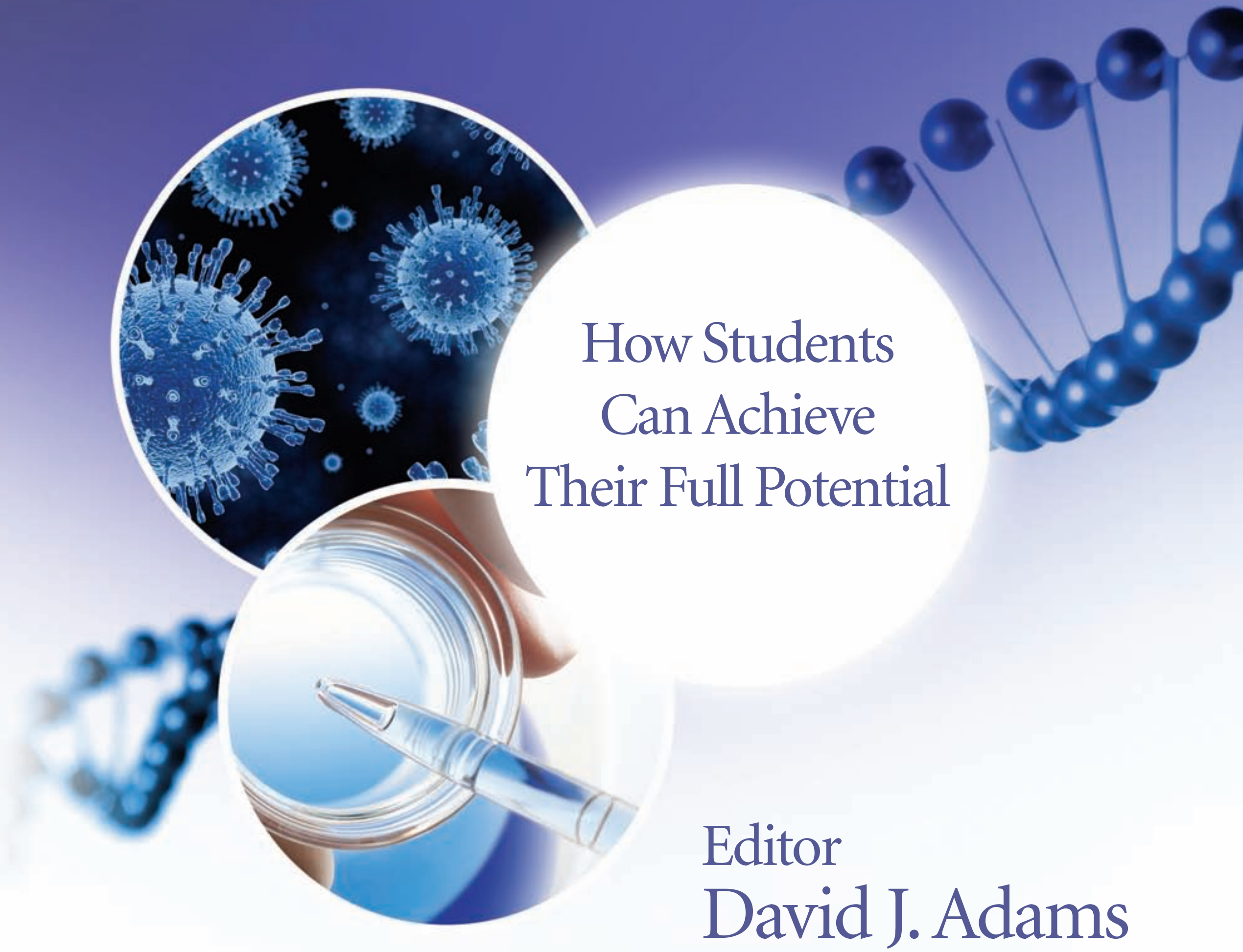
Effective Learning in the Life Sciences

How Students Can Achieve Their Full Potential



Editor
David J. Adams

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UK Centre for Bioscience, Higher Education Academy

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First Impression 2011

To my colleagues in the UK Centre for Bioscience.
It was a pleasure and a privilege to work with you all.

