Agro-Technology

Humans have been modifying plants and animals for millennia. The dawn of molecular genetics, however, has kindled intense public scrutiny and controversy. Crops, and the food products which include them, have dominated molecular modification in agriculture. Organisations have made unsubstantiated claims and scaremongering is common. In this textbook R. Paul Thompson presents a clear account of the significant issues – identifying harms and benefits, analysing and managing risk – which lie beneath the cacophony of public controversy. His comprehensive analysis looks especially at genetically modified organisms, and includes an explanation of the scientific background, an analysis of ideological objections, a discussion of legal and ethical concerns, a suggested alternative – organic agriculture – and an examination of the controversy's impact on sub-Saharan African countries. His book will be of interest to students and other readers in philosophy, biology, biotechnology and public policy.

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A Philosophical Introduction

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For Olivia

May the wind be always at your back.

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Preface

I have a long-standing personal interest in food: its history, its biology and chemistry, its production and its preparation. Hence, cooking provides a creative outlet, one in which my academic curiosity about the history, biology and chemistry of food can be combined with creating new methods of preparation, new ingredients and combinations of ingredients, and new combinations of flavours. Pursuing this interest has led me to delve into the history of food, especially the last 10–15, 000 years of the domestication of plants and animals and the introduction of novel foods in diverse regions of the globe, including wild sources of ingredients (see Elias and Dykeman, 1990; Gardon, 1998; Henderson, 2000; Thayer, 2006). It also has led me to study food chemistry and the cell and molecular properties of food, the transformation of food during preparation (such as the Maillard reaction when food is heated), the physiology and neuroscience of taste, and modern agricultural practices, food processing and food distribution. This book focuses mostly on the latter, specifically on biotechnology in agriculture and the controversy surrounding it.

I bring to the material in this book a special, though far from unique, combination of perspectives and knowledge. My academic interests breach the normal divide between science and the humanities. On the one side, I have a background in philosophy, hold an appointment in the Institute for the History and Philosophy of Science and Technology, and teach courses on the philosophy of biology and the philosophy of medicine. On the other, I also have a background in biology, hold an appointment in the Department of Ecology and Evolutionary Biology, and currently teach a biology course on molecular genetics and biotechnology. Over the last 30 years, I have taught biology courses on population genetics, evolution and epidemiology, and a diverse array of philosophy courses, including ethics, social issues, the philosophy of science, the philosophy of medicine and mathematical (symbolic) logic. I hope in the course of this book I can help others bridge what is often a deep chasm.

This is not an advocacy book but no one writes about issues as contentious as agricultural biotechnology without numerous influences, and preformed ideas and positions (hopefully positions based on the best available evidence and sound reasoning). Intellectual openness does not require coming to an issue with a blank slate or pretending to be positionless, but it does require that positions be open to change in the light of revised or new evidence, or exposed deficiencies in reasoning. To do otherwise is dogmatic and irrational.

A simple statement of thanks at the end of a preface dramatically underestimates the contribution made by so many to the ideas and analyses in this book. Some are long deceased philosophers reaching back to Plato and Aristotle. Others are contemporary researchers and scholars, from biologists to political scientists and economists to philosophers. Yet others are friends and colleagues. My long-standing and very close friends Michael Ruse and Paul Gooch opened up the rich and deeply important world of philosophical ideas and analysis. Hugh Grant, Jerry Steiner, Rob Horsh, Kate Fish and Dianne Herndon revealed the complexities of the world of biotech business. Rob Paarlberg, a friend and intellectual colleague, has written an important and insightful book (Paarlberg, 2008), from which I gleaned much about the political dynamics of biotechnology and Africa. My richest insights into agriculture in rural East Africa are due to Ruth Oniang'o (Honourable Professor Ruth Oniang'o). Ruth is a remarkable woman. For many years she was a professor of nutrition at Jomo Kenyatta University in Nairobi. She founded the *African Journal of Food, Agriculture, Nutrition and Development* and a local non-governmental organisation (NGO), the Rural Outreach Programme. She served as a member of the Kenyan parliament for one term. Working with her NGO and visiting rural areas of western Kenya have profoundly shaped my views on agriculture in Africa. The HIV/AIDs and poverty relief work of my niece, Jessica Bokhout, in South Africa and Zambia are inspiring. She read and discussed with me many of the chapters of this book. Her insights on the inner workings of NGOs are rich and nuanced. Her views on the potential harms of patents on those in low- and middle-income countries, on the attraction of organic farming and, especially, on the content in the chapter on Africa offered a helpful and needed alternative perspective. I have learned a great deal from David Castle's writings on social issues in genomics and biotechnology and from stimulating conversations over the last few years. As is always the case, this book would not have appeared without the fine work of Hilary Gaskin, Joanna Garbutt,

