separating them. Can the gulf be bridged? One example of creativity at the interface of rationalism and spirituality in the biological realm is conservation biologist Aldo Leopold's *A Sand County Almanac* (Oxford University Press, 1949). Leopold gives three reasons for preserving native wilderness areas: science, wildlife and recreation. On the value of preserving wilderness for the few who practise the primitive arts of canoeing and packing, Leopold wrote: "Either you know it in your bones, or you are very, very old." And on recognizing the cultural value of wilderness, he wrote that it is "a question of intellectual humility". I believe Silver would view these as spirituality-based statements, yet we could do worse than accept Leopold's wisdom and the creatively combined rationalism and spiritualism informing it.

Most left-brained people will love this book. It may annoy right-brained people, but their response to it will enhance the creative, democratic dialogue so badly needed on the issues addressed. ■

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# Biology's big idea

**In the Beat of a Heart: Life, Energy, and the Unity of Nature**
by John Whitfield
Joseph Henry Press: 2006. 261 pp. $27.95

**David Robinson**

D'Arcy Wentworth Thompson is the hero with whom John Whitfield begins and ends his engaging book, *In the Beat of a Heart*. Teaching "at a provincial university in a coarse, industrial Scottish city" in the early twentieth century, Thompson's obsession was the search for principles to unify the diversity of life. This is the springboard for Whitfield's lively account of more recent attempts to answer questions that Thompson posed.

Thompson's 1917 book *On Growth and Form* famously depicted his (often incorrect) ideas about how organisms are as much the products of physics as of natural selection. A polymath of astonishing accomplishment, Thompson was better equipped than most to appreciate how physical simplifications of nature can reveal things about the living world that traditional approaches cannot uncover. He believed that however much evolution causes animals or plants to vary in delightful ways, feathers and foliage hide universal features of structure or function that reflect unbreakable physical laws. Identifying those features was Thompson's goal. His work needed bold generalizations, and he was unafraid to look at nature in a different way from everyone else. Eighty years after *On Growth and Form* first appeared, its unfashionable philosophy was emulated by the main protagonists of Whitfield's book.

In 1997, physicist Geoffrey West and two ecologists, Jim Brown and Brian Enquist, developed a theory to explain why many familiar biological patterns vary as quarter-powers of body mass. For example, a mammal's heart rate varies, on average, as its body mass to the power –1/4; an animal's lifespan varies as its body mass to the power 1/4; tree height varies as body mass to the power 1/4, but tree density in a forest varies as body mass to the power –3/4, and so on. These patterns suggest that there is an underlying order to the living world, but how could such order possibly arise among organisms and processes so diverse?

Did Jonathan Swift use quarter-power scaling to decide Gulliver's food intake in *Gulliver's Travels*?

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West, Brown and Enquist answered this question by explaining why metabolic rate tends to scale as body mass to the power 3/4, one of the most fundamental and enigmatic of biological relationships (and, Whitfield tells us in passing, one that was implied in *Gulliver's Travels*). With thompsonian economy and elegance, West and his colleagues specified the kind of branched vessels needed to transport blood efficiently around an idealized organism, worked out how those vessels could be packed optimally into bodies of different sizes, and predicted how the organism's metabolic rate would then vary with its mass. The resulting algebra yielded the magic number 3/4. From this initial triumph, the theory has since evolved spectacularly to account for many broad features of metabolism, ecosystem processes, life histories, developmental rates, community structure, the global carbon cycle, tumour growth and so on, and, somewhat improbably, even makes predictions about human fertility and the wealth of nations. Like evolution by natural selection and the DNA double helix, this theory explains so much with so little. It is breathtaking in its ambition and scope.

Any new theory that is apparently so omniscient will attract as many grumbles of doubt as gasps of admiration, and this one is no exception. Its fans accept as strengths its physical simplifications, its neglect of biological detail and its mathematical reasoning, all of which leave critics uncomfortable. But for many, the clincher is this: within the limits of its assumptions and the bending of its rules by biological variation, West, Brown and Enquist's theory accurately predicts an extraordinary range of phenomena. No comparable idea yet matches it, despite its inevitable limitations.

Whitfield does a fine job of describing the logic behind the theory and its antecedents. He unpacks its key assumptions and describes what the fractal plumbing system responsible for quarter-power scaling would look like. No armchair pundit, Whitfield interviewed the theory's authors and their colleagues, censused trees in Costa Rican forests with Enquist's team of students and postdocs, and spent a few less arduous hours having his own metabolism measured in London. His first-hand experiences at the subject's coalface are vividly readable. Whitfield's later chapters consider how metabolism relates to biodiversity and biogeography, and how it might dovetail with genetics. They also dwell on how these grand ideas might apply, or not, to the largest part of the tree of life: microbes. Overall, Whitfield's book provides the best available introduction to West, Brown and Enquist's big idea.

But is the big idea correct and so universally applicable? Whitfield does not ignore its critics, but they get relatively thin coverage despite their prominence in the pages of specialist ecology journals. This is understandable in a book of this type, which sets out to popularize as much as inform, but it implies that the theory itself is virtually home and dry. The most explicit cautionary note comes from West himself: "If it's wrong, it's wrong in some really subtle way."

West and his colleagues have been almost as vigorous in defending their idea as they have in using it to attack ever more diverse biological problems, and strong personalities on both sides of the debate have generated robust exchanges. To his credit, Whitfield resists the temptation to overdramatize the disputes that often accompany important scientific developments. Instead he focuses on the power of a beguilingly simple idea about how the living world might work, and on the remarkable men who conceived it. ■

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