Introduction

At some point in their work, most biology students will ask themselves: why is there so much to learn? Though the deeper principles of science may be valuable, they are always in danger of being overwhelmed by the mass of detail that fills all textbooks, and attends all courses. For students and teachers alike, undergraduate courses in the biological or life sciences can easily become exercises in fact management. This is a problem for the many students interested in exploring how their subject relates to wider contexts, or who are uneasy at the narrowing choices they had to make in order to study any of the biological sciences at university. Others, who want their biology degree to be as useful as possible, need to see that science can be discussed in a way that non-scientists find compelling and important. For those who choose a career in research, the necessarily strict disciplines of laboratory life are likely to need complementing with a feeling for the philosophy of the subject: a knowledge of how biology gains its authority, how it presents itself in public, and how it relates to other sciences, to the arts and to the humanities.

The purpose of this book is to make these connections. It aims to help students find some new intellectual perspectives on their studies. This is why the book is called *Thinking About Biology*. Throughout, I try to illuminate two kinds of connection. The first set explores the links between different parts of biology, emphasising the relations between evolution and genetics, between cell theory and the techniques of microscopy, and between organismal biology and molecular biology. These connections have a simple purpose: to remind the student that the different modules they may compile during a biology course do indeed link up – they are part of the same discipline. My second set of links are more unusual for a biology textbook, because they extend far beyond the conventional bounds of a life

sciences course. Here I explore our subject's philosophical foundations, its relationship with politics and ethical discussion, and its representation in the media. These are topics that are interesting to most students and teachers, and are important tools for anyone wishing to put their work to use. Their obvious value as an accompaniment to, and motivation for, the study of biology is being increasingly recognised by the more enlightened schools, colleges and universities.

Thinking About Biology is a textbook because I ground all my discussions in material likely to be found in any life science or medical curriculum. I start with the biology, and then look further afield. Thus the book is not an introduction to the history and philosophy of science, though it goes some way in that direction. Amongst my diverse set of topics and arguments, a few broadly philosophical themes recur. For example, I explore the way a topic as fundamental as the cell theory has an argumentative and fraught history, one that suggests facts are not timeless discoveries, but are rather more fragile and dynamic than that. Similarly, though one can make a conscious decision to view modern molecular genetics simply as a set of technical achievements, *Thinking About Biology* explores the way such achievements relate to the public debate about the limits of science. An important theme of the book is that the well-trained graduate knows how science impacts on society, understands that science itself is affected by society, and must be responsive to wider debates.

In short, this book is a practical manual for the thinking student. It provides just a few of the tools needed to become a reflective, as well as a technically proficient, practitioner of the craft of biology. As the book puts such an emphasis on the concept and desirability of the 'reflective scientist', I should briefly flesh out why I consider this important.

No one could oppose the idea that the learning of biology should be a thought-provoking exercise. Obviously, biology classrooms, lecture halls and laboratories are filled with people trying to make sense of nature. The problem is that the academic environment may hinder, rather than enhance, the intellectual spirit. For the students, courses may be too fragmented, too laden with factual content, or too heavily assessed. Teachers face pressures too. College and university lecturers are themselves assessed, tests based in many cases on where, and how often, their research is published. The institutions where they work are as likely to compete as to collaborate, and find themselves anxiously occupied with their ratings in league tables. All of this makes it much more difficult to provide

in formal education the open-ended and meandering discussions needed for encouraging reflection.

Yet the need for such discussions is very great. Firstly, it is absolutely clear that students enjoy the chance to discuss and debate their subject, and want more of these opportunities. Secondly, a glance beyond the university and college corridors quickly reveals that a great deal of science is being discussed in the press, on the broadcast media and through the Internet. Some scientists consider this debate largely misinformed, usually sensational and inevitably oversimplified. Others realise that so great a public interest in such matters as genetic modification, bovine spongiform encephalopathy (BSE) and xenotransplantation, is largely a good thing – and that it would be mad for scientists and students simply to ignore it. However, to take part in the debate and to make a contribution, we will need to avoid all arrogance and be prepared to listen. Nor need this simply be a buttoning of the lip. The philosophical and historical themes explored by *Thinking About Biology* show science to be a fallible and human endeavour, one incapable of establishing final truths. Instead, just like the rest of life, it is argumentative, wandering and personal.