Anna Lowe and Christina Sarigiannidou at Cambridge University Press, and thanks to Joe Garver for meticulous copy-editing.

I owe an enormous debt of gratitude to my wife, Jennifer McShane, whom I met in high school and to whom I will have been happily married for 40 years in 2011. She has constantly supported my endeavours, endured my philosophical analysis of nearly every idea and action arising in our lives, and proofread all that I have written over the last 40 years. Although my three adult children, Eirinn, Kerry and Jonathan, and my dad, Lewis, and his wife, Pat, have not made a direct contribution to this book, their love, support and individual achievements are part of the foundation on which my own sense of self is built.

Introduction

Food and water are essential to human life; more specifically, safe water in sufficient quantities, and safe and nutritionally balanced food in sufficient quantities are essential to good health. Until the twentieth century in developed countries (rich countries), neither could be taken for granted; for most of the world's people today, neither can be taken for granted. People in rich countries, however, have for most of the last century had access to abundant, affordable and safe food and water. This is, incontestably, a direct function of advances in science and technology. Moreover, meeting the challenges of tomorrow will depend on continued advances. Jeffery D. Sachs eloquently makes this point in his book *The End of Poverty*:

> I believe that the single most important reason why prosperity spread, and why it continues to spread, is the transmission of **technologies** and the ideas underlying them. Even more important than having specific resources in the ground, such as coal, was the ability to use modern science-based ideas to organize production. The beauty of ideas is that they can be used over and over again, without ever being depleted. Economists call ideas nonrival in the sense that one person's use of an idea does not diminish the ability of others to use it as well. This is why we can envision a world in which everyone achieves prosperity. The essence of the first industrial revolution was not the coal; it was how to use the coal. Even more generally, it was about how to use a new form of energy. The lessons of coal eventually became the basis for many other energy systems as well, from hydropower, oil and gas, and nuclear power to new forms of renewable energy such as wind and solar power converted to electricity. (Sachs, 2005, pp. 41–42)

This, although completely accurate, is the rosy side. The benefits of science and technology have not been achieved without attendant problems. It is worth noting that many, but by no means all, of these problems have resulted from human inattention, greed and optimism and are not the result of advances in

science and technology *per se*. Furthermore, even factoring in the problems, few people, on balance, would wish to relinquish the benefits that arise from science and technology; very few would trade the challenges of today for those of 500 years ago. Our almost universal embrace of the benefits of science and technology in medicine and dentistry – including those arising from medical biotechnology during the last several decades – provides powerful support for this view. Nonetheless, one obvious lesson from the history of science and technology is that anything less than intense and continual vigilance is irrational and imprudent. Seizing benefits and identifying and mitigating harms are inextricably connected endeavours. To believe that benefits can be seized while identifying and mitigating harms ignored is sheer folly.

