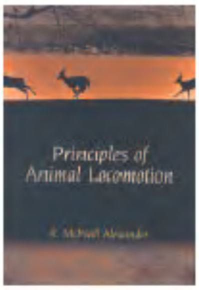

Principles of Animal Motion. R. McNeill Alexander. Princeton University Press, 41 William Street, Princeton, NJ 08540, USA. 2003. 371 pp. Price not mentioned.

The surest indication of life is movement, although we seem to reserve locomotion for animals. The most fascinating aspects of behaviour are also movements. Plants and bacteria do move, movements of the foetus are well known and amazingly, *Drosophila* embryos twitch long before development is completed. The little marsupial embryo crawls out to find a tit to grow on and stays glued there till such time that the mother decides to nourish it. Animals with even the most rudimentary nervous system move. And there are Olympians among animals, not just the cheetah, but some surprising ones like the cockroach, estimated to be the fastest running insect. It moves 50 body lengths a second, a speed record listed in the *Guinness Book of World Records!* Animals crawl, squirm or run, swim and fly and each of these movements, in its own way, is problematic. The fly landing on a ceiling, the versatile lizard in Australia running on the surface of a water body, or the dragonfly which can fly back and forth unlike many fliers, each faces its own peculiar problems. Birds, bats and fixed-wing planes all fly, but they are all mechanically different and there are very sound engineering principles in use in each of these. I read somewhere how elegantly the bending of a bat's bones in flight was measured and how dramatic the bending is. Fruit bats are just designed to carry an orange home, but may literally break their bones if they attempt to carry a mango!

Muscle and nervous system constitute to a large extent the animal world and its success. There is a recent spurt in research in biomechanics of motion. Learning the secrets of animals' amazing speed control and mechanical stability, it is hoped, will lead to design of better robots. What has emerged is a set of principles common to animal locomotion of all kinds, whether it is running two-four-or six-legged, swimming, flying, crawling or wriggling. After sound and vision, the physics of one area that I would teach enthusiastically will be animal locomotion. I had always found papers discussing motion in animals most engaging but was perplexed at the absence of scholarly work or books on the subject. The book under review is meant to fill that void and it does so admirably. This book covers most knowledge in this field and its breadth indicates how nascent research in this area is, although potentially so rewarding both as a pure scientific endeavour and one with palpable immediate applications.

The first chapter itself is illustrative of the power of Alexander's style; the most difficult concepts are laid out in a simple understandable manner. That one could plot the Olympic world records in running races to make a meaningful statement on animal movement is such an elegant thought, but no one seems to have ever done this. The author uses this analysis to discuss how endurance might have evolved as a strategy for successful predation.

Almost all aspects of animal motion are dealt with and the author analyses energetics and efficiency of animal movement from principles of mechanics and dynamics. In running, the leg strikes the ground and kinetic and gravitational potential energy is stored as elastic strain in muscles and tendons in the first half to be recovered during the second propulsive half. His simple illustrations of how animal posture accounts for stability under gravity are a treat. I checked out my understanding to see if I would get answers as to why the cattle egret and the praying mantis swing before pouncing and for sure Alexander's book has a description of how animals use principles of the pendulum to keep themselves stable and gain potential energy to launch. His revealing analyses tell us why only flying animals, seals and whales could be expected to benefit from long migrations. Methods of studying motion are as varied as the types of movement are. Conveyor belts and wind tunnels keep animals stationary for observation, while parameters of movement are recorded. I learnt for the first time how they measure oxygen consumption in a swimming animal, either a fish or a duck that paddles, from reading the fifth chapter in this book. Animals which have four legs use different gaits at different speeds. The logic of such choices seems not to have been analysed. McNeill Alexander elegantly argues that gaits are adapted to minimize energy costs by calculating metabolic energy costs for running.

At the end he points to several areas for further research, for example, into what seems an intuitively unsound observation that muscles of small runners are less efficient than those of large ones. Another area where much is not known is about change of gait in animals, including flying birds and swimming fishes.

The nicest thing about this book is that finally it tells you that all animal motion is pogo sticks, springs and garrottes, wheels or somewhat like them, waves and aerofoils. At the end of it one gets the comfortable feeling that all forms of animal motion are understandable in terms of a few common principles. Common are also principles of energy exchange and use of force for propulsion. This synthesis is superb and one does not deal with the orange-hitting Sir Isaac, different from the legendary apple. While it is technically challenging, the book is also enormously absorbing. This is one book that should be a must for a course on integrative or systems biology and I recommend this highly to the physicist looking for interesting things to do in biology.

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