The book has two parts, Chapters 1–4 and Chapters 5–8. The first half is longer and embarks on a study of some relatively conventional areas of the philosophy of biology. Chapter 1, **Facts?** uses the history of cell biology as a vehicle for exploring biological methods and their reliability. Chapter 2, **Reductionism**, follows aspects of the well-known anxiety surrounding biology's tendency to understand organisms by first breaking them up. Chapter 3, **Evolution**, is an area that is traditionally the home for literary and thoughtful biologists. Chapter 4, **Biology and animals**, ventures into animal rights, an area that seems appropriate for students to discuss, but unfortunately remains a somewhat tight-lipped debate in biological circles. The second half of the book takes on wider contexts. Commentary on scientific controversies, for example the public rows about BSE (mad cow disease), genetic modification and xenotransplantation, forms Chapter 5, **Controversies in biology**. The ethical implications of the Human Genome Project are discussed in Chapter 6, **Making sense of genes**. Chapter 7, **Biology and politics**, looks at some links between politics and biology, such as the history of eugenics. The book finishes with Chapter 8, **Research ethics**, in a consideration of this contemporary topic that takes as its centre a debate about the honesty of scientists.

How should you read the book? Most importantly, remember that *Thinking About Biology* aims to be thought provoking rather than

authoritative. There is no need to read the chapters in order. Like any textbook, you should use the Contents section and the Index to find areas that interest you, or are related to your studies. Each chapter is made up of a few sections, each designed to be read reasonably easily, and I hope enjoyably. You will find comments, references and suggestions for further reading in footnotes throughout the book. References introducing the philosophy of biology are given in the short list below.

Further reading:

Chalmers, A.F. (1999). *What is This Thing Called Science?* 3rd edn. Buckingham: Open University Press.

Ruse, M. (ed.) (1989). *The Philosophy of Biology*. New York: Macmillan.

Sterelny, K. and Griffiths, P.E. (eds.) (1999). *Sex and Death: an Introduction to Philosophy of Biology*. Chicago: Chicago University Press.

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Facts?

1.1 The problem with cannabis

In Amsterdam, they say, you can approach a policeman and ask the best place for buying cannabis. Very likely you will be courteously pointed to one of the city's 'coffee shops', where marijuana in a number of forms is on sale, to be enjoyed along with coffee and newspapers. The legalisation of cannabis in the Netherlands is 'The Dutch Experiment', and is a focus of interest for the interminable arguments about drug control in other countries. The liberal Dutch attitude contrasts with the stricter attitudes of the authorities in the UK, where until recently cannabis use was an arrestable offence, with 300 000 people street-searched each year and 80 000 arrested. The differing attitudes of the European countries to drug use is one reason for the constant newsworthiness of cannabis. Another reason is its widespread use. Some 50% of British 16–19 year olds have smoked cannabis; across Europe, there are 45 million regular users. The controversy takes various forms. Some argue that cannabis should be decriminalised. With this strategy, possession remains an offence, but leads to a fine or a warning, rather than to prosecution and a criminal record. Others go further and call for legalisation, so that cannabis is freely available, taxed and even supplied by the state. According to its advocates, legalisation of heroin and ecstasy, as well as of cannabis and amphetamines, will reduce the demand for drug dealers, and so reduce drug-related crime. Moreover, so the argument runs, when criminal suppliers are put out of business, the health problems associated with contaminated drugs will disappear too: government-controlled supplies will be quality assured.

In July 2002, the UK Labour Government confirmed that it was to reclassify cannabis, changing it from a Class B to a Class C drug, so that it will be in the company of mild amphetamines, tranquillisers and anabolic steroids rather than barbiturates, codeine and speed.[1] The change has a pragmatic element and was driven by a consideration of police priorities. Telling someone to stub out a joint takes 10 seconds; arresting and charging them takes 3 hours. No doubt establishment opinion is warming to the idea that cannabis is no more dangerous than alcohol or nicotine: politicians want to visit their undergraduate sons and daughters at college, not in jail. Changing views in the medical profession are also forcing a reappraisal. For example, in 1998 a committee of the House of Lords (the UK parliamentary upper house) recommended that doctors should be able to prescribe herbal cannabis to people with certain illnesses, such as multiple sclerosis. According to the committee's report, the possible benefits patients might get from cannabis meant that it was wrong to expose such patients to legal action simply because they decided themselves to use the drug to alleviate symptoms. Scientists too are involved in the debate over society's proper attitude to drugs. It might be, for example, that scientific research will establish more precisely when and how cannabis, or heroin, is dangerous. A government, facing calls for a change in the law, will ask the following questions: does cannabis use carry the risk of long-term personality change, does it reduce your aptitude to work, is it addictive? The experts called in to rule on the issue will be physiologists as well as the police, psychologists as well as head teachers.[2]

There have been many scientific trials trying to measure the short-term and long-term neurological effects of cannabis or its active ingredient, tetrahydrocannabinol (THC). In addition, scientists and psychologists have investigated whether and how cannabis is addictive. Finally, it should be possible for social scientists to confirm or refute rumours that cannabis is a gateway drug, steadily drawing its users towards a life of needles, addiction and social dysfunction. On the one hand, no one disputes

[1] Class A drugs include heroin, opium, crack, LSD and ecstasy.