Science and technology have been at the core of the success of rich countries in thwarting the prediction of Thomas Malthus (1798). Malthus claimed that human populations will, unchecked, increase geometrically while resources (food, shelter and the like) will only grow arithmetically. At some point, the population will outstrip the available resources and an intense competition for resources will ensue, leaving many with inadequate resources and, hence, desperate. For most of the twentieth century, agricultural technology advanced by employing millennia-old breeding knowledge and coupling it with contemporary population, quantitative and molecular genetics. For millennia, animal and plant agriculture relied on selecting organisms with desirable traits as a breeding stock. As new advantageous traits were identified or emerged, organisms with those traits became the new breeding stock. As scientific knowledge advanced, especially in genetics, the understanding of traits, hybridisation and selection became more sophisticated. In the latter part of the twentieth century, based on advances in cell and molecular biology, biotechnological manipulation of the genomes of organisms became possible. Governments, agencies and regulators in most rich countries approved numerous medical, environmental and agricultural applications. Of these applications, agriculture – specifically plant agriculture – became the target of intense criticism. The debate over agricultural biotechnology continues to rage and that debate is the focus of this book. Although slightly dated, the collection of articles in *Genetically Modified Foods: Debating Biotechnology* edited by Michael Ruse and David Castle (2002) provides an excellent glimpse into the differing opinions.

Engaging in the debate, obviously, involves examining scientific evidence and considerable space in this book is devoted to scientific evidence. But the

things that have emerged as central in the debate are more philosophical in character. Issues, for example, about the sanctity of life and the immorality of manipulating it, the balancing of benefits and harms, the avoidance of certain kinds of harms, the ownership of new life forms, the value of biodiversity, the value of safe, affordable food and so on. Consider the claim made by Great Britain's Prince Charles in his Reith Lecture (HRH The Prince of Wales, 2000), 'I believe that if we are to achieve genuine sustainable development, we will have to rediscover, or re-acknowledge, a sense of the sacred in our dealings with the natural world, and with each other.' Lofty and eloquent as this sounds, drawing out its meaning is challenging.

What does 'genuine sustainable development' mean? Can there be ungenuine sustainable development? What is the measure of 'sustainable' and sustainable for whom or what? There are those who consider the continued loss of species as evidence of a failure to have sustainability. There are others for whom the essence of sustainable development resides in the continuation of humanity. For them, sustainable development is important – perhaps morally required – because continued human existence is under threat from a continuation of the practices of the last couple of centuries; this is a very anthropocentric motivation. There are, of course, other positions on the meaning and measure of 'sustainable' but all are philosophical in character. Furthermore, what might Prince Charles have meant by 'sacred'? Perhaps he had in mind a theological sense of the requirements of stewardship that God has given humans, and of humility that respects rather than usurps God's natural order. Or perhaps this is a thoroughly secular sense of sacred, something like recognition of the beauty and wonder of the natural world, and of the delicate balance that we can so easily disrupt. More importantly, what follows from accepting 'a sense of the sacred in our dealing with the natural world'? Surely, this is not a recommendation that we return to a way of life led by our early ancestors; caves for shelter, for example. The phrase is entirely unhelpful unless it can be given some substance. Is atomic electricity generation a violation of this 'sense of the sacred'? Is air travel a violation? Is using birth control pills a violation? Is producing recombinant insulin from bacteria a violation? In short, how will we know when we are adhering to and when violating this 'sense of the sacred'? Platitudes such as those invoked by Prince Charles are useful rhetorical devices but they do not advance rational decision-making; indeed, they frequently, as in this case, frustrate rational decision-making and lead to imprudent courses of action. This is why philosophical

analysis is an essential component in any examination and analysis of socially, morally, legally and politically important issues arising from scientific advances.

To further emphasise this essential role, consider yet another example. Vandana Shiva (1997) claims:

> When organisms are treated as if they are machines, an ethical shift takes place – life is seen as having instrumental rather than intrinsic value. The manipulation of animals for industrial ends has already had major ethical, economic, and health implications. The reductionist, machine view of animals removes all ethical concern for how animals are treated to maximize production.

