8 The 'kula ring' of scientific success

Elite male participants in a cultural complex extending from the Kwakiutl Native American communities in the Pacific Northwest to the Trobriand Islands in the South Pacific regularly meet to give away their most prized possessions to each other. The more material goods an individual gives away, the higher their social status and the more secure their standing within the group. This pattern of social relations, called the 'kula ring' in Melanesia and the 'potlatch' in North America, provides an informal means of organizing and redistributing resources and power in the community (Drucker and Heizer, 1967). 'And it is just through this exchange, through their being constantly within reach and the object of competitive desire, through being the means of arousing envy and conferring social distinction and renown, that these objects attain their high value' (Malinowski, 1922: 511).

Conducted at regular intervals, the kula ring has its analog in the way scientists exchange ideas, resources, and information. Like gatherings of Melanesian clan leaders, elite scientists who are linked by ongoing networks of relations and governed by norms of trust and reciprocity ritualistically meet to discuss collaborations, discover complementary areas of research, and introduce their graduate students and post-doctoral fellows to each other for future correspondence and employment.

Even members of the same department may experience the scientific world quite differently, depending on the configuration of their social networks. The differential effect of networks on women and men has also been noted, particularly in regard to problems of mentorship and networking across sub-areas that differ in status (Ibarra and Smith-Lovin, 1997). Suzanne Brainard, director of the Women in Engineering Initiative at the University of Washington (an organization that promotes the inclusion of women in the engineering professions) concluded that 'The major issue facing women at the academic level is isolation' (Emmett, 1992).

Epstein (1970) found that in medicine, law, and science, men get more opportunities for professional advancement through informal sponsors who provide advice and share tacit knowledge on how to get ahead. Reskin (1978) documents this exclusionary process for women in scientific careers. She found that when there are few women in an academic department or in an industrial or government research unit, and women are not well accepted by men in those settings, they experience the effects of isolation.

Post-graduate women in academic research groups also experience professional isolation more acutely than men as they become aware that they are not being invited, to the same degree as their male peers, to be part of the professional network that leads to contacts and potential job openings. A female graduate student commented on the frustration that this kind of perception creates about career prospects and job aspirations and said, 'If you had a job, who would you hire first? Someone you're buddies with, right?'

The benefits of being in a strong network of contacts are the mirror image of the problems of isolation. Early inclusion in a strong network provides a 'jump start' to a scientific career. For example, a professor's invitation to a graduate student to deliver a paper at an elite conference allows network building among fellow graduate students and their senior sponsors. Such connections create a stable and supportive reference group as well as providing channels by which to disseminate work and share ideas.

In this chapter, we argue that differences in scientists' social networks influence their career success by shaping their level of social capital. Like the more familiar concepts of human capital (a person's talents and know-how) and financial capital, social capital has exchange value and can be accumulated. It is different in that it depends on relationships to create and sustain it.

SOCIAL AND OTHER CAPITALS: DEFINING OUR TERMS

Social capital is one of several forms of 'capital' that have recently been recognized by analogy to monetary capital. Thus, human capital or 'what you know' is the intellectual reservoir of ideas, methods, and factual knowledge that one accumulates, whereas social capital or 'who you know' is the web of contacts and relationships that provide information, validation, and encouragement. Social capital refers to the relational aspects or informal dimensions (e.g., commitment and intimacy between persons) while 'cognitive capital' is the knowledge base that an individual has acquired in a particular field. Both kinds of capital, human and social, in optimum combinations are the key to achievement, reward and recognition in science.[1]

Thus, social capital refers to the productive resources a person gains access to through contacts that control critical resources, or creates with another person they have a relationship with, but which decrease in value if the relationship ends or the resources are transferred to another relationship. Social capital 'accrue[s] to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships [that are] embedded in a stable system of contacts possessed by an individual' (Bourdieu and Wacquant, 1992: 119). These resources include interpersonal trust and norms of

