Editorial

Creative science in theory and practice

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Bill Hamilton once explained to me his philosophy of scientific practice: building dizzying scaffolds of novel thought held together tenuously, at first, by theory and assumption. If the scaffold can support empirical data, then science has progressed by a bold, quantum leap upwards; if not, the whole edifice crashes in spectacular ruins, with damage mainly to pride or ego. He contrasted this scaffold model with one of masonry: collecting data brick by brick to build slowly upon a pre-existing, firm yet unexciting foundation. Solid progress, but nothing new, nothing inspiring, nothing... creative.

New ideas in ecology and evolution emerge from creative thought, from scaffolds that reach upwards and across disciplines. From where, then, does scientific creativity spring? And, if we know, can we deliberately seek to become more creative, and emulate scientists like Hamilton, Trivers, Hutchinson, MacArthur, or Darwin?

Scientific creativity has been studied in two primary domains. First, the causes and correlates of such creativity have themselves been studied, to develop and evaluate models for what makes some scientists more creative than others. Second, the psychological underpinnings of creativity have been analyzed, more broadly, as facets of natural human cognitive variation. Such psychological studies tend to focus on extremes of cognition and associated creativity, with emphasis on aspects of the psyche that underpin and foster creative insights or processes.

Creative scientists

Key correlates of creativity in scientists, as described by Dean Simonton, who has devoted his career to this

topic (see Simonton 2004), include having wide-ranging interests, reading voraciously even in areas tangential or removed from one's main area of research, and writing large numbers of articles, such that creativity is strongly, positively associated with lifetime productivity. Perhaps surprisingly, general intelligence, as indexed by IQ, is only weakly associated with creativity, and then only for the IQ range below 120. Over 120, where the great majority of academic scientists hopefully score, creativity is uncorrelated with IQ.

Our first lesson for increasing creativity in ecology and evolution is thus to read and think broadly and widely, and avoid overspecialization—an increasing danger as the scientific literature burgeons year by year. Read *New Scientist* and *Nature*, and even books (books?!) on topics of interest that are not within your core domain of inquiry. To be interesting, be *interested* in a variety of fields, across taxa, from molecular genetics to philosophy.

Back in the 1980s—before computers transformed most areas except scientific creativity—our muse, Bill Hamilton, had an extensive card filing system for his references, with illegible (to me) notes on each. One day, leaning over and thumbing through the cards, he looked up and softly opined: "these are the neurons of my brain." So too will all of your extensive reading and your filing system, come to represent the raw materials of your scientific brain and thoughts. Bill indeed once referred to himself as an "unrepentant library mole." With the world's literature now at our keyboards rather than file cards, opportunities for scientific digging and exploring have never been more exciting or open-ended.

The second lesson, high productivity, appears more difficult, but it directs us to focus on the need to write consistently and persistently, with discipline, strong

coffee, and likely, considerable psychic pain. Writing is an act of creation, and is the scientific bottom line. Never publish it—even on a blog—and it never existed; it was a waste of your time and someone's money. You will die, but ideas are immortal and can change the world.

Explicit models of how creativity works have been developed from studies of creative people and the genesis of their new ideas. Common features across such models include:

- curiosity, motivation, and toleration for ambiguity and uncertainty;
- generation of new ideas, which involves fluent exploration of ideational space, and novel combination and cross-referencing of thoughts and facts from across myriad domains—processes that involve divergent and defocussed thought, like a mental wander across a Wrightian adaptive landscape in search of higher peaks; and
- recognition and mental-Darwinian natural selection of the most-promising new ideas.

Hamilton's 1967 paper on Extraordinary Sex Ratios provides a simple example of this process: his years of “mole-ing” through the literature unearthed examples, from across disparate taxa, of insects that (1) lived in claustral, enclosed habitats, (2) exhibited wingless males, and (3) showed female biases in their sex ratios. What selective pressures could produce such convergence? Hamilton combined nascent gene-centred, inclusive-fitness thought with the idea of selection for female-biased sex ratios in such habitats, to create the field of sex ratio theory, and the first evolutionarily stable strategy model.