There is a lot packed into these three sentences. There are valuable insights and murky implications. Her main concern in this passage and in the section in which it occurs is animals – specifically agricultural animals. Beginning, however, with the phrase 'when organisms' invites one to generalise beyond agricultural animals, indeed beyond animals to bacteria, yeasts, plants and the like. In effect, she is generalising from a convincing case for agricultural animals to all organisms; her reference to 'organisms' entices the reader into accepting that her narrow claims apply to **all** organisms. I fully agree that most agricultural animals are treated appallingly and that ethical concerns are muted by a factory farm structure designed to enhance profits. Whether this is the result of a mechanistic and reductionist view is less clear but it is at least a tenable hypothesis. What does not follow is that ethical concern for 'animals' beyond agricultural animals is also removed. Cruelty to animals does occur but there is widespread public support – in rich countries at least – that such cruelty is unacceptable. Societies for the prevention of cruelty to animals abound, and research animals have for the last 25 years been protected by laws and review processes, precisely because there is little public tolerance for cruelty to animals. Without care, one can easily be seduced into accepting a view about all animals based on a narrow case for agricultural animals. Moreover, the case may seem to have been made for all 'organisms'; it has not. The importance of this latter point is that the emotive invoking of animals as machines and viewed through a reductionist lens, simply does not apply in any natural way to plants – agricultural, horticultural or other kinds – or bacteria, but they do seem to be gathered up in 'organisms' in this passage. There is a subtle analogy at work here, comparing attitudes towards, and treatment of, agricultural animals with attitudes towards, and treatment of,

all organisms. In Section 3.1 below, the value of analogy is explored, as is its abuse; Shiva's is clearly an abuse.

Furthermore, there is a significant difference between methodological reductionism (which abounds in all sciences and in medicine) and mechanistic reductionism. The latter involves accepting that **the nature of things** is such that whole entities (materials, organisms and so on) can be reduced to their parts in a way that the whole is no greater than the sum of its parts. It is not an assumption to guide research or investigation but a commitment to the ways nature is structured. I do not believe my dog is a mere machine (mechanistic reductionism) but if he is ailing, I assume, as a **method** of investigating the cause, that some part of him is not functioning properly (methodological reductionism). Shiva, as I conceded, may be correct that mechanistic reductionism is at work in the way we think about and treat agricultural animals but a biotechnologist does not have to accept this kind of reductionism (methodological reductionism is enough) to engage in genetic engineering and even if she did, it is not at all clear what the ethical implications of treating plants or bacteria this way are. By blending the two kinds of reductionism, she can slide from one to the other uncritically.

Finally on this example, there is the matter of 'instrumental rather than intrinsic value'. This is set up as a dichotomy; it is one or the other. Actually, as the discussion of Kantian ethics in Section 3.2 makes clear, it is usually both that are at work for humans as well as other animals. It is not ethically problematic to treat someone as a means (an instrument) if she is also being treated as an end (something with intrinsic value); labourers have this duality attached to them all the time. Also, the owner of a horse may well use the horse for instrumental ends – racing for prize money, for example – but also recognise that the horse has intrinsic value and needs to be properly cared for and tended: indeed, in many cases, owners confess they love their horse. Again, Shiva may be correct that pigs, poultry, cattle and such are seldom viewed by farmers as having intrinsic value but the generalisation to other contexts is again specious, as is the implication that valuing an animal instrumentally is incompatible with also valuing it intrinsically. And, how any of this applies to plants and bacteria is unclear.

Consider a final example, one that focuses on a reliable supply of food. Of late, a plethora of food movements has grown up in rich nations – nations where food is, with minor exceptions, plentiful, safe, affordable and readily accessible. The slow food movement (using fresh ingredients with dishes