[1] The 'social capital' thesis had its origin in a debate over the relative importance of family ties or formal schooling in occupational success. The social capital literature focuses on the role of the home and the school in reducing or mediating the negative effects of social origins through provision of a network of trust or what Granovetter (1985) calls 'embeddedness'. 'Social capital' also refers to the nature of relations between individuals based on their mutual expectations and obligations, channels of communications and social norms (Coleman, 1988). Families at all economic levels are becoming increasingly ill equipped to provide the setting that schools are designed to complement and augment in preparing the next generation. Within the family, the growth in 'human capital' is extensive, as reflected by the increased levels of educational attainment. But social capital (relationships and social ties), as reflected by the presence of adults in the home, and the range of exchange between parents and children about academic, social, economic, and personal matters, has declined, at the same time that the parents' human capital (e.g. level of education) has grown.

reciprocity as well as knowledge of new scientific ideas and strategies for developing a line of research.

Social capital provides an approach for analyzing differences in the success of men and women in a social context in which productivity is based on managing interdependence with others. Our hypothesis is that the role of social capital increases in a non-linear fashion. As individuals attain initial increments of social capital, their likelihood of obtaining future infusions grows ever greater. The presence or lack of connections to a mentor or role model of scientific success gives some individuals a head start and places others at a disadvantage. Importantly, social capital accumulation is all too often gender linked and makes a difference even among the successful. A recent Danish study of access to post-doctoral fellowships found that women had to have 2.6 times the publication productivity of males to achieve equal career success. Our hypothesis is that a greater measure of human capital was required to make up for a deficit of social capital.

We begin by describing how the production of scientific knowledge has changed from solitary work to production lab work that places new emphasis on social networks as the mechanism for linking interdependent scientists across departments and universities. Next, we describe the creation of social capital in scientific careers and its effect on both careers and knowledge production. This material provides the background for a later chapter which empirically examines the differences in the social capital of men and women scientists and the ways in which it influences their aspirations and career chances. Then we describe the role that social capital played in the race to discover the structure of DNA. Finally, we draw a series of inferences from the data analyzed earlier in the chapter about the relationship among women, social capital and science.

THE NEW ORDER OF SCIENTIFIC PRODUCTION

The model of scientific practice in the natural sciences that was once taken for granted, and was expounded by Vannevar Bush in his landmark vision *Science: The Endless Frontier* (1945), has materially

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changed. Bush argued that science follows three simple linear steps – basic research, applied research and development – and that a rich human capital base and heavy investments by the government drove the success of scientific achievement. The important factors are two: a strong, government-led financial infrastructure and a strong physical infrastructure composed of state-of-the-art technology, laboratories, instruments, and facilities. In the fifty years since *The Endless Frontier* the myth of the individual scientist has been supplanted by the reality that the development of scientific innovations requires not only financial and human capital, but also a store of social capital.

Nevertheless, the myth of the individual scientist persists as an instance of what anthropologists call 'cultural lag', where a belief about a practice may continue to be strongly held long after reality has irrevocably changed. Thus, funding agencies and scientists themselves refer to the 'individual investigator', who is actually a research manager, whether in academia or industry, who provides intellectual inspiration for the work of several graduate students, post-doctoral fellows, undergraduates and technicians, and who also raises the funds from granting agencies to support their work.

The managerial responsibilities assumed by the contemporary academic scientist who conducts funded research lead many of them to say that they feel like they are running a small business . Indeed, these academic quasi-firms have many of the characteristics of a business firm, save for the profit motive (Etzkowitz and Peters, 1991). Certainly academic science has come a long way organizationally from the individual faculty member before the Second World War, who might work with a few graduate students individually. The contemporary academic scene requires a continuing replenishment of resources, of varying kinds, to maintain the viability of a research group.

The pivotal role of social capital over and above the effects of financial and human capital is illustrated by recent research on successful university/industry partnerships in Great Britain, Germany, and the U.S. from 1850 to 1914 (Murmann, 1998; Murmann and Laudau, 1998). Murmann carefully measured and compared the government expenditures on R&D and education in these nations, as well as the quality of research faculty and the number of Ph.D.s awarded. He demonstrated that the decisive factor for the advancement of science was not the quality of the financial or human capital (even though some base level was obviously needed), because these were at equal levels in all the countries studied.

