The pursuit of creativity in biology

Why does *creativity* tend to be associated with artistic, musical and literary activities much more frequently than with scientific endeavor? In the Wikipedia, *creativity* is defined as "*a human mental phenomenon based around the deployment of mental skills and/or conceptual tools, which, in turn, originate and develop innovation, inspiration, or insight*". As a faculty of human mind, creativity can pervade and drive any human activity. Herein, my purpose is to make some reflections concerning the role played by creativity in the sphere of natural sciences (and, more specifically, in Biology). Furthermore, I will try to identify those main factors promoting scientific creativity and those others that avoid or obstruct the emergence of creativity in science.

The writer Arthur Koestler developed a complete theory of human creativity,[(1)] embracing both the arts and the sciences. In his view, scientific discoveries do not create anything wholly de novo but integrate pre-existing facts and ideas in a novel way. Dean Simonton argues similarly in *Creativity in Science* (2004)[(2)] that scientific creativity is essentially stochastic: new ideas arise by generation of combinations randomly. In the classic of science philosophy, *The Structure of Scientific Revolutions* (1962),[(3)] Thomas Kuhn proposed that the history of scientific progress is marked by long periods of "normal science", during which fundamental concepts (the so-called *paradigms*) are not challenged, interspersed with brief and explosive periods of sudden paradigm shifts, during which theories and ideas change radically and new concept systems are created. Pioneers contributing to such changes of paradigms are very rare, exceptional people. However, creativity in science is hardly restricted only to these brief and brilliant periods of revolution. Research within current paradigms also needs to be creative!

All human beings are endowed with creative potential. The conjunction of innate capacities and specific environmental circumstances promoting or obstructing its development will determine how much such a creative potential in each person can yield. Koestler[(1)] states that there are three different kinds of creative individuals: the *artist*, the *sage* and the *jester*. In Robert Stenberg's theory of creativity,[(4)] six features are identified as necessary and essential for the emergence of the creative act: *Intelligence, knowledge, a particular thinking style, a strong personality, motivation and a proper environmental context.*

Creativity cannot be taught, but can indeed be obstructed/blocked or stimulated. Although society applauds the signs of creative genius *a posteriori*, unfortunately it usually does favour it upon first appearance. Social and political organisations try to evade destabilizing criticism since independent thought is typically regarded as suspicious and serving to erode power structures. Sadly, this pattern is also seen in academic and scientific organisations. Giovanni Fava[(5)] goes so far as to state that a certain cult of mediocrity pervades all science. The very scientific research funding organisations and systems that are ostensibly there to promote discovery also serve to frustrate the emergence of creative thinking and work. Thus, researchers forced to live from project to project have a natural tendency to avoid risk in their applications, which thus gives them a conservative character. In fact, the peer-review system (in which most of the selection and funding systems are based) has a largely negative effect, behaving as a "selective filter" against an "excess" of creativity, suppressing many innovative proposals. Knowing how to "sell" well a product, "having contacts" and knowing how to pull the strings that control scientific policy are often more important than creative ideas to obtain funds. Ironically, inadequate funding can either stimulate or hinder creativity. Many scientists reach their highest levels of creativity when they face the need to improvise, when they lack of adequate large infrastructure and when they work with deficient funding. But below a certain minimum threshold, deficient funding is not stimulating to creativity but, on the contrary, becomes a barrier, making it impossible.

What can be done to favour and stimulate creativity in science? (To maintain systematically deficient funding, as a stimulant, is an option that most scientists would prefer to avoid!). In the above mentioned *Creativity in Science*, Simonton remarks that most of those scientists with outstanding creativity tend to work on several projects at the same time, frequently taking active part in scientific meetings and reading a lot in fields away from their own discipline and even far from science. Simonton suggests that laboratory meetings can be powerful tools to promote creativity within research groups, provided that these meetings are not too rigidly controlled, with a certain level of anarchy allowed to improve the flow and free exchange of ideas. On the other hand, biomedical researchers point to three potential "recipes" to promote the generation of creativity in this research area: more funds for research and for training of new young researchers, closer work between academy and industry, and much more multidisciplinary cooperation.

