Dynamics and Energetics of Animal Swimming and Flying: Introduction

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SOME GENERAL ISSUES

A few broad general questions have been central to the study of the dynamics and energetics of animal swimming and flying since the field began. A partial list includes:

1. What are the biomechanical bases for swimming and flying in the various groups of animals?
2. What are the kinematic and kinetic bases for swimming and flying? How do the shapes and movements of involved body parts generate thrust, drag, lift, dynamic stability, and maneuverability?
3. What are the energy costs of swimming and flying?

This symposium approaches answers to these questions from multiple directions.

Four primary sets of technological developments have come together in the past decade to make it possible to revisit each of these questions in innovative, quantitative ways. These developments are: a) high-speed digital video photography; b) algorithms for rapid analysis of digital images; c) laser based quantitative flow visualization techniques (DPIV: digital particle imaging velocimetry); and d) algorithms for computational fluid dynamics (CFD).

Interdisciplinary collaborative investigations using these technologies, involving physiologists, functional morphologists, mathematical and physical modelers, and engineers, are producing refined and elegant analyses of the dynamics and energetics of animal movements through both compressible and incompressible fluids. This symposium presents state of the art reports from active participants in this work.

In recent years four important research-related trends have converged:

a) The technical developments cited have made possible many kinds of measurements that were previously obtainable only with great difficulty, if at all. Many of the papers included here are based upon use of these new techniques.

b) The field has been enriched by the recruitment of a substantial number of new, creative, active younger researchers. Many of these people are represented here.

c) There has been an increase in the availability of research funds for these studies. As is often the case, this circumstance has resulted from the prospect of a range of significant new applications. A number of the papers included here refer to some of these interesting applications.

d) There is a trend toward increased openness on the parts of both some universities and some support agencies to new kinds of interdisciplinary or multidisciplinary collaborations. Most of the papers included here result from such collaborations.

RECENT BACKGROUND

This symposium highlights the rapid progress made recently in studies of animal swimming and flying, and the variety and significance of the new information obtained. It updates, complements, and supplements the proceedings of two other recent symposia.

A symposium entitled “Designs for life: the science of biomechanics” was presented at the March 1999 annual meeting of the Society for Experimental Biology (Altringham and Ellington, 1999). That symposium includes eight papers relating to topics also considered here.

A symposium entitled “Unifying principles in locomotion: water, land, and air,” was presented at the August 1999 5th International Congress of Comparative Physiology and Biochemistry (Boggs and Frappell, 2000). That symposium also includes eight papers relating to topics considered here.

This Symposium

The papers presented here are grouped into three subject matter categories: quantitative flow visualization (6 papers); modeling and computational fluid dynamics (5 papers); and other issues, other approaches (3 papers).

QUANTITATIVE FLOW VISUALIZATION

The first six papers consider recent developments in DPIV technology and a sampling of applications of those methods. A particularly challenging aspect is that of visualizing flows in three dimensions (3-D). Three different approaches to achieving this goal are represented here: i) synthesis from multiple 2-D images; ii) visualizations of small volumes using stereo photographic methods; and iii) larger volume, whole field visualizations, using defocusing DPIV (DDPIV).

Gharib et al. (2002) describe the principles underlying DDPIV and provide several examples of its use in engineering studies. At its present stage of development the method has tremendous promise for help-