Fostering creativity

A model for developing a culture of collective creativity in science

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Scientific progress depends on both conceptual and technological advances, which in turn depend on the creativity of scientists—their ability to produce new insights or ideas. The biological sciences in particular have been revolutionized by insights such as the discovery of the DNA double helix and the invention of the polymerase chain reaction. Various studies suggest that the creative processes behind these discoveries rely on mechanisms that are similar across disciplines as diverse as art and science. Furthermore, research into the nature of creativity indicates that it depends strongly on the cultural environment. Given the importance of creative thinking in science, is it possible to create optimal conditions in a research organization with the aim of enhancing the creativity of its scientific staff? This article describes a study that addressed this question in a large research institute—the European Molecular Biology Laboratory (EMBL; Heidelberg, Germany). The results show that conditions that enhance scientific creativity can be clearly defined, and thus applied to any organization striving for innovation.

Creativity is central to human activity and thought, and has been the driving force for all innovations throughout human history. However, it has long eluded precise definition and scientific study, although the literature abounds with many explanations ranging from the mundane to the highly complex (Taylor, 1988). One of the most useful definitions states that a creative idea cannot be produced by the same set of generic rules as a familiar idea, thus indicating that creativity depends on a conceptual shift in thinking (Boden, 2004).

Creativity has been traditionally associated with art and literature but since the early twentieth century, science has also been regarded as a creative activity. In contrast to art and literature, in which it is usually sufficient to create an original work, a creative scientific idea requires both originality and appropriateness (Amabile, 1996); creativity in science not only generates novel ideas but also aspires to produce a verifiable representation of an objective truth.

Apart from this distinction, how similar is creativity across different domains such as science and art? A study comparing the works of Albert Einstein and Pablo Picasso suggests that their creativity was based on strikingly similar elements (Miller, 2001): both strived to understand the underlying properties of space and how different observers experienced it. Furthermore, both had a strong sense of aesthetics, further suggesting that the mechanism and psychology of creativity is similar regardless of the discipline. Other studies have shown that various personality traits—including a high valuation of aesthetics, a

broad range of interests, an attraction to complexity, and the ability to deal with conflicting information—are often found in creative individuals in very different domains (Barron & Harrington, 1981).

Measuring creativity is a challenging task owing to its complex and elusive nature. Nevertheless, several attempts have been made to develop a creativity quotient similar to the intelligence quotient (IQ), based on the ability of divergent thinking and on problem-solving skills (Torrance, 1974). These studies show that a high IQ is not automatically linked to high creativity. Although a certain IQ seems to be necessary, it is not sufficient to generate creative ideas, indicating that creativity depends on the ability to combine general intelligence with other skills (Perkins, 1988).

Measurement of brain activity showed that creativity correlates with two brain states: a quiescent, relaxed state corresponding to the inspiration stage, and a much more active state corresponding to the elaboration stage (Martindale & Hasenpus, 1978). The quiescent state has a lot in common with some stages of sleep and dreaming, indicating that concentration on its own is not enough to generate creative breakthroughs, but must be combined with periods of low activity (Claxton, 1998). Highly creative individuals seem able to switch back and forth between active and quiescent brain states. This explains the observation that periods of 'incubation' or rest can enhance creativity (Ward & Saunders, 2003).

At least a dozen models of creativity have been proposed during the past century (Plsek, 1997). Most of these have a common feature: they depend on a balance between analytical and synthetic thinking,

and usually describe the creative process as a sequence of phases that alternate between these states. The model developed by Graham Wallas (1926), for example, consists of four phases: preparation—definition of the problem; incubation—ignoring the problem for a while; insight—the moment when a new idea emerges; and verification—analysis of the new idea. ‘Preparation’ and ‘verification’ depend on analytical thinking, whereas ‘insight’ is an expression of synthetic thinking. This is the most elusive part of the creative process because it emerges abruptly and unexpectedly, often at a time when the subject is not consciously thinking about the problem. This has led to the proposal that subconscious mental processes during the incubation phase are important for a creative idea.

Most research on creativity has focused on the individual, such as the many studies to characterize the personality traits of highly creative persons (Barron & Harrington, 1981). However, more recent studies suggest that creativity also depends strongly on the social and cultural context (Montuori & Purser, 1999; Paulus & Nijstad, 2003). For example, Vera John-Steiner’s examination of some of the greatest creative individuals in human history, including Einstein and Charles Darwin, reveals that their breakthroughs depended on collaboration and social support (John-Steiner, 2000). Teresa Amabile’s work shows how the social environment in business organizations affects the creativity of their employees—often undermining it by focusing on efficiency and control (Amabile, 1999); she concludes that, based on a deep understanding of creativity, managers can stimulate the creativity of their workforce.

