Reducing the problem to mere aptitude is clearly wrong, but treating women as 'men in skirts' ignores biology as well

suggested that qualified women could partly fill this gap (EC, 2005a). This dilemma can only be solved by combating stereotypes and by finding new ways to combine both family and career.

Sylvia Ann Hewlett, founder of the US National Parenting Association, thus argues for flexible working hours and more possibilities for women to re-enter their careers after a break (Hewlett *et al*, 2005). In a survey of 2443 women with professional or graduate degrees, Hewlett and colleagues found that 37% had interrupted their careers, 44% of these for family reasons. By contrast, only 24% of the 653 men who were surveyed had interrupted their careers, mostly for a change or further training. Only 12% of these men cited family reasons. Although the average length of the break was only 2.2 years, the cost to the women was extremely high in terms of income and career prospects. A significant proportion of women (38%) said that they had deliberately chosen a position with fewer responsibilities and lower compensation than the job for which they were qualified in order to fulfil their family responsibilities. Another 36% of the total surveyed had worked part-time for some time in an attempt to balance their work and personal life. Hewlett suggests that limiting the possibilities for women to re-enter or pursue their careers commensurate with their capabilities and qualifications costs the employer and society a great deal in terms of lost talent.

In his analysis, Summers made the mistake of comparing apples with oranges. He based his analysis of the career prospects of men and women on the assumption that both are sent into the race as equals. This is clearly not the case. It is difficult to estimate the damage his remarks have caused, given his role as President of one of the most prestigious universities in the world. But given the intense media coverage of his speech, his words have most certainly been read by many more people than all the subsequent studies, responses and counterarguments combined. Only a thorough understanding of all the differences in male and female career

paths and outcomes will lead to effective measures that could level the proverbial playing field.

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Gerlind Wallon

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Engendering creativity in the biomedical sciences

Innovation can be stifled inadvertently or intentionally. Fortunately, there are several ways in which scientists can foster creativity

In the early 1950s, Ludwik Gross found that a virus could transmit leukaemia: ground-up, filtered leukaemia cells induced a malignancy when injected into infant mice (Gross, 1951). This finding was anathema to the biological establishment—Gross commented that some oncologists “even doubted my integrity; one of the well-known pathologists [...] refused to shake my hand when I greeted him before one of my lectures” (Kevles, 1997). Gross, who later won the Lasker prize, might today have found himself hauled up on a charge of scientific misconduct or even fraud for announcing such a controversial discovery (Kevles, 1997). In the 1960s, Howard Temin faced resistance—even ridicule—when he suggested that viral RNA could generate complementary DNA. “I’ll give Howard’s idea the amount of time it’s worth—none,” said a leading virologist during a meeting at the time. About a decade later, Temin was awarded the 1975 Nobel Prize in

Physiology or Medicine for his discovery. In the 1970s, J. Michael Bishop and Harold Varmus faced similar problems when they proposed the oncogene theory of carcinogenesis, which won them the Nobel Prize in 1989 (Kevles, 1997).

... many factors conspire to hinder creativity on a broader scale among scientists

Pioneers whose work engenders such paradigm shifts are rare. Nevertheless, even prosaic ‘puzzle solving’ research within current paradigms needs creative, innovative scientists to rethink experimental protocols, modify hypotheses and strengthen theoretical frameworks. Challenging the consensus is the *sine qua non* of science. Yet Giovanni Fava, from the University of Bologna, Italy, recently argued that a “cult of mediocrity” pervades science (Fava, 2005). Fava

believes that “insufficient funding, lack of competing opportunities and the control of special interest groups, which disregard scientific merit and clinical value” undermine biomedical research in Europe. The special interest groups, he claims, include editors, reviewers and consultants to journals as well as non-profit organizations that support research. Talented and independent researchers, Fava argues, are denied promotion and funding because they may destabilize academia and unmask the hierarchy’s inadequacies. “Independent thinking [...] undermines the power structure,” he wrote. “Researchers who go abroad for several years often encounter tremendous difficulties coming back: they have become a threat to the local standards, which are shaped on mediocrity,” commented Fava in an interview for *EMBO reports*.

The experiences of Gross, Temin, Bishop, Varmus and numerous others seem to support Fava’s point that the biomedical establishment often finds radical ideas unpalatable. Moreover, other studies support his assertion that many scientists are content—or feel compelled—to strive away in obscurity and mediocrity. Citations, for example, are widely used surrogates for scientific impact. Only half of scientific publications generate a single citation. Less than 20 percent are cited more than 10 times (Simonton, 2004).

