Feedback

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Eureka moments or hard graft?

In reply to Phillip Ball's feature article "In search of claritons" (October pp30–34) about the different paths towards breakthroughs in physics.

Ball reported on the "Physics Imagination Retreat" workshop held in June at the University of Cambridge in the UK, at which a number of prominent scientists recounted their moments of sudden insight that led to scientific discoveries. It seemed, wrote Ball, that "Eureka" moments – abrupt moments when discoveries are suddenly made – may actually occur. But some decades ago, psychological research put paid to this supposition.

Perhaps the most famous Eureka moment is when Archimedes discovered a means to determine the gold content of a crown presented to his king without melting it down. He realized the solution – Archimedes' principle – while in the bath, presumably thinking of something else. Psychologists call this the "tip of the tongue phenomenon" or "mind popping". Extensive research has established that it must have been preceded by a great deal of hard conscious work on a problem. There is no creativity *ex nihilo* – creativity out of nothing. To speak about the suddenness of the inspiration ignores the time the problem's resolution was brewing in the unconscious – seconds, minutes, hours, days – before bursting out into the conscious.

The four-cycle description of creativity alluded to at the workshop runs as follows: after hitting a stone wall – an impasse, while working on a problem – the experienced researcher may take a break or speak to a colleague. But this is only a conscious break. The intense conscious desire to solve a problem keeps it alive in the unconscious, where the inhibitions and barriers from the conscious are not present. The problem can therefore be tackled with facts stored deep in long-term memory and by bringing

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into play disciplines that are apparently unconnected – in other words, in the unconscious, thinking is carried out in a massively parallel manner. In this way an illumination hopefully occurs, bubbling up into consciousness, at which point it can be verified.

An excellent example is Einstein's discovery of special relativity in 1905. After struggling with how to explain certain properties of light, he realized that there was a connection between the laws of thermodynamics and how bodies move in space and time – a most unlikely pairing. Sometimes the nascent moment of creativity can be triggered by a conversation, as was the case when Einstein discussed his struggles with simultaneity with his colleague Michele Besso.

From Ball's article it appears that no-one at the workshop realized it, but this four-cycle scenario of creativity goes back at least to the great French polymath Henri Poincaré who described how, in just this way, he had made one of his great mathematical discoveries.

As for discovery dreams, these also occur as a result of unconscious thought and would not have taken place had not some hard conscious thought preceded them. But dreams recounted by scientists can sometimes be untrustworthy. For example, August Kekulé's often-mentioned dream [of seeing the ring structure of benzene as a snake swallowing its tail] is apocryphal, and this story itself is fascinating because it was he who fabricated it.

Scientists' descriptions of how they made their discoveries have to be examined and weighed. I do hope that the two psychologists present at the workshop did just that. The scientific imagination holds wonders and the "raw" data from this conference will be useful for those of us exploring creativity.

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Ball's article concurs with my own experience that creativity is unleashed by a change of scenery and a break from routine. To the many examples cited, I would add Alexander Graham Bell's crucial insight that led to the invention of the telephone in the 1870s. The insight came, not while Bell was tinkering obsessively in his attic in the middle of the night, but while he was "slouched on a wicker chair" after going for a walk "far from the bustle of Boston", according to Charlotte Gray's biography.

However, I believe Ball is wrong to state that "there's no magic formula" for creating breakthrough moments and that "there's unlikely to be any recipe for producing them". The manufacture of ideas is neither mysterious nor magical but follows a definite method, just like the manufacture of cars in a factory production line. We can learn and control the method, and thereby increase the production of ideas.

To those who are interested, I would recommend James Webb Young's short book, *A Technique for Producing Ideas*. It is one of those rare period pieces that was written in the 1940s but still has currency today. I am told it is secretly in the desks of many top creative directors in the advertising industry, but I have never seen it on a scientist's bookshelves. I personally have been applying its methods to my research activities for about 10 years. I am convinced it has yielded the ideas for some of my best scientific papers, which otherwise might not have come into existence.

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Ball's article links the occurrence of Eureka moments, or "claritons", to instances where we are either relaxing, such as in bed, or doing something mundane like waiting for traffic lights to change. Why should this be? In "Solving difficult problems creatively: a role for energy optimised deterministic/stochastic hybrid computing" (*Front. Comput. Neurosci.* **9** 124), we liken the brain to an extremely energy-optimized computational device that operates on the borderline between determinism and stochasticity.

From a physical point of view, such stochasticity can be expected from the effects of thermal noise on signal propagation along very slender axons 0.1 μm in diameter, of which the human brain has many. As a result, one can postulate two cognitive modes: one where available energy is spread uniformly across the network of neurons, making many individual neurons susceptible to noise; and one where available energy