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that tissues would be used only for the specified purpose. Crichton makes an important point about the Catalona case, but the portrayal of this issue in *Next* is extreme.

Crichton thinks we should "rescind the Bayh–Dole Act", which allows US universities to claim ownership of patents derived in whole or in part from federally funded research done in the academic setting. He believes that this 1980 act has turned universities into money-hungry corporate monsters no longer motivated to seek truth, but rather to prove the efficacy of the pharmaceuticals their research labs produce. Thus, he contends, university faculty can no longer be relied on for an unbiased opinion on anything, let alone a reliable piece of data. The jury is still out on the Bayh–Dole act, but academic institutions and scientists would probably be looking beyond tuition payments, gifts and federal grants for funding with or without Bayh-Dole.

Most readers of *Nature* would surely agree with Crichton's other claims, that we should "pass laws to ensure that data about gene [therapy] testing is made public" and "avoid bans on research".

The book could have a role as a conversation starter for a course in bioethics. Most students would find it more entertaining than the typical textbook, and it covers a similar range of issues. There is no doubt that our scientific capabilities and our imagination have already gone well beyond the reaches of law and ethics, even though *Next* exaggerates the extent. The book is a reminder that we need to educate professionals in medicine and law about biotechnology so that the field's gargantuan potential, which Crichton's book never denies, can be realized safely and equitably. It never hurts to have this highlighted on *The New York Times* bestseller list. ■

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The two faces of science

The Intelligibility of Nature: How Science Makes Sense of the World
by Peter Dear
University of Chicago Press: 2006. 242 pp. $27.50

Richard Yeo

In 1690 the philosopher John Locke imagined a man with "microscopical eyes" many times more acute than the best microscope. Such a man, he conjectured, might grasp the deep "texture and the motion of the minute parts of corporeal things", but "would be in a quite different world from other people… I doubt, whether he, and the rest of men, could discourse concerning the objects of sight." We can surmise that the scientific explanations such a person offered might not be intelligible to others.

Intelligibility may be difficult to define but it plays a crucial role in the claim of science to offer credible accounts of nature, argues Peter Dear in his elegant book *The Intelligibility of Nature*, which is richly informed by scholarship in the history of science. Locke's point looks prescient when we consider the development of quantum mechanics from the 1920s. Its successful predictions of experimental phenomena were aligned with the disorienting prospect of an acausal, probabilistic world. Dear argues that by this time, 'instrumentality' — the power to produce and predict effects — had surpassed intelligibility as the main basis of scientific authority. The leitmotif of his book is that science has availed itself of two self-supporting, albeit circular, rationales: its account of the structure and processes of nature is backed by the success of instrumental techniques (such as the use of electron microscopes and DNA profiling); and explanations of why certain techniques work are grounded in intelligible, even if speculative, accounts of the natural world.

In Western culture there is an abiding distinction between understanding nature and doing things with it. This was formulated by Aristotle as *episteme* versus *techne* (the Latin equivalents are *scientia* and *ars*). Natural philosophy, the discipline responsible for seeking a causal understanding of natural qualities and processes, was classed as *scientia*, whereas mathematics, which deals with quantities that need not apply to real things, was regarded as a practical craft charged with measurement and computation. As Dear stresses, Isaac Newton's universal law of gravitation — the great scientific achievement of the seventeenth century — was viewed as a mathematical accomplishment. Although highly sophisticated, it was in the same class as utilitarian calculations of the relative movements of the stars and planets involved in almanacs and horoscopes. Moreover, Newton eschewed any account of what gravity was or how it acted at a distance in a vacuum. He did not provide a natural-philosophical explanation of the kind attempted by René Descartes, for example, who sought to understand celestial motion in terms of bodies in a fluid medium using the analogy of straws in the eddy of a river. Such an account was deemed intelligible, even if not demonstratively true. Newton's reluctance meant that his theory lacked intelligibility, even though it possessed striking instrumentality, as judged by the predictive power of the inverse-square law.

In discussing various scientific domains from the seventeenth century to the present, including celestial mechanics, taxonomy, atomism, natural selection, electromagnetism and quantum physics, Dear meditates on this

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Isaac Newton (left) and Antoine-Laurent Lavoisier were central to the creation of modern science.

tension within science. He contends that Newton's success and reputation allowed "the conflation of natural philosophy with instrumentality". Antoine-Laurent Lavoisier reinforced this by insisting that precise measurement of chemical reactions could be a model of scientific method without any commitment to a view about the underlying elementary structure of matter. In contrast, John Dalton's atomic theory was an attempt at traditional natural philosophy. In so far as Lavoisier was triumphant, the criterion of instrumentality began to rival that of intelligibility, the hallmark of natural philosophy. By the nineteenth century, modern science "was born a hybrid of two formerly distinct endeavours".

In 1833, William Whewell, surprisingly absent from the book, coined the term 'scientist' in opposition to 'artist'. Both the date and the terms of this contrast resonate with Dear's theme. If the dynamic between the two rationales for science was already in play by Newton's day, what was added in the nineteenth century? The dust-jacket suggests one answer, declaring that the investigation of nature "would be carried out by a new kind of person, the scientist". Although the features of this new persona are not made explicit, there are indications that it was, and remains, a problematic one. For a cosmologist, being a scientist might be a natural-philosophic quest for laws of nature that cannot become intellectual property; for a microbiologist, it is likely to involve a search for techniques that will be patented. Scientists who wish to reflect on their vocation will gain valuable insights from this beautifully contrived book, and all readers will be prompted to think more carefully about the nature and ethos of science. ■

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Ordering according to size

Why Size Matters: From Bacteria to Blue Whales
by John Tyler Bonner
Princeton University Press: 2006. 176 pp. $16.95, £9.95

Victor Smetacek

I used to think that the story of the mother who starts a letter to her grown-up son with: "Dear son, I am writing this letter slowly because I know you cannot read fast," was just funny. But after reading the tiny book *Why Size Matters* by John Tyler Bonner twice, I now realize that the story had a deeper meaning than had first met my eye. Bonner says in the preface that the big picture he has painted on a small canvas took a lifetime to mature and that writing this book was a slow process. Indeed, I found myself reading it slowly as well, making sure that I did not miss anything. The territory covered is so vast, as indicated in the subtitle, that I often stopped to get my bearings and ponder the view.