Provided that contemporary science can hardly be understood as something different from a collective enterprise, a question arises: *Is a collective creativity possible*? Creative work is essentially personal. When different people are involved in the same task, the need to establish compromises arises inevitably and the final product tends to be the result of consensus. Driven or forced to practice collective research, however, we need not renounce creativity. There are two fundamental kinds of collective scientific work that can yield creative products: a pyramidal organisation, with a creative "thinking mind" and a team of collaborators to carry out the tasks according to his/her instructions or, alternatively, a more "horizontal" organisation, with a sharing of tasks and responsibilities according to capabilities and skills of each member of the group, thus allowing everybody for their own space of creativity.

Ursula Goodenough is most probably the biologist who has made the deepest reflections on creativity in science. According to Goodenough,[6] the goal of every scientific research would be the achievement of "*eureka*" moments, the ineffable experience of discovering some of the "truths" of nature, of finding the "unity of variety" (a definition of *beauty*, according to the poet Coleridge). A way to reach such a goal would be the *immersion* in the system, which requires a high degree of *personal engagement*. Another component, however, is required: *intuition*. The intuitive feeling, the conjecture, requires familiarity with the studied subject, with scientific knowledge, but it also comprises qualities as ineffable as originality, imagination and courage. Even if all these requirements are fulfilled, the creative moment cannot be predicted or dictated. However, to have a beautiful idea is not enough for scientists: it must also be correct. Therefore, the creative scientist has a second task, after the "eureka" moment: to *demonstrate* the validity of the new principle. Usually, scientists apply inductive/meditative thinking up to the moment when they get a hunch and then, immediately, their minds change to deductive thinking. According to Goodenough, this change from meditative to deductive thinking, from holism to reductionism, in effect from right to left brain hemisphere activity, is crucial: "*Hunches and their deductions are essential to science, since they provide the frame, the paradigm, for making the observations*". In contrast to those who maintain that the actual creative work can only be individual, Goodenough believes that communication and cooperation are important in scientific creation. Scientists not only remain in a continuous dialogue with nature and with the scientific literature and their own mental faculties, but they are continuously talking to one other. In fact, many outstanding scientists claim that "*they had never had a new idea except in conversation, that they require the challenge and the stimulus of human engagement to think creatively*". In this context, Goodenough defends the importance of scientific work in research teams, since this is the natural way to achieve that complementary skills can combine properly. Of course, groups are sources of potential personal conflicts but, when they work well, they reach great synergy.

Perhaps the most original aspect of Goodenough's thinking about creativity in science is her stress on the importance of humour and play in science. One is able to make creative science when somehow one has the feeling of playing. *Playing*, in fact, may be the best metaphor to describe the process of scientific creativity.

Furthermore, all biological sciences are pervaded by the paradigm of evolution. As stated by Goodenough, "*if we define creativity as the putting together of things in original ways, then evolution is creativity par excellence*". Therefore, life and its diversity is by itself the sign of the creativity of biology. In a *BioEssays* editorial at the turn of the century,[7] it was claimed that consilience, complexity and communication would be the three greatest challenges for biology at the start of the new century. I would dare to add a fourth challenge: the promotion of creativity. Currently, the leading biology is becoming *big science*, dominated by great programs of investigation related to the different "-omics", with a strong technological component and mainly devoted to the massive accumulation and analysis of data. This trend will continue into the near future. However, today—more than ever—another kind of less-directed science, other approaches to the study of life are also required. To promote the emergence and development of new creative ways of doing science will be a major responsibility of funding agencies, scientific policy bodies, scientific educational enterprises and biologists, in general, if biological science is to continue to make outstanding advances in the 21st century.

Miguel Ángel Medina

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