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Introduction

There has never been a more exciting time to study biology. We hear almost daily of major developments in new areas such as nanobiology, stem cell research or GM technology, and the popular media are forever running stories on the global impact of the biosciences. You have the chance to participate in this ongoing revolution, and if you are to make the most of this opportunity you must be prepared to think for yourself and fully engage in the learning process. If you can make this commitment then you should benefit greatly from this book.

Many of the book's contributors have interacted closely with the UK Centre for Bioscience, and its predecessors, during the last decade. Together they offer a wealth of experience and expertise in a wide range of areas of current importance in bioscience education. For the first time in a single volume, topics such as creativity, e-learning, bioethics and bioenterprise are considered, in detail, alongside more traditional elements of bioscience degree programmes such as laboratory classes and fieldwork. In addition, the book addresses areas and issues frequently identified by bioscience students as problematic. These include lack of confidence when using maths or stats in bioscience settings, difficulties when solving problems and frustration with assessment and feedback procedures. The book is designed to help you with these issues, and you will be able to access further support through an *Additional resources* section at the end of each chapter.

There is emphasis on interactivity, with inclusion of worked examples and case studies throughout. If you participate in these exercises and make the most of each chapter you will acquire a wide range of skills. These include many of the skills currently sought by prospective employers. Industrialists and university research laboratory supervisors alike indicate they want well-rounded graduates who can solve problems creatively in a wide range of settings. Enthusiastic engagement with the contents of this book should therefore help ensure not only that you benefit maximally from your time at university but also that you improve your employment prospects and achieve your true potential as a life scientist.

The book, chapter by chapter

Students are imaginative and inventive individuals, but unfortunately they are rarely given any help to achieve their true creative potential during bioscience degree programmes. A distinctive feature of this book is the inclusion of a chapter (Chapter 1) that will help promote your individual creativity and the creativity that often occurs when students work together in groups. As with creativity, students of the biosciences are given little help to develop their problem-solving abilities; in the second chapter you will therefore be shown how to approach algorithmic and open-ended problems with confidence. The next two chapters focus on practical skills in the biosciences with emphasis on students achieving their potential in laboratory and field. Continuing the practical theme, *in vivo* work (i.e. work with animals) is an area that has been identified as of paramount importance by the UK Government, researchers and educationalists, and an unusual and useful feature of this book (Chapter 5) is the consideration of a wide range of approaches and issues associated with the use of animals in the laboratory. In the final year of your studies you are likely to be engaged in a major research project. In recent years universities have offered a wide range of formats for projects, and these are considered in Chapter 6, which should help you identify the type of project best suited to your needs. The next chapter considers issues associated with maths and stats for biologists and describes how you can build your confidence in these areas. Chapter 8 contains a state-of-the-art update on e-learning in the biosciences, with advice on the use of new technologies including mobile phones, blogs, wikis, Facebook etc. You should know about traditional, as well as the most recent and innovative, assessment procedures used in universities. In addition you should be fully aware of the sort of regular feedback you can expect during your degree programme. These issues are considered in Chapter 10. It is essential that bioscientists should be able to communicate their ideas and general scientific information to other scientists and to members of the public. Chapter 11 describes traditional and novel approaches for communication in the biosciences. Two further notable features of this book are chapters on Bioethics and Bioenterprise. These are areas of great current importance to bioscientists. A considerable amount of material already exists in the field of bioethics, and Chapter 9 will raise your awareness of current approaches in this area. Bioenterprise and Knowledge Transfer are topics that are being embraced enthusiastically by many universities and the final chapter of the book considers how students of the biosciences can achieve their enterprising and entrepreneurial potential.

Tutor notes

The bioscience knowledge base is growing at a remarkable rate, and this can lead to tutors placing great demands on students who are asked to absorb enormous amounts of information. Unfortunately this can be at the expense of course components designed to promote independent thought and real engagement with the Scientific Method. This book is intended to redress this imbalance by raising students' awareness of their own considerable potential in areas of traditional and emerging importance. It is much more than a study skills guide, in that in each of the 12 diverse chapters the authors aim to build students' confidence to the point where they can decide for themselves whether they are making the most of their time at university.