[2] The British parliamentary Conservative party generated amusement during its 1999 conference when Anne Widdecombe, then the party's home affairs spokesperson, declared that once in power she would inaugurate a 'zero tolerance' policy towards cannabis. Under the new law, anyone found in possession of even the tiniest amount would automatically face a fine of £100. The policy was quickly dropped after five senior Conservative politicians revealed that they had smoked cannabis when they were students. Soon cannabis was to be reclassified, and it became common to hear police chiefs speculating about the positive effects of full legalisation. The magazine *New Scientist* has a useful archive on both the scientific and the political debates (http://newscientist.com/hottopics/marijuana/). See also the archive of articles on the topic maintained by the UK newspaper *The Guardian* (http://www.guardian.co.uk/).

the importance of the issue: if cannabis is dangerous, then people should be protected. On the other hand, if it is not harmful, or can even alleviate medical conditions, then people should not be jailed for growing it in the greenhouse. Yet, in spite of the science brought to bear on the issue, no final judgement on the safety of cannabis has yet emerged. Even the facts generated by the scientific research are disputed: there are plenty of research data, but no one can agree on what they mean.

Take the question of addiction. An American study at Baltimore's National Institute on Drug Abuse described caged squirrel monkeys becoming addicted to THC. The monkeys were given an injection of THC every time they touched a lever. Soon enough they were hitting the lever deliberately and giving themselves injections as often as 60 times an hour; the conclusion drawn is that cannabis is physically addictive. Meanwhile, the statistics from the Netherlands, where cannabis is decriminalised, are sometimes used to point to an opposite conclusion: that cannabis is not addictive. The percentage of Dutch people who use cannabis is lower than in many other European countries, including Britain. Moreover, the number of Dutch drug addicts has not increased; in fact their average age is rising, showing that young cannabis smokers in the Netherlands are not moving onto something harder. The problem for campaigners on both sides is that the statistics do not close the argument. Neither the data from the Netherlands (done by survey of people's behaviour), nor the data from the Baltimore experiment (done by laboratory work on monkeys), are conclusive. Instead of producing useful predictions for people's behaviour and physiology in a wide variety of situations, the Dutch and Baltimore studies may simply tell us something about people in Amsterdam, and monkeys in Baltimore.

Apart from the question of addictiveness, one of the particular concerns about cannabis is that it lowers mental performance. Once again, science finds it hard to rule one way or the other. There are claims that cannabis users do worse at school and college, and are more likely to become delinquent, but the evidence for this is disputed. For example, there are trials where heavy cannabis users are asked to refrain from smoking for some days, and then to undergo manual and intellectual tests. In a study at Harvard Medical School, individuals who had smoked more than 5000 joints agreed to abstain and then take part in some computer games. They were found to be more aggressive than a group of light smokers. This, however, does not prove long-term damage, but perhaps only the irritation caused by withdrawal symptoms. Moreover, people who become

aggressive in laboratory trials will not necessarily be violent in the real world. Even if it was shown that cannabis users underperform in class, this would not necessarily pin down the drug as to blame. Perhaps people who fail at school are also more likely to use cannabis. The old stereotyping of cannabis users as lazy, or underachieving at college, or unable to maintain relationships, are not likely to be judged true or false by simple scientific trials. The problem is distinguishing between cannabis as a cause, and cannabis as an irrelevance. One in ten road accidents involve drivers with cannabis in their bloodstream, but many of these drivers have alcohol in it as well, and the way individuals vary in their response to cannabis simply is not understood. As a result of these kinds of problems, neither the effects of cannabis, nor its dangers, are reducible to a neat series of undeniable statements. The scientific research is not producing general truths.

The fact that the science does not offer certainty allows another factor to make a strong impact. This is the world of social and political opinion. Many people are horrified by the idea of cannabis being decriminalised. For them, it is simply a fact that cannabis is dangerous, causes college dropout, and inevitably converts our finest youth into comatose junkies. They would much rather someone drinks half a bottle of whisky, than smokes a joint. The fact that others consider alcohol more dangerous, more addictive and more socially ruinous, is an irritation mostly ignored. Clearly, prejudice is at work here. Could prejudice affect the interpretation of scientific results, turning the data in a particular direction, or in none? Cannabis researchers may be looking for particular results. The availability of money may determine whether research is done in the first place, and who does it. Opinions affect whether research is carried out, how it is received, and even whether it is published. The conclusions of the House of Lords report, though based on sifting through the scientific evidence available, were sidelined by the UK Government, who announced that they would wait for more conclusive evidence to emerge. More dramatically, when the World Health Organization compiled a report comparing the dangers of cannabis with those of alcohol and tobacco, and this showed that cannabis is the least dangerous of the three, political pressure led to the report remaining unpublished.

