DRAWING FOR SCIENCE, INVENTION & DISCOVERY

Even if you can't draw

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But I'd really like to thank Alice Roberts for responding so kindly to my work and making me believe that it was relevant.

Paul Carney

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ILLUSTRATIONS

Fig 0 Anatomy drawing by kind permission of Alice Roberts

Fig 1 Photo 51, Rosalind Franklin and Raymond Gosling 1952, by kind permission of King's College London

Fig 8 *From Life*, Borland Christine 1994. Photo by kind permission of Christine Borland

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FOREWORD

Professor Alice Roberts, University of Birmingham

"Drawing," writes Paul Carney, "is much more than a vague, abstract notion; it is deeply rooted in what it means to create rational thought."

I remember the dismay I felt when, at the age of sixteen, it seemed that I would have to give up doing art at school in order to fit in physics. I loved them both. I needed physics A level in order to apply to medical school. And while the university admissions teams might not have cared a jot whether or not I'd continued art to A level, I needed to.

Even back then, I found the hard lines drawn, the barriers erected, between different subjects, quite intrusive and even arbitrary. I knew how much drawing had helped me with the sciences - from sketching out quite abstract ideas in physics to painstakingly outlining the reproductive organs of a flower in biology classes, or drawing the macabre still-death of a freshly dissected rat, its organs laid bare for me to sketch and comprehend. The process of drawing itself helped me to understand - I had to look carefully, pick out salient features, and make a record that I knew would stick in my memory so much more easily than a list of words. But art wasn't just a way of helping with the sciences, a handmaiden to the subjects now obscurely and pompously referred to as STEM (as though they are so important you should immediately know what this acronym means; as though they're so important that they are central and trunk-like, while the arts and humanities are confined to the periphery: pretty, ornamental leaves; nothing more). Art helped me see and approach the world in a different way, and I knew that I would be impoverished without it.

And so I did both physics and art A level. Though physics was, of course, the subject that demanded its true place in the curriculum, while art was relegated to the interstices - I fitted it in around the rest: in my lunchtimes, my study periods, my evenings. I may have been estranged from the A level art class, but my wonderful teacher, Mrs Sutherland, made me feel secure in my exile.

Once at medical school, drawing became my primary tool for learning my favourite subject of all, anatomy. I would draw and draw and draw the structures of the human body - copying out diagrams and pictures from my old edition of Gray's Anatomy, and from my gorgeous two-volume Sobotta (which I had quickly realised was the epitome of anatomical atlases, being both stunningly beautiful and unerringly accurate; my grandparents had bestowed it on me as a christmas present, shelling out what they must have felt was far too much for a book, even two books). And I took my sketchbook into the dissection room and drew the body I was dissecting with my student friends: six of us around a body, battling with layers of thick, greasy, yellow fat and the dissembling fascia in order to reveal the intricacies of organs, nerves, vessels, muscles and tendons. Like everything that went into the dissection room and came out, the sketchbook gathered its own, not-so-subtle, aroma of sweet formalin - a scent familiar to any medical student in the 1990s, or indeed, to any other student who happened to live in close quarters with one of us. But as surely as the smell of the fixatives seeped into the pages of my sketchbook, the drawings of human anatomy seeped into my brain, colonising my synapses with a mental map of the landscape of the body.

As a doctor, I used drawings to explain surgery to my patients. Then I took a side-step into academia, and drawing became my ally as I taught medical students, dental students and vet students anatomy - sketching structures on the blackboard (and latterly, the vastly inferior whiteboard) as I lectured, preparing handouts with more pictures than text. The students loved them. And they responded with their own drawings, in answer to my exam questions and in their projects. And recently, when I sat down to try to probe into the mechanics of joints with my PhD student, we sketched out ideas together, working out hypotheses in pictures before we articulated them in words. We weren't just drawing to remember; we were drawing to understand.