You will find *Tutor notes* throughout, or at the end of, chapters. The notes will direct you to a great deal of additional material in support of teaching in the biosciences. This includes a very wide range of online and other resources provided by the UK Centre for Bioscience, Higher Education Academy.

David Adams
July 2011

1 Creativity

David J. Adams and Kevin Byron

1.1 Introduction

We should start by defining the terms 'creativity' and 'innovation'. *Creativity* involves original and imaginative thoughts that lead to novel and useful ideas. If you are to put these ideas to good use, you must be innovative as well as creative. *Innovation* may be defined as the exploitation of ideas in, for example, the development of new procedures or technologies. An excellent illustration of the distinction between creativity and innovation is the invention and development of the electric light bulb. Most people would identify Thomas Edison as the light bulb's inventor, yet over 20 individuals are thought to have invented similar devices up to 80 years before Edison's contributions. Only Edison was sufficiently innovative to refine his invention until it was a practical device that could be brought into commercial use in partnership with an electrical distribution company. You will learn how to ensure that *your* creative ideas are brought to fruition in Chapter 12.

Students of the biosciences are rarely encouraged to be truly creative or innovative (Adams *et al*., 2009). A notable exception may arise during a final-year project, when you might be asked to come up with some novel ideas or solve a problem creatively. However, it is unlikely that you will be offered any help in generating original, imaginative thoughts or solutions. Indeed, in our view, bioscience students are rarely given the opportunity to develop anything like their full creative potential. This is a great shame because bioscience graduates will frequently be expected to be creative in a wide range of career settings.

In this chapter we consider a number of issues associated with the promotion of creativity in bioscientists. We start by inviting you to decide whether you consider yourself to be a 'creator' or whether your natural inclination is to be more of an 'adaptor'. The outcome of this exercise will help you make the most of the subsequent sections that deal with how to define problems, then solve them creatively as an individual or as a member of a team.

1.2 Adaptors and creators

It would seem that some people are naturally more inclined than others to take risks, challenge assumptions and be creative. Indeed, the psychologist Michael Kirton suggests that we can each be placed on a continuum based on our inclination to 'do things better' or to 'do things differently' and

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Figure 1.1 The adaptor–creator continuum (figure courtesy of Vitae, UK)

Table 1.1 Some of the characteristics associated with individuals located at the extremes of the adaptor–creator/innovator continuum

Adaptors	Creators/innovators
Seek solutions to problems in tried and tested ways	Willing to challenge the rules/assumptions and approach a task from an unusual angle
Risk averse	Like to take risks
Plagued by self doubt and always inclined to seek consensual view	Have low self doubt and pay little regard to the views of the majority
Focused, efficient, organised, disciplined with ability to concentrate on a task for a long period	Capable of detailed, routine work for only short periods
More likely to persist with a project and ensure outcomes delivered	May be poor at pursuing a project to fruition and ultimately making things happen

he labels the opposite ends of this continuum *adaptive* and *innovative*, respectively (Figure 1.1; Kirton, 1976). You may find it useful to consider where you fall on such a scale (Table 1.1). If you feel you are more of a creator/innovator than an adaptor then you are likely to benefit most from the problem-defining and problem-solving frameworks outlined in Section 1.3 of this chapter. On the other hand, adaptors should find of most value the techniques designed to promote creativity (Sections 1.4–1.9).

1.3 Defining problems

1.3.1 The 5Ws and 1H tool

Before committing a great deal of time and energy to creative problem solving you should make sure that you are entirely clear about the nature of the problem you wish to solve. The **5Ws and 1H** questioning tool may be used to help define and clarify the nature of the challenge.

Rudyard Kipling expressed this idea in verse:

I keep six honest serving-men
(They taught me all I knew);
*Their names are **What** and **Why** and **When***
*And **How** and **Where** and **Who**.*

