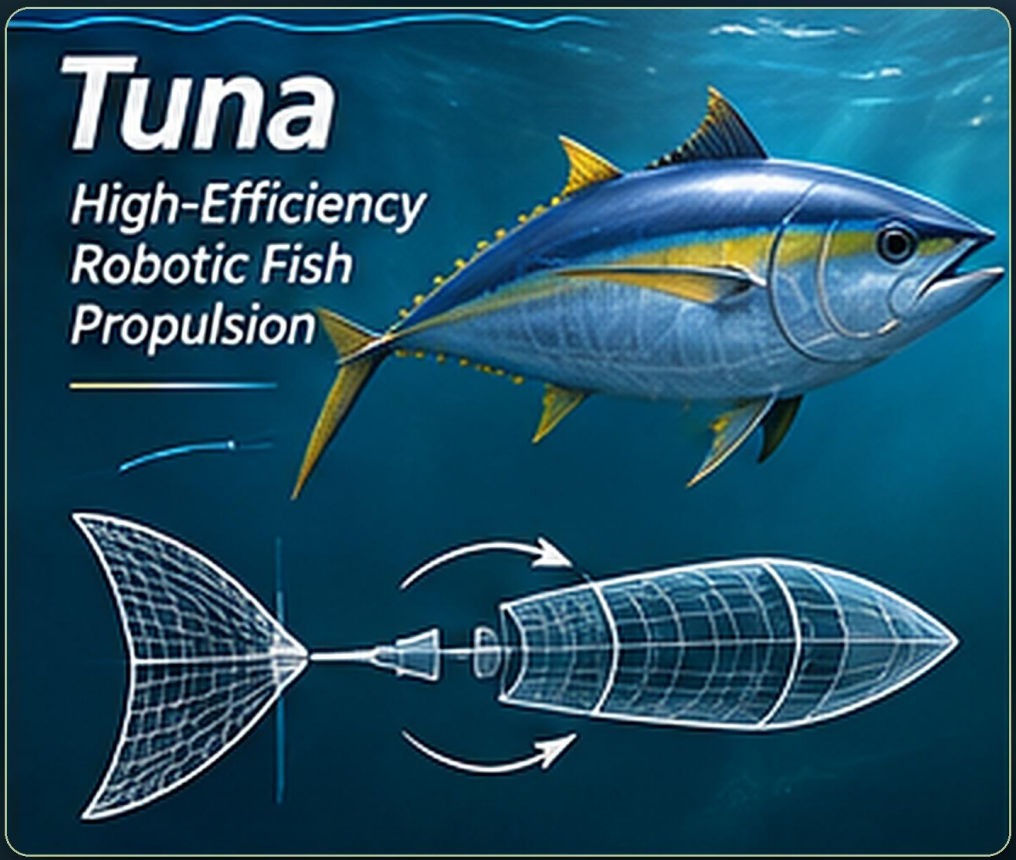
NATURE-INSPIRED INVENTIONS

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From living designs to working machines

BIOMIMICRY • ENGINEERING • INNOVATION

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Tuna

High-Efficiency Robotic Fish Propulsion

Nature-Inspired Inventions

Volume 019 of 255

WealthSphere Labs

Tuna: High-Efficiency Robotic Fish Propulsion

Nature-Inspired Inventions, Volume 019

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About this book. This is an educational guide to biologically inspired engineering. The invention concepts in it are design ideas for study and experimentation, not tested or certified products. Worked numbers illustrate methods unless a source is named. Nothing here is engineering certification, legal advice on patents, or a substitute for qualified professional review of anything that will carry people, loads or risk.

First edition, 2026.

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Introduction: The Ocean's Endurance Swimmers

Tuna are built for sustained speed. Bluefin tuna cross entire ocean basins on their migrations. Skipjack, yellowfin and albacore tuna swim constantly; many species must keep moving to force water over their gills. Their bodies show the engineering of endurance: a streamlined, rigid torpedo shape; fins that fold into grooves; a narrow tail stalk with keels; and a tall, crescent-shaped tail that beats quickly and efficiently. Unusually among fish, many tuna keep their swimming muscles warmer than the surrounding water, boosting muscle performance.

Tuna have inspired some of the best-known robotic fish, from MIT's RoboTuna in the 1990s to more recent high-speed robotic tuna that have reached tail-beat frequencies comparable to real fish. These machines are tools for understanding how fish swim efficiently and prototypes for quiet, efficient underwater vehicles.

This volume explains how tuna swim, the physics of thunniform propulsion, the history of tuna-inspired robots, and how designers can build efficient fish-like propulsion systems.

How this book is organized

Chapters 1 and 2 cover tuna swimming and anatomy. Chapter 3 explains the physics of fish propulsion. Chapter 4 surveys the history of robotic tuna. Chapters 5 to 7 cover translation, mechanisms and control. Chapter 8 presents ten design concepts. Chapters 9 to 13 cover testing, failure modes, approval, a workbook and a case study.

Figures for real animals and machines are rounded and typical. Worked numbers are illustrations unless a source is named.

Chapter 1: How Tuna Swim

Swimming modes in fish

Fish swim in several ways, classified by how much of the body moves:

Mode	Body motion	Examples	Strength
Anguilliform	Whole body undulates	Eels	Maneuvering; confined spaces
Subcarangiform	Rear half undulates	Trout	General purpose
Carangiform	Rear third moves	Mackerel, jacks	Faster cruising
Thunniform	Mainly the tail and peduncle	Tuna, lamnid sharks	Efficient high-speed cruising
Labriform	Pectoral fins	Wrasses	Precise low-speed control

Tuna use thunniform swimming: the body stays nearly rigid, and almost all motion is concentrated in the narrow tail stalk and the tail fin.

Constant motion

Many tuna species swim continuously, partly because they rely on ram ventilation — swimming with their mouths open to push water over their gills. Their entire design is optimized for long-duration, efficient cruising.

Speeds

Tuna cruise steadily at speeds of around one to two body lengths per second, and can sprint much faster for short periods. Their efficiency at cruise is more important to their lifestyle than their sprint speed.

Chapter takeaways

- Fish swimming modes range from whole-body undulation to tail-only oscillation.
- Tuna use thunniform swimming, keeping the body rigid.
- Their design favors efficient, continuous cruising.

Chapter 2: Tuna Anatomy

Body

The tuna body is a smooth, rigid, fusiform shape with a fineness ratio typically around 4. Its maximum thickness is about a third of the way back.

Retractable fins

The first dorsal fin and the pectoral and pelvic fins can fold flat into grooves when not needed, leaving a smooth body — like retractable landing gear.

Finlets

Between the second dorsal and anal fins and the tail, tuna have a row of small finlets on the top and bottom of the body. Research by Jennifer Nauen and George Lauder, published in the early 2000s, studied finlet motion and suggested that they may direct flow toward the tail, possibly improving thrust.

Narrow peduncle and keels

The tail stalk (peduncle) is very narrow, reducing the drag of the oscillating part. Lateral keels on the peduncle may reduce drag as it sweeps sideways and help direct flow.

Lunate tail

The tail fin is tall, narrow and crescent-shaped (lunate), with a high aspect ratio. Like a high-aspect-ratio wing, it produces thrust efficiently with low induced losses.

Warm muscles

Tuna have a counter-current heat exchanger in their blood vessels that keeps their red swimming muscles warmer than the water, improving muscle power and endurance.

Chapter takeaways

- Rigid body, retractable fins and narrow peduncle minimize drag.
- Finlets and keels may direct flow to the tail.
- The lunate tail is a high-aspect-ratio thrust foil.
- Warm muscles improve performance.