prepared just before serving, by contrast with fast food – e.g. McDonald's – factory prepared and prepackaged food) and the locavore movement (using ingredients grown or raised locally – e.g. the 100-mile diet) are examples. Although there are clear aesthetic, health and environmental benefits to eating locally grown food, favouring free-range animal farming, enjoying on-site preparation using fresh ingredients, and minimising prepackaged and pre-processed foods, there are also demonstrable harms, as will become apparent from the examinations undertaken in this book, especially in Chapter 7 on the organic food movement. Staying with the locavore movement, one potential harm is an inability to respond to local crop failures. A reliable, adequate supply of food requires widely distributed sources. Without this, a local population (a 100-mile-diet population, for example) risks famine from inclement weather, plant or animal disease, elevated pest populations and the like. Famine from crop failure, disease outbreaks and so on occur frequently around the world. The solution, especially in rich nations, is to import excess production from elsewhere. In a world where every community relies heavily or exclusively on local production – 'local' often extends beyond 100 miles but then so do most crop failures due to weather or pest invasions – there will be no incentive to produce food beyond local demand; modest unplanned excesses will occur from time to time but not in the quantities needed to relieve a significant famine elsewhere, and certainly such excesses cannot be relied on. So a world of local production and consumption is a precarious world, one that actually looks a lot like agriculture in low- and middle-income nations in Africa today and agriculture in Europe 300 years ago. The pattern of famine, starvation and poverty that is characteristic of African nations should make people in rich nations nervous about abandoning a global agricultural model. A healthy global agricultural marketplace is consistent with, indeed may benefit from, some level of local consumption, but eating locally cannot be the global norm without courting disaster.

Obviously, finding the right balance between local and global, price and quality, small scale and large scale is a prudent and rational approach, and is critical to successful policy and action. Finding the right balance contrasts with championing one end of a spectrum; many advocates of the 100-mile diet champion one end of the food source spectrum, thereby risking the harm outlined above. One component of the analysis undertaken in this book is the identification of end-of-spectrum views, the uncovering of their benefits and flaws, and seeking the rational balance that maximises human well-being,

reliable food supply, environmental protection and sustainable agricultural practices – sustainable economically and environmentally.

These three examples draw out different facets of the same point. Philosophical analysis is an essential element of any examination of the ethical, social, legal and political aspects of issues arising from scientific advances. Failure to engage in the analysis is an abdication of reason and a ceding of the debate to mere persuasion, with confusion, an untameable cacophony of voices, and ill-considered policies, laws and attitudes. It would be disingenuous, and entirely irresponsible, not to concede, at this point, that philosophical analysis is not a panacea for these ills. The point is not that with philosophical analysis everything is rational and right but rather that without it the situation is many times worse. Philosophical analysis is one element in gaining traction on complex social issues, not the golden path to Utopia.

In the preface, I indicated that this is not an advocacy book but I obviously have positions and commitments that it would be disingenuous to deny or try to conceal. In the chapters that follow, I examine many conflicting claims, positions and arguments and the evidence given to support them. My current conclusions are favourable to agricultural biotechnology; I support agriculture shifting towards more genetic modification and it is, therefore, not surprising that the conclusions of the various examinations in the book are tilted in that direction. I also conclude that organic agriculture has a meaningful role to play. By contrast, I am quite negative on the continuation of non-GM (non-genetically modified), conventional agriculture. This is largely because of its unsustainable negative environmental impact – an impact I outline in Section 5.1. So, while this is not an advocacy book, it is also not a dispassionate, disinterested examination. I contend, however, that it is an evidence-based and reasoned examination; with issues of this importance, complexity and controversial nature, that is the most honest, helpful and rational approach possible.

To make sense of many of the touted benefits and harms of biotechnology in agriculture, a modest knowledge of the genetics underlying the technologies is helpful. For example, understanding some of the requisite conditions for, and mechanisms of, horizontal gene transfer enhances a rational assessment of the probability of such a transfer in the case of GM crops as well as the extent of harm from such a transfer – both, as made clear in Chapter 8, are essential elements of a robust risk analysis. Hence, in Chapters 1 and 2, I sketch, in as non-technical a way as possible, the core scientific underpinnings

of biotechnology, and the techniques and applications found in agricultural biotechnology. In some cases, the exposition of some specific aspects of science and technology is associated with the topic for which it is most relevant. Two considerations motivate this strategy. First, Chapters 1 and 2 are designed to provide some background science and technology that is relevant to more than one topic or chapter. In addition, the intention is for those chapters to expound broad features of the science and technology rather than more specialised domains. Second, juxtaposing specific aspects of science and technology and the issue to which they are relevant permits a dynamic interaction between them. For example, the discussion of the purported harm of horizontal gene transfer benefits considerably from associating the scientific evidence with the various points raised.

