Preface

Flying insects represent a fascinating example of evolutionary design at the microscopic scale. Their diminutive size does not prevent them from perceiving the world, flying, walking, jumping, chasing, escaping, living in societies, and even finding their way home at the end of a long day. Their size and energy constraints demand extremely efficient and specialized solutions, which are often very different from those that we are accustomed to seeing in larger animals.

For example, the visual system of flying insects, which features a compound eye comprising thousands of ommatidia – "little eyes" – represents a dramatic alternative to the design of our own eyes, which we share with all vertebrates and which has driven the design of today's cameras. Do insect eyes differ from human eyes only superficially with respect to the optical and imaging characteristics, or do the nervous systems of their owners process the information that they receive in different ways? Several aspects of this question are explored in this book.

The nervous system of flying insects not only coordinates the perception and motion of the animal at extremely high speed and in very dynamic conditions, but it actively monitors features in the surrounding environment, supports accurate landings in very tiny spots, handles recovery from high turbulence and collisions, directs the exploration of the environment in search of food, shelter or partners, and even enables the animal to remember how to return to its nest.

Flying insects move their wings by using the whole thorax to produce fast, resonating, respiration-like contractions that result in the movement of the wing appendages, whose morphology and constituent materials then modify the basic, passive flapping motion through the air. As such, these creatures represent a fascinating source of inspiration for engineers aiming to create increasingly smaller and autonomous robots that can take to the air like a duck to water, and go where no machine has gone before. At the same time, robotic insects can serve as embodied models for testing scientific hypotheses that would be impossible to study in numerical simulations because of the difficulty in creating realistic visual environments, capturing the physics of fluid dynamics in very turbulent and low-speed regimes, reproducing the elastic properties of the active and passive materials that make up an insect body, and accurately modelling the perception-action loops that drive the behavior of the system.

Despite much recent progress, both the functioning of flying insects and the design of micro flying robots are not yet fully understood, which makes this transdisciplinary area of research extremely fascinating and fertile with discoveries. This book brings together for the first time highly selected and carefully edited contributions from a community of biologists and engineers who share the same passion for

understanding the design principles of flying insects and robots. The book is the offspring of a stimulating meeting with the same title and organizers that was held in the summer of 2007 at Monte Verità in Switzerland. After the meeting, we decided to assemble a carefully edited volume that would serve both as a tutorial introduction to the field and as a reference for future research. In the months that followed, we solicited some of the participants, as well as additional authors whose research was complementary and would fit the book plan, to write chapters for a larger audience. The authors and the editors spent most of 2008 writing, revising, and cross-linking the chapters in order to produce a homogeneous, accessible, and yet up-to-date book.

Approximately half of the book is written from a biological perspective and the other half from an engineering perspective, but in all cases the authors have attempted to use plain terminology that is accessible to both sides and they have made several links and suggestions that cut across the traditional divide between biology and engineering. The book starts with a description of today's advanced methods used to study flying insects. After this, the reader is taken through a description of the perceptual, neuronal, and behavioral properties of flying insects and of their implications for the design of sensors and control strategies necessary to achieve autonomous navigation of miniature flying vehicles. Once this ground has been covered, the reader is gradually introduced to the principles of aerodynamics and control suitable for microsystems with flapping wings and to several examples of robots with fixed and flapping wings that are inspired by the principles of flying insects. We encourage readers to photocopy the figures of Chapter 15, cut out the drawings, and assemble a moving model of the thorax, which should provide an intuitive understanding of the typical workout routine of a flying insect. Two chapters venture into the area of robots that live and transit between the ground and the air. Although these chapters are more speculative from a biological perspective, they highlight the fact that flying insects are also terrestrial animals and that robots capable of a transition between terrestrial locomotion and flight can have several advantages. Finally, the book closes with two engineering chapters: one dedicated to energy supply and the possible use of solar cells to power micro aerial vehicles, and another to the technology available today and in the near future for realizing autonomous, flying micro robots.

We sincerely hope that you will enjoy and learn from this book as much as we did throughout the entire creation and editing of this project. We would like to express our deep gratitude to the contributors of all the chapters, who enthusiastically presented their knowledge and achievements in such a small space and time, and who displayed amazing patience and dedication in revising their own material and that of their colleagues. Last, but not least, we would like to thank Ronan Nugent at Springer for welcoming this project, following it through all its production stages while accommodating many of our requests, and making sure that it is presented in a form that best fits its content both on the Internet and in the printed edition.

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http://www.springer.com/978-3-540-89392-9

Flying Insects and Robots

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(Eds.)

2010, XII, 316 p., Hardcover
ISBN: 978-3-540-89392-9