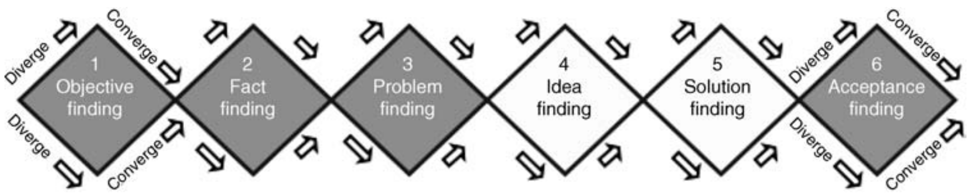
Consider the example of a first-year bioscience student who is trying to decide whether she should apply for a placement in industry during degree studies. Perhaps most importantly, she begins by asking herself **Why?** she wants to do this, and concludes that she wants to acquire new skills, new perspectives on the science she is studying, contacts in industry and experience that will make her CV stand out in the crowd. Next she considers **What?** sort of work she would like to do and realises she would really like to work in a research laboratory. She wonders **Who?** will be affected by any decision to spend up to a year on a placement, perhaps hundreds or even thousands of miles from home, and realises that such a placement will have a major impact on friends and family. As a result, when she thinks about **Where?** she might spend the placement, she realises that this need not be in a large and distant company in the UK or abroad but could be in one of the much smaller companies located closer to home. She now thinks carefully about **When?** the placement should take place and compares the benefits of a formal, one-year placement with much shorter periods of summer or other vocational work. Finally she considers **How?** she can arrange for a placement ideally suited to her needs, and realises that she must build up a network of 'contacts' who can help her, including friends, family, her tutor and the University Careers Service. She also realises that she must 'target' companies engaged in the sort of research work she finds interesting and stimulating.

By weighing up all of the issues in this way, the student has defined, much more clearly, the problem she wants to solve. She now realises that she definitely wants the experience of working in industry during her three-year degree programme, but decides that she can obtain all the benefits she wants from interaction with industry by working during her summer vacations in one or more of the local 'spin off' companies associated with the universities located close to her home. The original problem: 'Should I apply for a placement in industry during degree studies?' has been redefined as 'How can I arrange for summer work in local biotechnology companies?' Her in-depth consideration of the issues means she is already well on her way towards solving this problem. However, now that she is clear about the real problem she wishes to solve, she may also benefit from engagement with the creativity techniques described in Sections 1.4–1.9.

1.3.2 Problem-solving frameworks

Various authors have devised fairly elaborate frameworks for creative problem solving, and perhaps the best known of these is the Osborn–Parnes creative problem solving (CPS) process illustrated in Figure 1.2. You will note that this framework has six steps involving objective, fact, problem, idea, solution and acceptance finding, and that each involves a period of 'divergent' thinking followed by a 'convergent' thinking phase. These terms should be defined at this stage.

If you are to be creative and have ideas, you must think *divergently* by using your imagination, challenging assumptions, rearranging information and examining it from new perspectives (see Section 1.4). Students of the biosciences are likely to be much more familiar with *convergent* thinking. It involves rational and logical reasoning that leads to convergence on the best solution to a problem. Convergent thinking is therefore essential when you wish to evaluate the ideas generated during a divergent thinking phase. In Section 1.3.1, the student who pondered how she might gain experience of industry was initially thinking divergently as she asked a series of questions,



Steps	Stages
1–3	Identifying and clarifying the challenge
4–5	Generating and evaluating ideas
6	Implementing solutions

Figure 1.2 Osborn–Parnes creative problem solving

rearranged and re-examined information, and used her imagination. She then began to converge on the solution to her problem.

Creative problem solving is dependent upon an effective combination of divergent and convergent thinking: creative frameworks like the Osborn–Parnes CPS process (Figure 1.2) are designed to ensure that a period of divergent thought is always followed by convergent thinking as problems are defined, and ideas generated and evaluated. You can find out more about these structured approaches to problem solving elsewhere (see Section 1.14, Additional resources). We will return to convergent thinking towards the end of this chapter when we consider how you might evaluate your ideas. However, we will now focus on divergent thinking and the approaches you can use to generate the ideas you will need to solve problems creatively.

1.4 Accessing your creative potential

The approaches and techniques described in this section will help build the confidence you need to have ideas and solve problems creatively. If you are to be successful in this you will need to be bold and ready to move out of your ‘comfort zone’. For example, you should be prepared to:

(1) **Welcome the unexpected:** Alexander Fleming noted a mould contaminant growing on his plated culture of bacteria. Instead of simply throwing away the plate, he looked more closely and observed inhibition of growth of the bacterium close to the fungal contaminant. He was curious about this effect and published his observation. During the next two decades Fleming’s publication prompted others to isolate and develop penicillins as the first and, ultimately, most successful group of antibiotics. If, during research project studies, you notice something unusual, take the time to consider the implications of your observation.