The message of this book is that size rules biology to a greater extent than most of us are aware, because our untrained mind's eye expects its sense of proportion to be universal, whereas in reality, it is relative. When things get bigger, their length increases linearly but their surface area increases by the square and their volume by the cube. So when the proportions, properties and performances of organisms, such as body shape, life span or speed of movement, are plotted against size or weight in log–log graphs, they fall on straight lines with interesting exponents.

The relationship between weight and strength dates back to Galileo, who calculated the effect of increases in animal size on body proportion. I find his sketch comparing the bones of a 'normal' and an oversized animal greatly exaggerated. I cannot train my mind's eye to conjure up images of small and large animals commensurate with Galileo's bones. To me, a tiger viewed from a distance looks as graceful as a house cat. On the other hand, the branch-breaking, heavy-duty elephant and the leaf-nibbling, slender giraffe look so different because they do different things, which need varying levels of strength. Yet both animals need to spend most of the day feeding. But these are minor details on log–log graphs.

In general, life is shorter, hence time flies faster, the smaller the organism. So the bigger the picture, the longer one needs to get it. Perhaps that's why I was puzzled to read that life in the microbial world, where viscosity becomes more important than gravity, is "very slow, majestic and regular". The medium might be like molasses but it still takes high-speed cinematography to follow the movements of a feeding zooplankter. And the bacteria zipping around in the water sample under a microscope are not an optical illusion, as Bonner suggests; rather, they are moving at more than a hundred body lengths a second — equivalent to 720 kilometres per hour for a 2-metre-sized organism like humans. It is not the bacteria, but the planes overhead, flying in the same range of body lengths per second as the fastest bacteria, that seem to move majestically.

Bonner argues at length why size should matter, but deals perfunctorily with the question: 'What made size matter in the first place?' Selection by predators is the most obvious reason, with increasing size a type of escape. A 'food-for-thought' insight I had was the statement 'there is always room at the top', implying that organisms can always get bigger. But the bigger they are, they harder they fall, so it is the small ones that are less vulnerable in the long run. There is another intriguing insight on size and speed waiting for the reader in the penultimate chapter, but I will not divulge it here.

Bonner's style is to open windows and then step aside so that his readers can see for themselves. If you are up to date with the recent literature on size rules then you have already looked through many of these windows, but if you have not done so consciously, or if you are studying the topic, this pithy little book is worth the time spent reading it, whether slowly or not. ■

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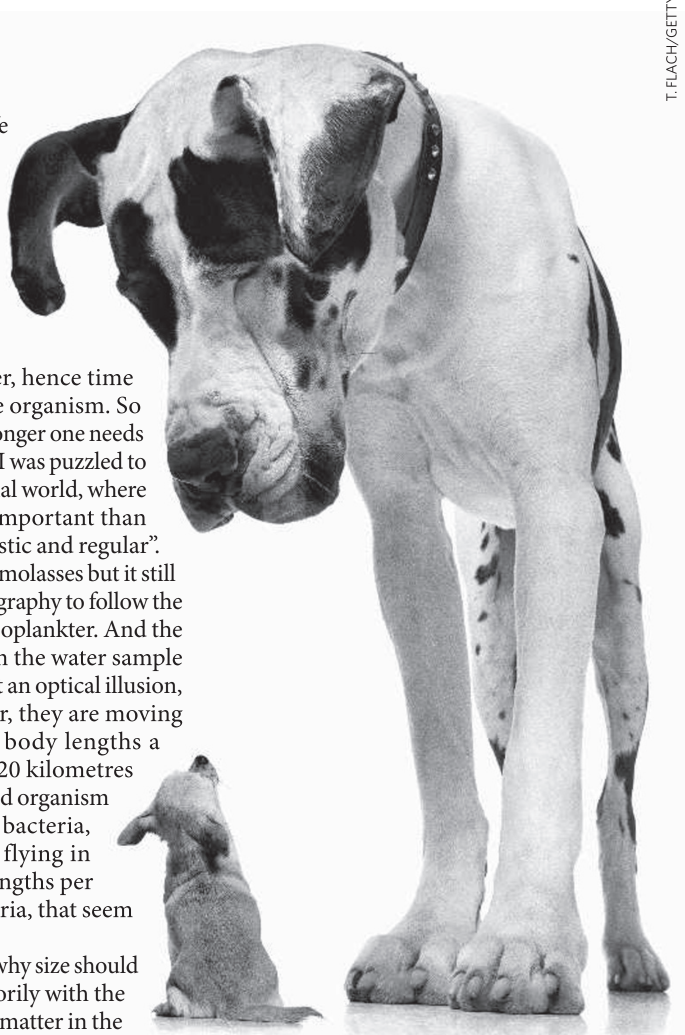
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Size differences among animals can result in great differences in the way they move and live.