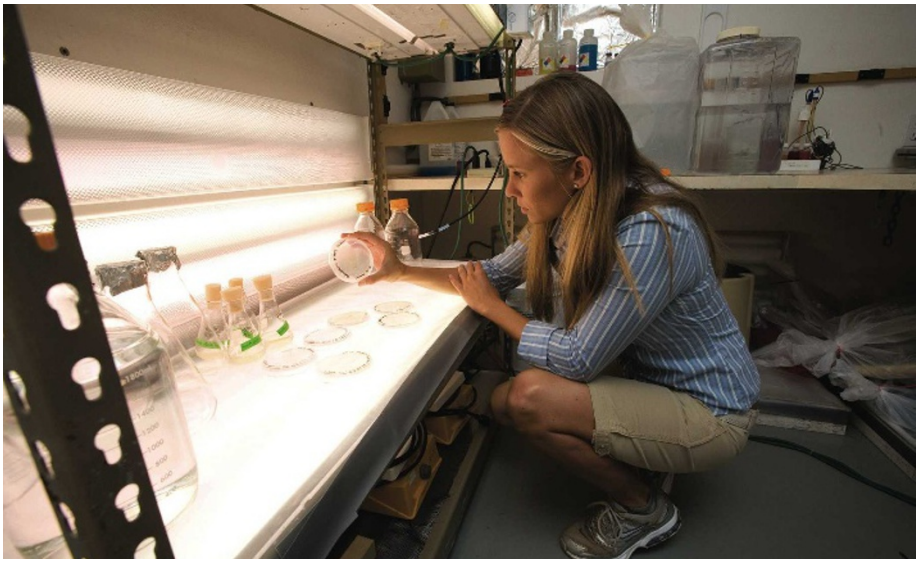

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Finding new biofuel sources, such as algae that make hydrogen gas, might help solve the energy crisis.

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

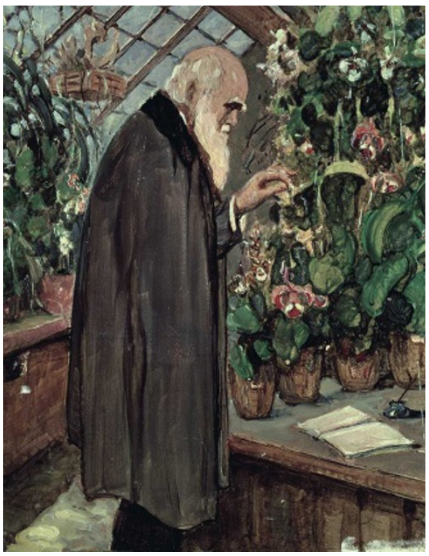
Darwin's Garden: Down House and The Origin of Species
by Michael Boulter
Constable & Robinson/Counterpoint: 2008/2009. 320 pp/272 pp. $16.99/£17.95

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



J. COLLIER, DOWN HOUSE, KENT/BRIDGEMAN ART LIBRARY

Darwin's scientific ideas were influenced by observations he made in the gardens and greenhouse at his home, Down House in Kent.

disentangle Darwin's influences. Darwin's work at the time was constrained by the lack of an explanation for the inheritance of characteristics, by the controversy surrounding the age of the Earth — at that stage few geologists, including Charles Lyell, advocated an Earth that was sufficiently old for the evolution of so many complex organisms — and by the prevailing views of society on the roles of mankind and religion in the world. These issues apply to all Victorian scientists, whereas the influence of Down House is specific to Darwin. Separate chapters on each topic might have made for a clearer analysis.

The book suggests that many of Darwin's breakthroughs came in single flashes of inspiration in the garden, rather than after years of painstaking work. Although it gives due credit to the years that Darwin spent investigating the morphology and taxonomy of barnacles, it gives much less weight to his similarly detailed work on orchids and other plants, work that made essential contributions to the development of his ideas about reproductive isolation and speciation. Boulter ascribes Darwin's explanation of how species become reproductively isolated from one another to his noticing a single hedge parsley plant in an unusual location. Boulter alleges that, from seeing a single plant in the wrong place, Darwin apparently became convinced that migration and subsequent geographically isolated speciation could explain the origins of all new species. Yet it is highly unlikely that so simple a sight could provide all the answers. Evolutionary biologists still debate the issues surrounding speciation today.

Boulter next explores how Darwin's thoughts and experiments have contributed to modern science. He describes recent research on the mutant forms of orchid, which Darwin studied in the greenhouse at Down, and recent explanations for the rapid spread and diversification of flowering plants, which Darwin described as "an abominable mystery". This readable section provides insights into how a changing scientific and social perspective can influence our interpretation of the living world. Yet here, in an understandable attempt to make difficult concepts clear to a broad audience, Boulter sacrifices scientific accuracy to an extent that undermines the specialist reader's confidence in the book as a whole. Contradictory statements about the ages of certain groups of organisms, a long section that gives the impression that *hox* genes controlling animal body segmentation are present in plants and a misleading definition of a gene are just some examples of the book's numerous errors.

Darwin's Garden is an enjoyable read that introduces some thought-provoking ideas about the roles of place, time and perception in the scientific process. If the science and the history are taken with a pinch of salt, it makes for a very good story. ■

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