(2) **Challenge assumptions:** during the 1968 Olympic Games, the American, Dick Fosbury, challenged the effectiveness of the popular ‘straddle’, ‘scissors’ or other high-jump techniques, and introduced the ‘Fosbury flop’ that involves the athlete jumping ‘back first’ over the bar. His willingness to challenge assumptions revolutionised the sport and helped win him a gold medal. A good and recent example of the importance of challenging assumptions in biology is provided by non-coding DNA. More than 98% of human genomic DNA does not encode proteins. Most of

these sequences have no obvious role and until recently were often referred to as 'junk' DNA. However, during the last few decades, many biologists have questioned the idea that such abundant, non-coding DNA should make no contribution to cellular activities in humans and other organisms. Their curiosity and investigations have been rewarded by the identification of an increasing number of diverse roles for non-coding sequences in gene expression, meiosis and chromosome structure, while additional lines of evidence indicate that other 'junk' sequences have essential but as yet unidentified roles in cells.

Unfortunately, students of the biosciences frequently require a great deal of encouragement before they will challenge assumptions. You should bear in mind that information provided by academics is not necessarily written on tablets of stone! This is of particular importance during lectures and seminars that involve cutting-edge developments in biology. In these situations you should keep an open mind and consider alternative interpretations and models that might be built around the data presented. Hold on to the curiosity about the natural world that probably led you to study biology in the first place, and don't be afraid to ask lots of questions!

(3) **Shift perspective:** when we shift perspective we change from one way of looking at things to another. In the illustrations in Figure 1.3 it is likely that initially you will be aware of only one interpretation. For Figure 1.3a you may see only a young woman wearing a feather boa, but if you look at the image in a slightly different way can you also see a much older woman? In Figure 1.3b you may see a pair of twins or a vase, but don't stop there. You might see a whale fin, a key hole, two cars parked bumper to bumper, a seal, a coat hanger etc. These are simple examples of what it feels like to shift from a single to an alternative, or multiple, perspective(s). If you develop the capacity to shift perspective then it is likely you will be more creative. The Hungarian biochemist Albert von Szent-Györgyi underlined the importance of shifting perspective in scientific research when he said 'Discovery consists of seeing what everybody has seen and thinking what nobody has thought'. He won a Nobel prize for his work on the isolation and characterisation of vitamin C, and another excellent quote attributable to this inventive scientist is 'A vitamin is a substance that makes you ill if you don't eat it'! Next time

(a) (b)

Figure 1.3 Shifting perspective

you have a problem to solve, try viewing the situation by looking at it from a different angle. For example, ask yourself how someone from another planet might solve the problem. Or, if you had unlimited money and resources, how that might make a difference to your approach. The new perspectives you adopt will hopefully help you be more creative.

(4) **Make connections:** look out for opportunities that will enable you to meet and talk with colleagues from other disciplines, e.g. chemistry, engineering. If a creative environment is designed carefully (see Section 1.7), it ought to facilitate this sort of interaction. You can then exchange ideas and perhaps identify unexpected connections between the problems you are trying to solve and what appear to be unrelated phenomena. An excellent illustration of the creativity that can emerge following the interaction of individuals with markedly differing backgrounds and expertise is provided by the Ultracane, a mobility aid for the visually impaired (Figure 1.4). It employs an echolocation technique similar to that used by bats (it therefore also provides a very nice illustration of 'bioinspiration' – see Section 1.5.3.4). The Ultracane came about through interdisciplinary brainstorming sessions involving Dean Waters, an expert on bats, Deborah Withington, a biomedical scientist with expertise in human aural physiology, and Brian Hoyle, an engineer and expert on intelligent sensing.