Obviously, in any field only a few reach the pinnacles of creativity. A James Joyce or Marcel Proust is as rare as a Howard Temin or Linus Pauling. However, many factors conspire to hinder creativity on a broader scale among scientists. Investors pick biotech’s best ideas, while leaving the next crop financially untended, perhaps to wither on the vine. Researchers forced to live from grant to grant often choose—understandably—to play it safe with their applications. Even those responsible for awarding grants admit that the system is imperfect and innovative research can lose out.

Ironically, inadequate funding can both stimulate and hinder creativity. “Many researchers are at their most creative when they need to improvise, without a large infrastructure and when working with inadequate budgets,” said Anthony Walker, CEO of Onyvax, a biotech

company based at St. George’s Hospital Medical School, London, UK, that develops therapeutic cancer vaccines. “Often, moving to a marble and glass building, with all the hierarchy, systems and bureaucracy, stifles creativity.” But below a certain threshold, inadequate funding becomes a pervasive hindrance. According to Charles Pusey, Professor of Medicine at Imperial College (London, UK) and Academic Registrar at the Royal College of Physicians, it is the major factor currently stifling scientific creativity across Europe. “It’s getting harder and harder to find funds. Many British charities now fund only 1 in 8 or 1 in 10 of the grant applications. Excellent research proposals that would have been funded a few years ago are now falling by the wayside,” he said. “It’s demoralizing. Many talented researchers leave academia because they become disillusioned when one grant after another is turned down.”

Grant-funded researchers who stay the course survive from one award to the next, unable to plan their lives or their careers more than three or four years in advance

Walker was one such casualty—he left academia after completing his PhD. “I saw the writing on the wall,” he said. “I couldn’t face the uncertainty of living from grant to grant.” Grant-funded researchers who stay the course survive from one award to the next, unable to plan their lives or their careers more than three or four years in advance. Those with tenured appointments often struggle to build research groups. This produces two problems that conspire to stifle innovation. Firstly, Pusey said, it is difficult to build up a stable, well-funded team with the experience to develop innovative approaches. Secondly, there is an understandable tendency for academics to “play safe” and apply for grants that the funding body is likely to approve. Walker, who sits on several grant approval committees, admits that the system is imperfect. But he paraphrases Winston Churchill’s maxim about democracy: “No one pretends that grant approval committees are perfect or all-wise. Indeed, it’s the worst mechanism to assess

... most creative scientists tend to work on several projects at once, actively participate in meetings and read widely outside their discipline and science

research—except for all those other forms that we have tried from time to time.”

“Unfortunately, funding very much depends on peer review, whose effect on suppressing innovations is well known,” Fava commented. “At least as much weight should be placed on the background of a researcher and his or her accomplishments. I bet that funding decisions based on citation analysis of previous research would yield far better results than those based on peer review only. The boss who is a mediocre investigator, but a good manager, does not fear creativity. But there are a lot of academic professors who do not care much about scientific production.” Walker notes, however, that many researchers do not maximize their chance of success either. “Often grants are unrealistic, over-ambitious for the time frame or too speculative,” he said. “They’re on fishing trips. Someone who puts together a hypothesis-driven proposal, based on a biological insight and supported by reasonable background literature has a pretty good chance of being funded, even if the idea is radical.”

Nevertheless, Walker admits that researchers might need to be persistent, which in many cases means having the security of a faculty position. Furthermore, he accepts that even outstandingly creative ideas in unfashionable areas will have a particularly tough time finding funding, especially if they butt against scientific politics. “Academic politicians are much more vicious than the real things in Brussels, London or Bonn,” Walker commented.

Scientists have long understood the need to play the political game to obtain funding. In the 1940s, researchers found that mouse breast milk transmitted a carcinogenic factor. Some, such as John Bittner, a scientist at the Jackson Laboratory (Bar Harbor, ME, USA), suspected a virus was responsible. But Bittner dared not use the ‘V’ word in his grant applications. “If I had called it a virus, my grant applications would

automatically have been put into the category of 'unrespectable proposals'. As long as I used the term 'factor' it was respectable genetics," Bittner commented (Kevles, 1997). All this makes pretty depressing reading for anyone with an innovative idea, working in an 'unfashionable' area or struggling to establish a lab. Nevertheless, there are ways in which individual researchers and the scientific community can foster creativity and win those elusive grants.