Creative psyches

Models of creativity, and study of relatively creative scientists, are complemented by studies of the psychological underpinnings of creativity, with a focus on psychiatric conditions that appear to be associated with forms of creative thought and productivity. Much of this work has centred on individuals exhibiting psychological traits on the 'psychotic-affective spectrum', which includes the overlapping, highly-heritable conditions schizophrenia, bipolar disorder, and major depression. Each of these conditions exists, in its constellation of psychological phenotypes, on a continuum ranging from severe clinical impairment to what passes for normality (Bentall 2003). Thus, you and I are more or less schizotypal, occasionally somewhat manic, or tending to anxious or depressed. It is these *personality* traits, not madness, mania, or sadness themselves, that have been analyzed in association with creativity.

Schizophrenia-like cognition has been well-documented to engender strong imagination, divergent thinking, and 'loose' associations among thoughts and words, all traits that can enhance the 'exploration' phase of creativity and foster problem-solving that requires novel insights (e. g., Nettle 2001; Barrantes-Vidal 2004; Karimi et al. 2007). By contrast, mild forms of bipolar-disorder mania (referred to as hypomania) are notably associated with prodigious creative productivity, and often genius, apparently due in large part to increased goal-seeking and motivation coupled with high energy levels and positivity (Jamison 1993). Depressive temperaments have a less obvious connection with creativity. Some authors have suggested that the same generative brain regions are activated in creative thought as in depressive rumination, or, have linked creativity with depressive episodes over the long term (Flaherty 2005). For each of these conditions, relatively high (although not stellar) IQ may be pre-requisite for effects on scientific or artistic creativity: think John Nash's 'beautiful mind', or Albert Einstein's and James Watson's children with schizophrenia—each of the three an insightful, creative genius with alleles 'for' schizophrenia.

In contrast to creative, psychotic-affective personalities, autistic genius is usually characterized in terms of savant skills: remarkable, highly-specialized skills in a small set of areas including mathematical computation, rote memory, calendar calculating, perspective drawing, and absolute pitch (Happé and Frith 2010). Such extreme skills are usually lockstep with autistic social disabilities, and are usually not considered creative per se. Indeed, they appear opposite to novelty: individuals with autism show restricted interests and repetitive behavior—many also insist on sameness in their environment. But what of less-extreme autistic traits and skills? Autistic cognition has also been strongly associated with high levels of abstract, 'fluid' intelligence (Dawson et al. 2007; Hayashi et al. 2008), and enhanced visual-spatial skills, including aspects of mathematics and engineering (Baron-Cohen et al. 2001; Motttron et al. 2006; Nettle 2006), especially those involved in analyzing the workings and rules of 'systems' (Baron-Cohen 2006). Individuals with autistic personalities may thus be no less creative than their psychotic-affective-personality counterparts—just *differently* creative.

Autism is also highly heritable, and since we are stuck with our personal three billion base pairs from mother and dad, how do such psychological considerations affect our quest for enhanced creativity? Mainly, I think, through self-knowledge—knowing better our own mind's position on an axis from psychotic-affective, through normal, to autistic cognition (Crespi and Badcock 2008). Such information allows better

recognition of our own skill sets, and suggests how best to design one's career and target development of creative abilities. Indeed, a recent brain imaging study suggests tradeoffs between performance of divergent (open-ended) versus convergent (closed-ended) tasks (Chrysikou & Thompson-Schill 2011); how important are such tradeoffs in cognitive skills, and how do they impact performance in science? Most generally, still believing in Santa at thirty might bode better for focusing on scientific questions that require imaginative leaps, while autistic tendencies should better serve systematic, rule-governed and memory-based work. Do molecular ecologists differ from evolutionary theoreticians on scales of autism or schizotypy? Only a creative study will tell.

Science may be, or should be, a deeply creative enterprise, and the scientific study of creativity has yet to permeate far into its evolutionary or neurological-psychological roots. But for the future of humanity, if not our own careers, increased creativity provides a fundamental way onward, built with scaffolds of thought, and using some of the tools that we have discussed here.

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