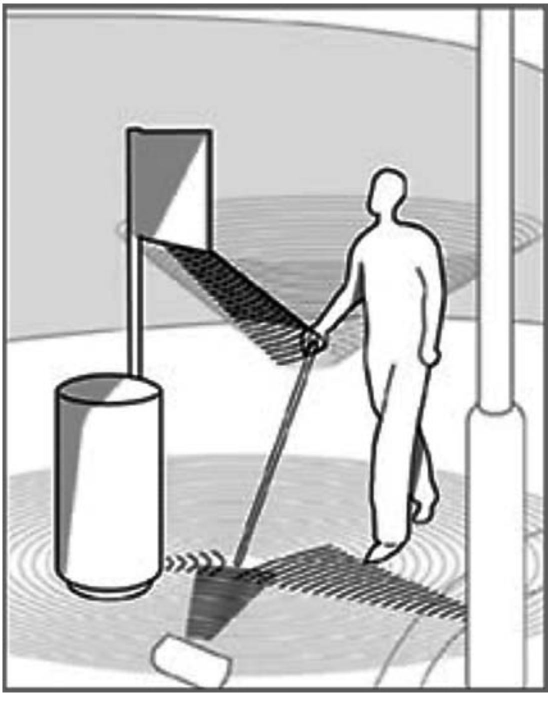


Figure 1.4 The Ultracane mobility aid: ultrasound transducers convert echoes from objects to vibrations in 'tactors' in contact with the fingers of the hand holding the cane. This, in turn, enables the brain to build a spatial map of the immediate surroundings (Figure courtesy of Professor Brian Hoyle, University of Leeds.*)

* www.soundforesighttechnology.com

Another good way to broaden your horizons and make connections is to attend obscure seminars that may appear, on the face of it, to be of only peripheral interest and relevance. You will be amazed by the new perspectives and insights these experiences can generate.

Fortunately, there are literally hundreds of techniques available that can promote creativity by encouraging individuals to challenge assumptions, shift perspective and, perhaps most importantly, make connections between what often appear to be unrelated phenomena. We describe a selection of these techniques in the following section and you will find many more in the books listed in Section 1.14, Additional resources, at the end of this chapter.

1.5 Creativity techniques

Well-managed, interactive group sessions (Section 1.8) can be extremely effective in generating ideas and suggesting novel approaches to problem solving. However, in a group, the views of the more dominant team members can rapidly prevail, and the potentially valuable thoughts and ideas of the more shy and reticent participants may be lost during discussions. In this section we therefore place emphasis on the generation of ideas by individuals *prior* to structured group sessions.

1.5.1 Case study Creativity in the Biosciences website

The freely available *Creativity in the Biosciences* website (Figure 1.5; www.fbs.leeds.ac.uk/creativity) uses a research-led teaching approach for the promotion of creativity in students working as individuals and in teams.

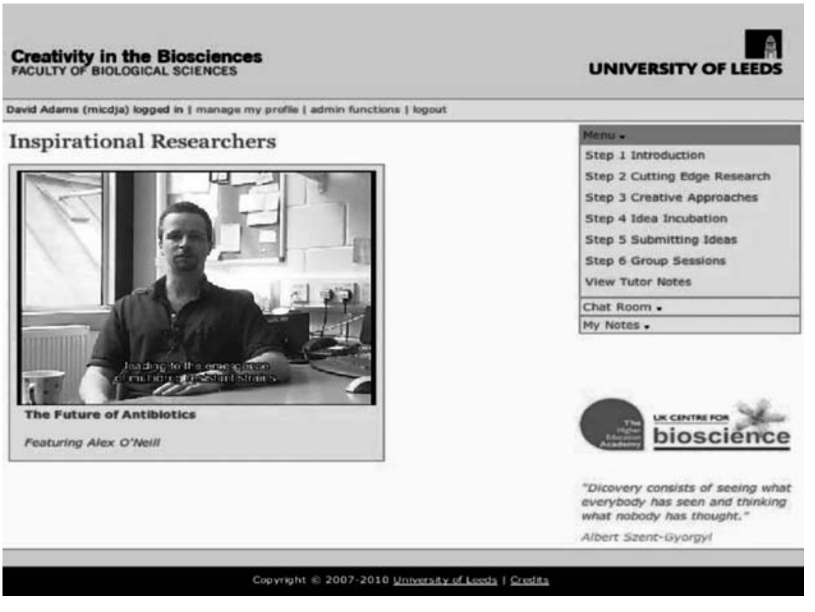


Figure 1.5 *Creativity in the Biosciences* website