

PREFACE

This is the first multi-authored volume on fish biomechanics to appear in over twenty years. In that time the field has grown immensely, with many new experimenters using new experimental techniques to probe questions of how fish work. Consequently, the published literature in fish biomechanics has grown rapidly, and it is time for a comprehensive review and synthesis of the important findings of recent research to update the classic *Fish Biomechanics* volume edited by Paul Webb and Danny Weihs in 1983.

This book begins at the front end of the fish with important biomechanical events that involve the head: breathing and eating. The complexity of head structure is one of the most distinctive and evolutionarily interesting aspects of fishes. The interaction of bones, joints, and muscles of the head is highlighted in Chapter 1 by Brainerd and Ferry-Graham in their review of the mechanics of respiratory pumping. They discuss two-phase (suction and pressure) pumps, as well as ram ventilation and air breathing. The theme of head structure as a set of muscle-powered levers and linkage bars is further elaborated in Chapters 2 and 3, which present detailed accounts of feeding mechanics, a classic illustration of an elegant form and function relationship. Westneat reviews the great diversity of skull morphologies and feeding strategies in fish groups, showing how different kinematic models have been developed, and provides clear illustrations based on high speed videography, as well as discussions of muscle activity patterns associated with feeding activities and their evolutionary relationships. Wainwright then describes how the pharyngeal jaw apparatus, a unique aspect of fish trophic biology, is designed from multiple skeletal elements modified from gill arches. He summarizes recent work on the morphology and the kinematics of pharyngeal jaws based on experimental approaches of cineradiography and sonomicrometry.

Apart from breathing and eating, one of the most important and interesting activities fishes perform is locomotion, and this is broadly the focus of the remainder of the book. Swimming and maintaining hydrostatic equilibrium go hand in hand. In Chapter 4, Coombs and van Netten discuss the structure and biomechanical features of the lateral line system as a collection of flow sensors, and how this system is used to provide information to the fish about

the hydrodynamic structure of its environment that aids locomotion and behavior. The body of a fish can be regarded as a complex mechanical structure in which muscles generate forces and movement, while skeletal elements bear the loads and link the internal muscle action to the external resistive fluid medium. In Chapter 5, Summers and Long provide an overview of the engineering principles used to analyse both the static and dynamic mechanical properties of biological materials, and then discuss current data on the mechanical behavior of fish skeletal tissues in the context of the various locomotor modes of fishes. A major focus of research on fish swimming has been the contractile properties of locomotor muscles, most recently advanced by use of the *in vitro* work loop technique to study power production under simulated swimming conditions. In Chapter 6, Syme provides a comprehensive review of the biomechanical properties of skeletal muscle, and shows how studies of isolated muscle have been used to understand the various strategies fish use to power swimming under different conditions. The use of muscle in undulatory swimming is further considered in Chapter 7 where Shadwick and Gemballa describe the structural organization of the lateral myomeres and their connective tissue linkages as the pathway of force transmission along the body. They also discuss body kinematics and muscle dynamics in steady swimming, noting the general trends as well as the exceptions exhibited by the highly specialized tunas and lamnid sharks. The important problem of maintaining both stability and maneuverability is discussed in detail by Webb in Chapter 8, illustrating the elegant biomechanical solutions attained by fishes, and highlighting the importance of this knowledge in biomimetic designs of underwater autonomous vehicles. Wakeling reviews the specific problem of unsteady fast-start maneuvers in Chapter 9, by considering the sequence of events that initiate muscle contraction, bend the body, and generate the hydrodynamic forces that accelerate the fish. The fast-start (c-start) escape response of fishes has been of great importance as a system for understanding the neural control of behavior, and this chapter provides a synthesis of recent advances in the biomechanics of fish escape responses.

Fish pectoral fin function during locomotion has received a great deal of attention in the past twenty years. In Chapter 10, Drucker and his colleagues review a large amount of data on pectoral fin morphology, kinematics, and hydrodynamics, and discuss the ecological implications of different pectoral fin designs. Perhaps the most noticeable feature of fish locomotion is the bending of the body. Lauder and Tytell update classical descriptions of undulatory locomotion with recent experimental data in Chapter 11, where they also discuss new hydrodynamic data from freely-swimming fishes that highlight the importance of three-dimensional effects. Finally, biomechanical approaches are moving out of the laboratory and playing an increasing role in understanding the field behavior of fishes and helping in conservation efforts.

In Chapter 12, Castro-Santos and Haro synthesize a large body of work on the migration and passage of fishes around dams, and describe new tagging technology and bioenergetic models that will guide future efforts in conserving fish stocks.

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