Dean Simonton, from the University of California, argues that scientific creativity is essentially stochastic. In his recent book, *Creativity in Science*, Simonton suggests that scientific creativity is combinatorial: in other words, new ideas emerge by generating chance combinations. You need to sift through numerous combinations that are, for example, logically flawed, already in the literature or impractical to obtain a creative, innovative combination. The more trials you run, the greater your chance of success.

Against this background, Simonton notes that most creative scientists tend to work on several projects at once, actively participate in meetings and read widely outside their discipline and science (Simonton, 2004). The oncogene pioneers, for example, were intellectual cosmopolitans. Varmus undertook a year's graduate work in Anglo-Saxon and metaphysical poetry and Bishop reads widely in literature, philosophy and history (Kevles, 1997). This diversity produces 'cross-talk' that can lead to unexpected solutions, even if the projects do not seem closely related on the surface (Simonton, 2004). The more projects you work on, the more ideas you are exposed to, the greater your chances of finding that spark of creativity.

Pusey therefore encourages his staff "from the newest technician to the most senior post-doc" to contribute during the regular lab meetings. "Anyone in the team can challenge me," he said. "I welcome a robust debate." Similarly, Onyvax foster a "relaxed and open" corporate environment to encourage innovation and creativity. "We're not a hippy commune," Walker said, but "we aim for more of a collegiate approach." Such approaches fit Simonton's combinatorial hypothesis. A free-flowing lab meeting generates numerous ideas from different perspectives and this exchange of ideas can stimulate

participants to follow unexpected avenues (Simonton, 2004).

Pusey suggests three further ways to engender creativity in biomedical research. Firstly, he argues, national funding bodies need to realize that increased funding for medical research and for training young academics is essential to improve standards of patient care in the future. Secondly, multidisciplinary collaboration is invaluable in opening new research vistas. Pusey's work offers insights into the basic mechanisms that underlie inflammation, so he collaborates with a group investigating rheumatoid arthritis. "More multidisciplinary meetings would be valuable," he said. "However, when you reach the cutting edge of your discipline you often come across like-minded people to collaborate with." Fava would also like to see changes in the structure of scientific conferences, making them more independent and informal. "The main scope of many scientific meetings today is to sell the participant to the sponsor," he remarked.

Thirdly, Pusey believes that academics need to work more closely with industry, particularly in clinical research. There is a certain degree of mistrust on both sides: industry tends to regard some academics as being unsympathetic to their commercial imperatives, and some academics regard working with industry as a compromise to their independence. Pusey commented that the two sides need to trust each other and if the relationship is transparent and open, both parties can benefit without any conflicts of interest. "Five or ten years ago academics regarded those who worked with industry as having sold out. Industry often regarded academics as dwelling in ivory towers," Walker agreed. "Today, close collaborations are increasingly common and, provided the process is open and transparent, conflicts of interest don't really emerge."

Walker added that biotechnology companies and large pharmaceutical companies are always interested in innovative ideas that have commercial potential as diagnostics or therapeutics. Currently, however, getting venture capitalists and institutional investors interested in innovative ideas is increasingly difficult, which obviously stifles creativity. Investors are much more cautious about high-risk

projects than in the past. As a result, they increasingly focus on late-stage projects, and justify their approach by noting, for example, that no European biotech company can currently match the success of Amgen (Thousand Oaks, CA, USA) or Genentech (South San Francisco, CA, USA), who successfully commercialized their innovative intellectual property. It is a short-sighted view, believes Walker. "The lack of investment in early stage research is a worry. If we don't seed research now, there won't be any late-stage projects for investors to cherry-pick when the current crop runs out," he said. "The stock market is cyclical and I'm sure investment will return. But at the moment investment is out of balance."

... creativity underpins all scientific success from the technician to the opinion leader at the peak of his or her career

It is a simple fact of life that few researchers will be in the right place at the right time to experience the spark of creativity that wins a Nobel Prize or forces a paradigm shift. Nevertheless, creativity underpins all scientific success from the most recently recruited technician to the opinion leader at the peak of his or her career. Researchers who want to enhance their creativity need to increase the likelihood of the serendipitous cross-fertilization that breeds innovations and the biological insights that underpin successful grants. After all, as Simonton wrote, "Even the lone article published by an otherwise unknown scientist may stimulate the thinking of the most illustrious scientist in the same discipline. The odds are not high, but they are not zero either."

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Mark Greener

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