

spinning globe would not be perfectly spherical, but would bulge around its equator, like a pumpkin. This contradicted theoretical work done by René Descartes earlier in the century. Descartes' champions contested Newton's prediction, as did measurements from surveyors working on the national map of France. Indeed, there seemed to be evidence that Earth might be pointed at its poles like an egg. National pride (France versus England), scientific approach (mathematicians versus cartographers) and bragging rights in physics (Newton versus Descartes) were all at stake — not to mention the accuracy of charts and maps, crucial in a world of expanding global trade.

Resolving the question demanded the careful measurement of the length on the ground of a degree of meridian arc — first in one place, ideally near the equator, and then in another, ideally near a pole. If each 360th of Earth's axial cross-sections was the same length, then we stood on a sphere; a difference in those lengths would indicate a spheroid, be it oblate like a pumpkin, or prolate, like an egg.

The fieldwork for these precise measurements was arduous. Highly accurate astronomical observations were needed to establish that the endpoints of the arc marked off a true degree. Working out the length of the degree on the ground required fanatically attentive techniques of land surveying: first pace off a baseline, then project this length through an array of triangles, sighted from promontories along the degree. With all the angles of the triangles known, it was mere trigonometry to work out the lengths of their sides, and thereby, the length of the degree itself. After several months of these exertions, most of the Frenchmen had stopped talking to each other, having fallen out over protocol and procedure. It looked as if each team was going to work up a separate set of results. So much for scientific universalism. Throw in hostile encounters with the locals, a shortage of cash, and larger political machinations — the Spanish crown and its officers had mixed feelings about a bunch of foreign scientific interlopers making maps in the heart of an Iberian colony — and you have all the ingredients for a fiasco.

This, in many ways, is how the La Condamine expedition has been remembered, not least because the explorers had barely set their telescopes up in the Andes when they learned they'd been beaten to the punch. The dashing polar explorer Pierre Louis Maupertuis had turned up in Paris in an unusual fur hat to announce that Earth was indeed flatter at the poles: Newton was right! Maupertuis and his crew had received the easier geodetic assignment from the Académie des Sciences. Instead

of going halfway around the world to the equator, they had simply zipped up to Lapland, where favourable conditions and organizational zeal led to a speedy set of measurements of the polar degree, which could be compared with measurements already done in France. Maupertuis — a playboy mathematician with a flawless sense of theatre and lots of yarns about ice and reindeer — was the toast of the town.

Not to be outdone, La Condamine broadened the scope of his investigations. He descended the Amazon River on the lookout for Amazons and El Dorado, throwing himself into botanical and zoological collection, writing extensively, if not very accurately, about Amerindians, and generally trying to rescue a more-or-less failed geodetic expedition by transforming it into a grand exploration of Spanish America, commemorated in texts and maps.

It is with these latter documents that Safier is, on the whole, concerned. He attempts to trace the paths by which the explorer's experience in the field — native informants, empirical observations, elements of fantasy — make their way into books, pictures and charts. But the yield is meagre. He repeatedly alerts the

reader to the “insidious effacement” of the role of indigenous peoples in the production of knowledge. Although this is an interesting topic, and one that has been pursued by a number of scholars in recent decades, Safier's examples are not persuasive. It is true that La Condamine doesn't say much about the porters who carried his equipment, but so what?

The conclusion of the book raises the interesting possibility that La Condamine used his ideas about native American women and runaway slaves to buttress his claims about the reality of Amazons, and there is a strong chapter on the French republishing of a Spanish history of the Incas. But on the whole, few readers will enjoy *Measuring the New World*. Freed from the straitened preoccupations of disciplinary history, the palpably smart Safier might yet give us a lovable and insightful work on Latin American exploration. Perhaps a satirical play? ■

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## Microbial fuels for the future

### Bioenergy

Edited by Judy D. Wall, Caroline S. Harwood and Arnold Demain

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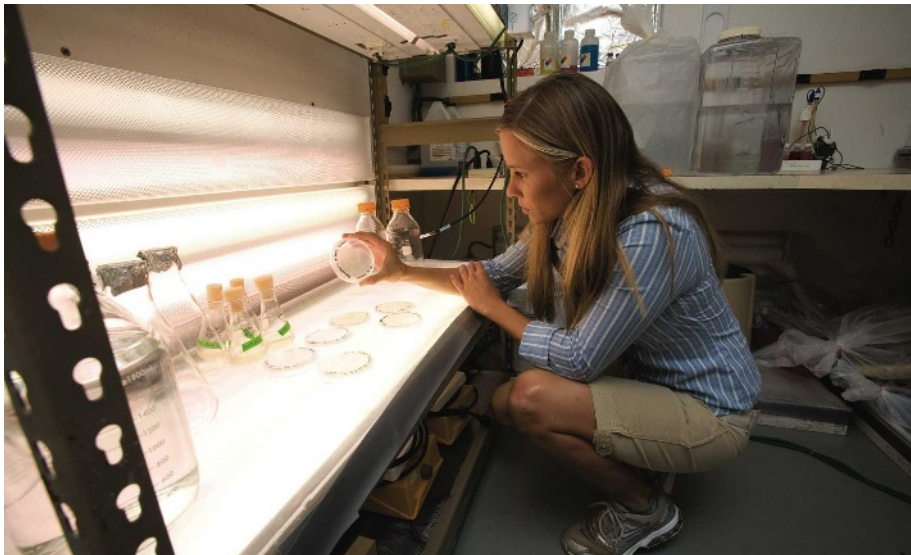
An individual in the United States consumes the equivalent of 100 watts of continuous power from food, but it takes more than a hundred times this amount to sustain their lifestyle. Fossil fuels cannot provide this much power for every person on the planet, and we must reduce our dependence on these fuels to address global carbon dioxide emissions and climate change. To succeed, we need sustainable and carbon-neutral sources of energy. How can we find or make these fuels?