Rather, the nature of social ties among scientists in the academic community and industry was the key factor that stimulated scientific innovation and the likelihood that laboratories, led by university professors, would develop world class research and products. It was the higher level of social capital among German scientists – that is, their ties within the university, and between university and industry – that enabled them to pool resources and ideas more effectively than those in other nations.

We believe that social capital is even more important in scientific production today than it was nearly 100 years ago. First, beyond the formal structure of courses and examinations, contemporary advanced scientific training is increasingly based on transfer of tacit knowledge in group settings among peers and with mentors and through learning-by-doing.

Second, most problems are too large for a single individual to tackle alone, given the increased specialization of subfields and the high costs of analysis, testing, and product development. The success of research projects increasingly depends upon the coordination of several scientists and non-scientific groups that bring diverse scientific as well as managerial and financial competencies to bear on problems that are increasingly at the interface between science and commerce.

The complex reality of rapidly developing fields, in which knowledge is both sophisticated and widely dispersed, demand a range of intellectual and scientific skills that far exceed the capabilities of any single organization, as illustrated by two notable recent discoveries in biotechnology. The development of an animal model for Alzheimer's disease appeared in a report (*Nature*, Feb. 9, 1995) co-authored by 34 scientists affiliated with two new biotechnology

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Similarly, a publication identifying a strong candidate for the gene determining susceptibility to breast and ovarian cancer (*Science*, Oct. 7, 1994) featured 45 co-authors drawn from a biotechnology firm, a U.S. medical school, a Canadian medical school, an established pharmaceutical company, and a government research laboratory. More important than the number of authors is the diversity of sources of innovation and the wide range of different organizations involved in these breakthrough publications (Powell *et al.*, 1996:118–119). All of this work suggests that as knowledge becomes more fragmented and dispersed among individuals and organizations that are geographically separated and institutionally independent, the role of social networks in forming information bridges and providing social support increases.

THE MOBILIZATION OF SOCIAL CAPITAL IN SCIENTIFIC CAREERS

Social networks emerge as a matter of necessity around scientists who must pool resources and talent, providing members of these networks with special access to information that is not available to those outside. An important aspect of social networks is that they influence how individuals exchange ideas, information, and resources in ways that other forms of information transfer, such as journals or gossip, do not. In particular, a quid pro quo logic of exchange is the norm in networks as new members (e.g., incoming graduate students) feel indebted to others in the network for bringing them in and sharing with them their knowledge and resources. As this indebtedness builds up among different members in the network, the social network becomes a repository for opportunities and investments that can be drawn on when needed and are reciprocated at some time in the future back to the group.

In this sense, networks share similarities with revolving credit associations – associations in which members donate resources to the group and draw on them when in need. The result is that social capital builds at different rates depending on the structure and membership of a person's network, and that social capital is created as a by-product of many different activities which share a common thread of generating, consuming, and investing in productive resources.

As this process extends over time and to new contacts, an individual's social network is enriched with opportunities (social capital) that can facilitate success. Contacts can be called to access information about jobs before they are nationally posted, to discover what areas might receive special funding consideration, to locate unpublished material, or to garner the validity of new research findings. Being invited to participate in research grant proposals by senior faculty members increases chances of success; exclusion sends a strong message to women to seek another position before tenure review.

In one department that we studied, junior female faculty members in an electrical engineering department reported that they were left out of invitations given to young males to participate in large-scale research proposals. The negative message this gave to one female faculty member was so strong that she resigned her research position in favor of a job at a teaching college. This capital also plays a critical role when evaluation is equivocal (e.g., the evaluation of work), when favorable interpretations are important, or when referrals are made to individuals in other networks with other opportunities for jobs, research projects, and funding. To begin a career without these connections isolates an individual at the very stage of a scientific career when visible achievement is crucial to long-term success (Merton, 1968; Lin, Ensel and Vaughn, 1981; Fernandez and Weinberg, 1997).