As the creative process relies on similar fundamental mechanisms in all forms and because these critically depend on the socio-cultural environment, is it possible to design an organization that enhances creativity? So far, most approaches designed to foster creativity have been targeted at the individual (Nickerson, 1999). Although creative individuals are essential, the strong link with the environment indicates that creativity might be greatly enhanced by generating a culture that supports the creative process.

To address this question, I examined EMBL as an example of a large and creative organization. EMBL was founded in 1974 as an international research institute, based on

the European Center for Nuclear Physics (CERN; Geneva, Switzerland). One of the missions of EMBL is trans-national cooperation: its five outstations are situated in four countries and its staff collaborate with scientists in many more locations. Another important feature is its interdisciplinary approach: EMBL staff includes physicists, chemists, engineers, mathematicians, computer scientists, medical scientists, molecular biologists and biochemists. Almost 90% of the EMBL staff—comprising approximately 1,400 people from 60 nations—have temporary positions, which creates a high turnover and a youthful research faculty. This combination has proven to be successful: in a study of highly cited molecular biology and genetics publications from 1992 to 2002, EMBL was ranked as the top non-US institution (Science Watch, 2003).

If the next generation of insights in science depends on creativity, how then is creativity nurtured at a successful research institution such as EMBL; is there a culture supporting and enhancing creativity? If so, can this culture be further defined and used as a paradigm to enhance creativity in other organizations? To address these questions, I performed a series of interviews with 15 EMBL group leaders—about 20% of the total number of group leaders—working across a wide range of research topics. The interviews comprised a standardized, open-ended protocol with questions exploring both the individual and collective dimensions of creativity, by focusing on the personal experiences of the interviewees and by examining the roles of the environment and of other staff.

Many of the interviewees repeatedly emphasized three main qualities necessary to be a good scientist: rigorous intellect, the ability to get the job done and the ability to have creative ideas. Rigorous intellect is clearly an expression of analytical thinking, whereas creative ideas are based on synthetic thinking; one group leader explicitly made this point: “Creativity is coming up with an approach that leads to a new discovery. Also, at the moment of insight we’re creative because we make a new connection in our mind—or we see a connection that was already there, but was hidden.” This emphasizes the synthetic nature of creativity: it brings together previously unlinked ideas to generate a new concept.

While talking about their most important scientific discoveries, almost all interviewees characterized their breakthrough moment as an abrupt leap in understanding,

leading to a marked reconfiguration of their view of the issue: “You didn’t have an explanation before, and you do have an explanation afterwards. It just takes a fraction of a second. Then you understand everything, but you couldn’t have articulated it before.” This corresponds well with the description of the moment of insight as a sudden emergence. One interviewee described the creative process as both gradual and a leap: “It’s a path, it’s always steps, but a certain step can be the triggering one.”

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Although breakthroughs in science depend on such an ‘internal’ conceptual shift, they also rely on ‘external’ experimental results. However, most interviewees described their breakthroughs as largely internal: “Somehow, I have a vision of how it works—I just ‘see’ how it works.” Only two scientists expressed the view that their breakthroughs were purely external events, based on the observation of novel data. A third point of view, combining the other two, was expressed by three interviewees who described their breakthroughs as having both an internal and an external aspect: “Before the breakthrough we had a lot of information, and we knew the gene was doing something important, but we didn’t know what that was. With the critical experimental result... our thinking about the problem changed in a very abrupt way.” This connects the inner shift to an outer event: a fundamental insight is triggered by a particular result, which suddenly makes sense of previously puzzling fragments of information by integrating them into a coherent picture.

Science is usually seen as a precise enterprise that relies on observation, reproducible experiments and critical analysis. Given this view of the scientific method, it is interesting that only two scientists felt that intuition does not have a role in research: “We discover how the world works simply by fiddling around with it.” Two-thirds of the interviewees expressed the opposite: “It clearly involves intuition. Intuition is how you put the pieces together, which allows you to see the picture.” This is remarkable,

as intuition is defined—by Wikipedia—as “direct cognition without the use of rational processes”, which relies mostly on unconscious mental processing. Nevertheless, about half of those who said that intuition is necessary emphasized that it must be combined with rational thinking to be effective: “You need more than a guess. [...] You need an understanding of how processes work, even if you don’t know all the players involved. And surely a lot of that is intuitive, but intuition alone wouldn’t get you anywhere.” This is consistent with the idea that creativity depends on a combination of synthetic and analytical thinking. Although the synthesis of a new concept relies on intuition, which is based on subconscious mental processing, it must be subjected to conscious examination and analysis.