Microbes, according to the microbiologists and biochemists who contribute to *Bioenergy*, hold the answers. Editors Judy Wall, Caroline Harwood and Arnold Demain have assembled 31 impressive chapters that address the opportunities and challenges of using microbes to produce bioelectricity, to help in oil recovery or to make biofuels — including ethanol, methanol, methane and hydrogen.

*Bioenergy* supplies a wealth of technical information. Each chapter has an accessible

introduction and each author positions their favourite fuel within the larger context of energy production and utilization. Nancy Nichols and her colleagues note that in 2008, the United States will produce 30 billion litres of fuel ethanol, mainly from corn (maize). In 2006, around 20% of the US corn crop was used to make ethanol, which represented more than 2% of all liquid fuels used for transportation. Z. Lewis Liu and co-workers say that if all of the corn grown in the United States was used to make fuel, only 15% of current US fuel needs would be satisfied. These numbers show that we will need more than corn ethanol to fuel our cars.

Using any food source as a fuel is controversial. Perhaps reflecting this, only one of the twelve chapters on bioethanol directly addresses the use of food crops. Other chapters focus on the real challenge: how to turn cellulose, the main constituent of plant cell walls, into ethanol. Microbes can break down cellulose to produce sugar efficiently, but during the process they also consume the sugar. This loss can be avoided by using enzymes instead of microbes, but enzymes are expensive to make. After ethanol is formed by fermenting the sugar, another energy-intensive process is needed to remove the water by-product.



Finding new biofuel sources, such as algae that make hydrogen gas, might help solve the energy crisis.

Gaseous biofuels, such as hydrogen and methane, are made easily from many source materials using mature technologies. Hydrogen gas and volatile fatty acids, such as acetic acid, can be made from cellulose by fermentation. According to Ann Wilkie, most biomass sources can produce biomethane after limited preparation, such as drying or shredding. Certain microbes can convert acetic acid into methane gas, and methane or hydrogen can be converted to methanol. Hydrogen and methane are highly insoluble, so they can be recovered from water more easily than ethanol. In one of the seven chapters on methane and methanol, Bakul Dave reminds us that single-carbon fuels such as methanol lack carbon-carbon bonds, and therefore do not leave residues during combustion.

Combustion of hydrogen gas is better than methane as it produces only water. Three chapters are devoted to the production of hydrogen by photosynthesis in algae or bacteria, but none describes the use of fermentation or microbial electrolysis cells to make hydrogen. According to Marc Rousset and Laurent Cournac, hydrogenase enzymes that catalyse both the production and the consumption of hydrogen offer excellent opportunities to capture energy directly from sunlight, rather than through biomass, by splitting water into hydrogen and oxygen. But the sensitivity of these enzymes to oxygen needs to be decreased. Caroline Harwood describes using whole cells of purple non-sulphur bacteria to form hydrogen without splitting water. She notes that these cells can be immobilized in thin latex sheets to form panels. If perfected, this wonderful method could make hydrogen through the use of biosolar collectors.

My favourite bioenergy approach involves using bacteria to make electricity directly in microbial fuel cells. Certain strains of *Geobacter* might power these, but Peter Aelterman and his colleagues explain that many different types of bacteria release electrons to electrodes and can yield useful current. Why such a variety of bacteria can transfer electrons, in both directions, across their outer cell membranes remains a mystery worthy of further investigation. In the near future,

microbial fuel cells could harness energy from waste water by replacing the energy-consuming bioreactors used in conventional treatment systems with those that produce bioelectricity or biohydrogen.

What is missing from *Bioenergy* is a discussion of the social and political implications of a microbe-based, biofuel economy. For example, growing algae or certain crops for biofuel production requires enormous amounts of water. Nutrient releases from different crops into the environment also need to be critically evaluated. The possibility of extracting methane from gas hydrates in the ocean floor is addressed but, from a climate-change perspective, the release of stored carbon in this fuel could have disastrous consequences.

Solving the energy crisis using renewable biofuels will require microbiologists, electrochemists, engineers and politicians. This book is an excellent overview of the many possible methods for harnessing microbes to make energy, and I hope it will inspire researchers from fields outside microbiology to move into bioenergy production. ■

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## A potter round Darwin's patch

**Darwin's Garden: Down House and The Origin of Species**  
by Michael Boulter

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Writing of his discovery, with Francis Crick, of the structure of DNA in *The Double Helix*, James Watson remarks: "much of our success was due to the long uneventful periods when we walked among the colleges". Likewise, the influence of place on the intellectual processes of the scientist is one of the most engaging ideas in Michael Boulter's new book about Charles Darwin's garden.

Darwin bought Down House, 23 kilometres from the centre of London, in 1842. He lived there with his family until his death 40 years later, and almost all of his most significant books and papers, including *On the Origin of Species*,

published in 1859, were written in its study. The 7 hectares of land belonging to the house provided Darwin with a range of environments in which to formulate, develop and test his ideas. The long Sandwalk, a circular path through native trees, was Darwin's main thinking spot, and he would walk several laps every day. In the kitchen gardens and meadows, he investigated the effects of natural and artificial selection, and in the glasshouses he experimented with the cross pollination of exotic plant species.

Boulter sets out in the first half of *Darwin's Garden* the history of the purchase of Down House, the family's move there and the use of the garden in Darwin's scientific work. The ideas explored are thought-provoking, and there can be no doubt that the garden at Down had an extremely important role in Darwin's work.

However, Boulter moves too frequently between discussion of the importance of place and of time, making it hard for the reader to