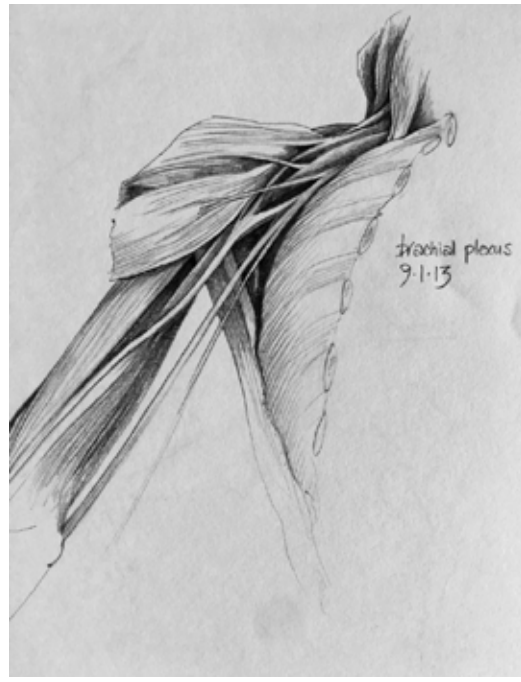

Figure 0 Anatomy drawing by Alice Roberts

(By kind permission of Alice Roberts)

Drawing has had a bit of a renaissance recently: a plethora of books and apps have appeared, promoting drawing for mindfulness. And this time I think it's more than just a bit of quackery and faddishness; for me at least, drawing directs attention in a way that seems to creates focus and a feeling of deep serenity at the same time. But the process of drawing does more than unlocking this state of mind; it can inspire creativity. It complements rational investigation. It helps us create and remember and build on our mental models of the world around and within us.

In this book, Paul Carney considers the differences and similarities between the processes of science and art, and writes about how observation, adaptation, collaboration, knowledge and serendipity play roles in the pursuit of both. These comparisons then lead into practical exercises. No matter where you're starting from - whether you've always loved drawing, or you're just trying it out; or whether you think of yourself as an 'artist' or a 'scientist' - I think the exercises in this book could help to make you a better draughts-person and encourage you to realise your own creative potential.

This is also a book about iconoclasm. The icons to be smashed are not the subjects of our education themselves, carefully divided and corralled, but the walls between them. Those walls only really exist in our minds. So: free your brain ; unlock your creativity - start drawing!

Alice Roberts
Author; anatomist; broadcaster; drawer of things

1. INTRODUCTION

> 'The process of drawing is before all else the process of putting the visual intelligence into action, the very mechanics of taking visual thought.'
>
> (Ayrton, 1957: 64)

What are the traits of the world's greatest innovations and discoveries and can they be learned through drawing?

Scientists call it curiosity. Artists call it motivation or a muse, but they're two sides of the same coin. Curiosity and motivation have taken us to the top of mountains, to the north and south Poles, to the depths of the oceans and to the surface of the moon. They've sent probes into outer space, space ships to Mars and even seen beyond our Solar system. They've helped us solve our worst humanitarian crises, cured some of our worst diseases, given most of us more comfortable, healthier lives and helped construct awe inspiring feats of engineering. Curiosity and motivation defines us as a species and have contributed to the greatest discoveries, innovations and creations the world has ever known. Creativity is fuel for the fire of curiosity. Without it, the fire burns out and all we have is what we know. But keep it burning and anything is possible, at any age, in any location.

The objectives of this book are to identify the mechanisms from which the world's greatest inventions and discoveries come about and to demonstrate that these can be illustrated, explained and taught through drawing. Whether you can draw or not is irrelevant, because the quality of outcome or end product is not what we are seeking. What is crucial is the cognitive process you'll go through.

So why drawing? Drawing is a profoundly important tool in the development of human consciousness. It originated long before we developed writing and in fact, as babies we still draw before we can read or write. Even writing itself is simply a form of drawn symbolism. Drawing helps us visualise our thoughts and ideas, it helps us describe things and provides information and instruction with vivid clarity. Most man-made things began life as a drawing.

In *Sketches of Thought* Vinod Goel (1995) argues that a cognitive, computational conception of the theory of mind requires our thought processes to be precise, rigid, discrete, and unambiguous. Yet this computational model does not account for ambiguous, and amorphous symbol systems, like sketching, painting, and poetry, found in the arts. So any complete cognitive model needs to account for these internal symbolic systems. This implies that drawing is much more than a vague, abstract notion; it is deeply rooted in what it means to create rational thought. In addition, in *Thinking with Sketches* Tversky & Suwa (2005) argue that sketches serve to externalise ideas and turn internal thoughts and concepts public. Using sketches in this way, as a form of schematic vocabulary, requires constructive perception, a combination of a perceptual skill of reconfiguring and a cognitive skill of finding remote associations. So drawing is an important mechanism in our capacity to think, imagine and realise our cognitive intentions.