As many of the interviewees mentioned creativity as an important trait for a successful scientist, I asked them if this trait can be broken down further into specific mental skills or attitudes. About six such ‘sub-traits’ were described. Of these, one that was mentioned most often was ‘the ability to make unexpected connections’: as one interviewee explained, “It isn’t completely deductive, that’s clear. We take things we know from different contexts and we put them together in new constellations.”

Making such unexpected connections relies on the ability to choose relevant possibilities from an infinite set of irrelevant ones. This seems to be a rather mysterious talent, but the following point might provide an explanation: “Creative scientists have the ability to step back from what’s happening in the lab and look at the big picture and put things in perspective.” This ‘ability to see details in a larger context’ could explain how relevant connections are chosen: only those that make sense in the larger picture are retained, whereas others are discarded. Admittedly, this fails to explain the subconscious mental processing that precedes the conscious choice, but it does suggest how the process might be guided.

Another important trait was described as ‘interest in the unknown’: “Good scientists are not afraid of tackling something new, but at the same time are aware of what they don’t know. There has to be a certain humility, otherwise it doesn’t work.” This is a somewhat obvious point: a focus on well-documented and accepted ideas is unlikely to yield any new insights. An awareness of the unknown is therefore crucial for

innovation, and one reason why excess training—or even ‘indoctrination’ in a particular point of view—might block creativity.

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Furthermore, ‘enjoyment of the creative process’ and ‘stimulation outside the lab’ were also mentioned as favourable for creativity. These two points seem to be connected, as what one does at work and outside work are not separate, but intimately connected: “The office is not a good place for inspired thoughts because it’s too hectic. To get new ideas, the best situation is one with tranquility and focus. For me, many of these moments happen when I’m exercising.” This is consistent with research showing that alternating regularly between an active and a relaxed brain state is best for creativity (Martindale & Hasenfus, 1978; Claxton, 1998). It also shows that extracurricular activity, when done in this spirit, can be directly beneficial for creativity at work.

Finally, every interviewee emphasized the importance of ‘stimulation by interacting with colleagues’. This is undoubtedly the most crucial trait for creativity, which thrives on the exchange of ideas: “It’s by listening and talking to people that I get my inspired thoughts. As I listen to them, I immediately try to find a way to use their approach for my own question, especially if their ideas are exciting.” As this point was brought up in all interviews, it seems to be of crucial importance and is therefore the subject of detailed analysis in the following sections.

In the second half of each interview, I asked if, and to what extent, breakthroughs depended on other people, to address the question of whether the individual or the collective is more important for generating creative ideas. Strikingly, only one scientist felt that the individual is more important, whereas two said that the collective is more important. The majority felt that the individual and the collective are equally important: “Although the actual idea and the experiments came from me, I couldn’t have done it if I hadn’t been in the right lab at the right time, with the right colleagues around.”

It is therefore logical to ask what interactions are optimal for creativity. The majority of interviewees answered that other people provided them with ‘inspiration to do something new’: “It was just a small suggestion by a colleague, but the project wouldn’t have happened otherwise. And a lot of the later ideas came out of discussions with other colleagues.”

Several people also said that positive feedback after the emergence of a new idea is almost as important as the inspiration that triggered it: “It’s very important for someone with an unusual idea to find a positive response. If you only talk to people who want rock-solid data and everything proven, then this won’t generate a flow of ideas.” Similarly, several interviewees emphasized that critical feedback can be very important when analysing a new idea—however, the criticism must be constructive to be helpful.

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Finally, it was pointed out that the ‘collective provides the individual with technical expertise’. A research institute represents a repository of materials and know-how that is beyond the reach of most individuals; however, only three scientists emphasized this point, whereas all emphasized the importance of discussion and interaction. The material foundation provided by an institute might be taken for granted, whereas a culture of interaction and mutual inspiration is not. As such a culture depends on a shared value system, which has to be developed and cultivated, it is more difficult to generate than to bring together the most advanced technologies. Therefore, scientists would value a culture of interaction and mutual inspiration more highly than access to technology, although the latter is essential for their experiments.

At the end of the interviews, each scientist was asked to describe the best possible conditions for generating creativity at a research institute. Of the five main points that emerged, the most important one—described in all interviews—was ‘being in an interactive environment’: “Cross-fertilization is absolutely essential. Before I came here, I hadn’t looked for other serious

influences that would push me in a different direction. Here you're almost forced to change your tune, and see things in a different way." This interviewee added that it is almost impossible to avoid innovation when exposed to very different perspectives. The fact that an interactive environment was emphasized as a critical condition for creativity in all interviews is consistent with the earlier points that the most important trait of a creative scientist is to seek stimulation by interacting with colleagues, and that the individual depends largely on inspiration provided by others to generate new ideas. These results indicate strongly that an interactive environment is the single most important factor for stimulating creativity. Two other conditions that were regularly mentioned were mere elaborations of this theme: 'interacting with people doing very different things' and 'interacting with colleagues informally'.