Summary: the facts of cannabis

Cannabis contains a chemical that affects the body. Many claims are made about the dangers of cannabis – to individuals and to society. With so many people buying and smoking cannabis in defiance of a hostile

establishment, it is important to research the truth of these claims. The scientific tools for this research include neurophysiology, psychology and sociology, but we have seen that science is not able to close the argument: its data are disputed, and its interpretations vary. It is a common assumption that the particular merit of science is that it is one area of life where proof and certainty are guaranteed. The cannabis debate suggests something else: that science does not provide final answers and definitive proofs, but rather, that all science involves dispute, and that all science is fought over. This is true not only of the science of cannabis, but of every area of biology too.

1.2 The making of the cell theory

I started this chapter by discussing cannabis. I emphasised how hard it is to find clear evidence on the safety of cannabis. Clearly, social prejudice is a powerful force in determining the history of legal attitudes to cannabis. I discussed too the way that scientific research also finds it hard to avoid dispute and equivocation, and I suggested that this ambiguity, or at least lack of certainty, is a core feature of all of science, not only of admittedly complex physiological interactions. In this section, I take the argument further by looking at cell biology, a much more traditional and mainstream area of biological research than tests on cannabis addiction in monkeys. Cell theory, like evolutionary theory, is a well-established field that forms the basis of all biology courses, and of all biology. Surely this is a field so well understood that it has long since settled into a middle-aged complacency, with everything determined except for a few minor upsets here and there. I will suggest instead that here too, uncertainty and dispute are a central theme. My aim is to raise in your mind the idea that biology is more dynamic, and less fact oriented, than some of your textbooks, and your teachers, may suggest. In particular, I will look at the history of research into what we now call fertilisation – the fusion of sperm and egg – and try to show how a basic biological idea was itself the product of much confusion and disagreement. However, I do not want to imply that all the disputes took place a long time ago, and by using some examples from contemporary cell biology, I hope that you will see that uncertainty and lack of knowledge are fundamental aspects of the modern scientist's life.

Behind the daunting detail of a cell biology textbook lies something simple and fundamental. I refer, of course, to the cell theory itself: the profound concept that all living things are composed of cells, that all

cells come from earlier, pre-existing cells, and that all organic material in nature has been formed by cells. Yet this basic rule of biology was not established merely as a result of the invention of microscopy and the first observations of tissue fine structure. There is a gap of 174 years between the first description of box-like units in cork (1665), and the confident assertion of the cell theory (1839). The pioneer microscopist was Robert Hooke, who examined slices of cork, and was reminded of cells – the places where monks sleep and pray; but he did not immediately suggest that all tissue is made of cells, or comes from cells – why not? The answer is that cell theory had to be made, a net of ideas had to form. It was not simply a matter of looking down a microscope at plant material, finding square structures, and instantly realising that cells make up all tissue, divide, and have different parts. It was not just a blinding flash of inspiration. A great amount of thinking and arguing, as well as looking down microscopes, would be needed before cells, at least as we conceive them, could be seen. Microscopes were needed to make the structure visible; but to make sense of that structure, you need to think, and to have arguments. Those arguments in turn influence how the microscope is used, and what is observed. It is this mix of looking and thinking that makes doing biology a creative process, not simply a cataloguing of facts. It is in this sense that cell theory was created, not discovered.

In order to develop further the creativity of making science, I will now concentrate on one type of cell, and its intellectual history: the reproductive cell – gametes, or sperm and eggs. As with cell theory in general, there was a huge gap in time between the first observation of sperm under the microscope, and their conceptualisation as partners in fertilisation. Sperm were first observed under the microscope in 1670. Yet the idea of fertilisation as a process that puts together inherited material from two parents, dates only from 1870 – a 200-year interval. This delay in reaching the modern understanding was not simply a matter of waiting for better microscopes: a great deal of thinking had to happen too.[3] Some of that thinking we now find strange: one nineteenth-century biologist, von Baer, thought that spermatozoa were parasitic worms swimming in the semen.

[3] Historians of science strongly dislike accounts of science that see the work of previous centuries as slowly clearing mists of ignorance. It is easy to characterise past scientific knowledge as simply a catalogue of mistakes. Historians point out that it is too simplistic to use the 'spectacles' of our modern understanding as a technique for judging the work of earlier scientists. This discredited historiographical method is known as 'Whiggish history'. Such accounts of the past are distorted by being filled out with recognisable ancestors to our intellectual world. Ideas that we now make no use of are simply stripped out, or condemned as absurd. As a result, the history becomes an unreliable account of the debates and intellectual battles that were actually taking place.