Drawing aids the learning process too. In two studies at the University of Massachusetts and Stanford University, Eliza Bobex and Barbara Taversky (2009) found that students who had created visual explanations of Science, Technology, Engineering and Maths (STEM) phenomena performed better in a post-test than those who had created verbal explanations. To that end, drawing is a cognitive tool, a means of visualising and rationalising our thinking and if it can do that, then it is logical that we should enhance and develop that skill.

This book is aimed at anyone interested in how we innovate, but especially scientists, inventors and problem solvers, as well as teachers and educators of STEAM subjects; Science, Technology, Engineering, Art and Mathematics, to help them develop more creative, critically aware students. STEM teachers may find these exercises useful to visit with their students on a regular basis, both to illustrate aspects of real practice and to broaden the capacity for creative thinking. I must stress that you don't need to be able to draw realistically to learn from the drawing process. There are a myriad of different ways to draw and few of them are about accurate representation. Besides, if you can write your name you can draw anything. Art teachers should find these exercises useful to develop the range of skills they and their students possess and also how art links to the wider world, because above all art is about thinking and this is never done in isolation. It's pointless doing the same tired drawing exercises again and again, we have to find fresh, innovative approaches to how we see and interpret the world, because the world is constantly changing.

My exercises attempt to demonstrate simple, practical techniques that can improve understanding of how innovation occurs and improve the ability to discover, invent and create. They should help scientists and engineers to become more cognitively flexible practitioners and help artists to think more laterally and diversify their process. I have developed many of these exercises specifically for this book and employed some familiar drawing exercises from the world of art education. Hopefully these will be cast in a new light and so gain a different meaning as a result. I've also adapted some exercises used by practicing artists that I thought were especially useful, though again, I've tried to put my own twist on them and make them more relevant.

My profession is that of an educator in art and design, but I am also passionate about science and all things technological. What I try to see when I study these disciplines as an amateur is not only the incredible achievement, but also the thinking processes that led to these great innovations. Just as I am always fascinated by the root motivation behind an artist's thinking and methodology, so I want to understand the where, when and why of invention, discovery and innovation. What I'm trying to do here in effect is to dig down in the dirt and pull up the roots of how things happened. What I find so intriguing is that the root causes of human achievement have such overlap with the driving forces of the greatest artistic expression. This book tries to encapsulate these cognitive processes and attempts to teach them in a formalised way. After all, you can't create anything unless you know the mechanisms of creation.

In the course of my research I've identified many traits behind the world's greatest innovations and often there are several wrapped up in the same breakthrough. But I've focused on nine traits here; observation, collaboration, knowledge, serendipity, methodical, alternative viewpoints, trial and error, and visualising. The ones I've chosen are ones I see time and time again across most fields of discovery and innovation.

In attempting to explain how these fields lead to innovation and how they might be taught through drawing, I have been conscious of striking a balance between evidence and practice. To that end I have structured the book into chapters where the proposing argument is supported with evidence from the scientific and mathematical world and the artists. I have also applied my own opinion as to how these fields relate, then provided you with the all-important means to promote these qualities in your students using art exercises. I hope this book will be of benefit to both art students and STEM students at all educational phases because, not only do I believe they are relevant, but I also believe they will benefit them. I have a secret wish that some practicing scientists might pick up the book and be inspired.

I believe that if we want our young people to become better innovators and solve some of humanities' problems, we need to teach them how to draw. Not only traditional, observational drawing, but new, cognitive drawing techniques that visualise and expand our thinking strategies. This is not a 'how to draw' book though, nor will it lead to pretty pictures that you can show your friends. It attempts to show you how drawing can manifest cognitive processes into visual forms. I hope, after reading this book that you develop your drawing skills and in the process discover something new.

> 'Our first endeavors are purely instinctive, promptings of an imagination vivid and undisciplined. As we grow older reason asserts itself and we become more and more systematic and designing. But those early impulses, tho not immediately productive, are of the greatest moment and may shape our very destinies.'
>
> (Tesla, 1919: 18)