Obviously, interactions within any institution are strongly affected by its organization. Several interviewees described 'an open hierarchy' as an important factor for creativity: "[EMBL] is so inspiring because it feels like a free-flowing hierarchical organization [...]. The hierarchy is based on genuine respect because people are great scientists, but at the same time they're very approachable and open towards what you have to say." A further condition is 'the freedom to try new things', mentioned by about half the interviewees: "An environment in which people are free to follow their own line of enquiry within a frame that's agreed upon is usually more conducive than when the boss expects a certain result by a certain date on his desk."

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These results suggest that the best conditions for scientific creativity come with a free-flowing hierarchy and a highly developed culture of interaction to guarantee the exchange of ideas and inspiration. Furthermore, interdisciplinary interactions lead to the generation of new and unusual ideas. Finally, because of the freedom to try new things, these ideas can be tested and eventually generate new insights.

Creativity can be described as an emergent phenomenon in which the whole—the creative process—is larger than the sum of its parts—the conditions, facts and assumptions that started it. Both creativity and emergence are nonlinear phenomena: the emergence of a new steady-state in a dynamic system occurs abruptly as it crosses a particular threshold. This behaviour—sometimes described as the 'tipping point' (Gladwell, 2000)—is highly reminiscent of the abrupt and spontaneous nature of the creative insight.

Emergence depends on dynamic interactions between individual agents within the system (Holland, 1998). Similarly, creativity—if it is an emergent phenomenon—would benefit from dynamically interacting agents. This idea was indeed strongly supported by the interviewees who emphasized interaction with colleagues and the exchange of ideas and inspiration as the single most important factor for creativity to thrive. The importance of a 'freedom to try new things' and a 'free-flowing hierarchy' further supports the idea that individual components in an emergent system must be able to interact flexibly without central control (Holland, 1998).

This raises the question of whether EMBL has the properties of an emergent system so as to favour creativity and the emergence of new ideas. The answer seems to be yes: during the 30-year history of the Institute, its research units have undergone constant transformation—one of the hallmarks of an emergent system. Individual units were created or dissolved, expanded according to need or reduced over time. In the past ten years, two research units—the European Bioinformatics Institute in Hinxton, UK, and the Monterotondo outstation in Italy—were created *de novo*, three others were transformed from old units, and the remaining three have changed substantially in research direction (EMBL, 2003). Regular turnover of EMBL staff seems to create more dynamic interactions without disrupting research. This too is in line with an emergent system defined by intense interactions among its components, most of which can be readily exchanged without affecting the whole system.

How could these conditions be improved further? During the interviews, it became apparent that although a culture of interaction and creativity exists at EMBL, this itself is not often the subject of discussion. The values on which this culture is based are

seemingly implicit rather than explicit. Potentially, the EMBL culture of interaction could be strengthened further by consciously expressing and discussing the values on which it is based.

EMBL seems to fulfil the requirements of an emergent system that fosters creativity; therefore, given its success as a research institute, could it act as a model for enhancing creativity in other organizations? Owing to its multinational nature, the conditions are, of course, different to those at a national research institution. However, one of the main missions of EMBL—to promote international cooperation to the fullest possible extent—and its emphasis on interdisciplinary research automatically create a culture of interaction, and therefore promote a value system favouring collective creativity. The multinational nature of the institute makes it easier to transcend traditional models of research because it is independent and, therefore, free to experiment with new approaches. In addition, the high turnover rate of EMBL staff promotes flexibility and novel interactions.

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Although it might not be possible to transfer all of these conditions to other institutes, EMBL can still be used as an example of how to enhance collective creativity, mainly by creating and enhancing a culture of interaction among staff. The Howard Hughes Medical Institute (Chevy Chase, MD, USA) recently opened its Janelia Farm research campus (Ashburn, VA, USA) as an experiment to generate optimal conditions for scientific creativity (Rubin, 2006). In addition to a number of distinct structural features—some of which are similar to those of EMBL, including small research groups and a high staff turnover—Janelia Farm is based on an explicit value system that emphasizes originality, creativity and collaboration. These values seem to be much more consciously expressed than at EMBL and, therefore, it will be interesting to see the result of this experiment in scientific culture.

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