The principal focus of this book is on the controversy over biotechnology in agriculture. That controversy, at this point, centres almost exclusively on plant agriculture, where most of the molecular modifications have occurred and have been commercialised. Consequently this book focuses mostly on GM plant agriculture. The controversy encompasses scientific, economic, political, regulatory, legal, ideological and theological dimensions. These are dealt with in Chapters 4, 5 and 6. A rigorous and robust examination of the various aspects of the controversy relies on analytical tools and methods. Chapter 3 describes the core tools and methods. At the heart of any analysis are reasoning and evidence; hence, I start Chapter 3 with an exposition of these. Many of the claims and arguments proffered in the controversy over agricultural biotechnology rest on ethical commitments. This is a complicated landscape. Different individuals and groups adhere to different ethical theories, and this, without care and attention to detail, will mean that they will fail to engage each other; they will be talking past each other. To use a word that has become common to describe such differences in theoretical commitments, their views will be *incommensurable* (there exists no common measure, no common assumptions). In Section 3.2, I set out the most commonly held ethical theories and note the differences among them but signal that in the context of biotechnology, there is a common measure: risk assessment. In subsequent chapters, I develop this claim of a common measure, especially in Sections 3.4 and 4.2.

Being aware of these different theories is essential to understanding many of the claims made and why those making them think they matter. It is also essential to understanding why gaining traction on an issue is so illusive.

Ultimately, I maintain, many of the issues arising from agricultural biotechnology can be examined in a way that mitigates the difficulties posed by different members and groups in a society adhering to different ethical theories. One element of this mitigation is risk analysis. Regardless of which ethical theory one adopts, many ethical, social, political and legal aspects of agricultural biotechnology require the identification of benefits and harms, an assessment of the balance of harms to benefits, and, if on balance the benefits outweigh the harms, a managing of the harms. For some ethical theories, risk assessment is fundamental; for others, fundamental ethical principles place constraints on risk analysis but do not render it ineffective or unnecessary. In Section 3.3, the various features of risk analysis are set out, including the essential role of values and goals.

One principle that some individuals and groups have elevated to a fundamental one is the precautionary principle. In its strongest version, it renders risk analysis entirely inappropriate. Few accept that strong version and, hence, few completely dismiss the relevance of risk analysis. Since the precautionary principle has been prominent in segments of the controversy over agricultural biotechnology, and because its interpretation and application interact with risk analysis, I examine it in Section 3.4.

Many who reject molecular biotechnology in agriculture look to organic agriculture as the alternative. In Chapter 7, I look in some detail at this alternative and the claims made about it. The thrust of the chapter is that organic is best contrasted with conventional agriculture and that the contrast with GM agriculture is unhelpful and contrived. If we are to escape the environmental ravages of conventional agriculture, GM and organic agriculture will have to be embraced. To put the view I support in its strongest terms, the antipathy towards GM agriculture expressed by those who support organic agriculture is irrational; conventional agriculture should be the target of their antipathy.

The low- and middle-income countries, in various ways at different times, have suffered at the hands of developed (rich) nations. The impact of rich countries' squabbling over GM agriculture is but another instance. Some low- and middle-income countries are slowly breaking the continuing colonial hold of rich nations, a hold that no longer depends on military subjugation but on economic control through vehicles such as trade. Sadly, that hold is also maintained by the views and actions of NGOs on whom poor nations and their impoverished citizens depend for assistance. This is sad because most of us financially support those NGOs, volunteer our time, or accept employment

with them because bettering the lives of the poor matters to us. The low- and middle-income countries about which I know the most and on which the impact of rich nations' squabbles have had the greatest negative impact are in Africa. It is a vast continent and its nations differ substantially in their resources, needs and abilities. Despite billions of dollars in aid and the activity of countless NGOs, the data on poverty and health are appalling and progress is illusive. In Chapter 8, I examine the promise of agricultural biotechnology for African nations and indicate the negative impact the debate over it in rich countries has had on poor Africans. I also highlight, again, in this context the hypocrisy of rich countries around biotechnology in agriculture, medicine and environmental amelioration.