Senior scientists who have developed a high degree of social capital can be thought of as 'social capital bankers' and typically have the greatest access to information; their networks are widely cast, cross-cutting research teams, departments, and universities (Zuckerman and Merton, 1972; Seashore *et al.*, 1989). These individuals are in the

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best position to spot opportunities and to connect less embedded individuals to opportunities. Persons new to departments, such as graduate students or assistant professors, are in the opposite position. They lack a large and well-developed network of opportunities and therefore are highly dependent, for information and contacts, upon individuals in central positions.

Elite scientists deposit social capital with their protegés and fellows in the form of invitations to high-level conferences and access to privileged information. Participation in a circle of investigators of related topics gives a scientist confidence to move swiftly in interpreting his or her findings, increasing the likelihood of being credited for a new discovery. Information gained through telephoning friends can be a crucial part of preparing an experiment and assessing results. Such ties provide informal access to knowledge about emerging topics for investigation along fast-moving research fronts, a hint of related results, or warnings about unfruitful approaches already attempted elsewhere, so-called 'telephone science.'

Offering access to protegés, who are viewed as rising stars enhances the prestige of a senior scientist and further expands their power just as the ceremonious circle of gift giving, among the Kwakiutl tribe, produces the 'social glue' that keeps the dispersed clans together as a collective entity. As with the Kwakiutl, access to participation in informal ties and networks is the surest path to high achievement and enhanced social standing in the group (Burt, 1992).

Exclusion from a network of social ties and critical mass contributes to the well-documented decline in the proportion of women who make it to each succeeding rung on the professional career ladders (Burt, 1997). But the exclusion also affects those seemingly 'successful' women who manage to persist all the way to the Ph.D. Here the issue is not one of survival, but of the quality of the experience in graduate school, and the efficacy of the tools that are available to make the transition to a productive and satisfying career.

Attaining formal status such as an advanced degree or a research position is a necessary but not sufficient condition for a highly successful career in science. Formal positions are only a rough indicator of success, since individuals of the same rank differ widely in the strength of their networks and their access to scientists with relevant knowledge for possible collaboration.

Thus, social capital plays an important role in enabling scientists to manage the interdependencies inherent in scientific labor and practice. It does not replace human capital or financial capital as the primary force but reveals the importance of resources that are lodged in relationships between people rather than in individuals, technology, or institutional systems in scientific careers and work. Social capital increases an individual's timing, access, and referral benefits, which span the contexts in which other 'capitals' operate, and also links them together in new combinations and innovations that result in the creations of privileged resources (Burt, 1992). While we postpone to a later chapter our exposition of how social capital is measured in the context of the hard sciences, we note that it depends on the structure of a person's network and the quality of the relationships they maintain with people who occupy that structure.

Large expansive networks of weak ties offer access to new and novel information while strong ties provide social support and a basis for gaining social and political support (Granovetter, 1973; Coleman, 1990; Burt, 1992; Uzzi, 1997). Our hypothesis is that men's and women's different career trajectories can in part be explained by looking at their differences in social capital.

SOCIAL CAPITAL, DNA, AND GENDER

In his memoir on the discovery of the structure of DNA, James Watson described the epiphany that he experienced at an international poliomyelitis congress in Copenhagen. After a week of '. . . receptions, dinners and trips to waterfront bars . . . an *important truth* was slowly entering my head: a scientist's life might be interesting socially as well as intellectually' (Watson, 1968: 40; italics added). Sharon Traweek, an anthropologist who conducted a participant observation study as a public information officer at the Stanford Linear Accelerator Center, al positions are only a rough of the same rank differ widely in their access to scientists with oration.

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observed the same kind of social interaction noted by Watson but among the average scientist and away from the spotlight of fame. At this leading high-energy physics research site, she found that groups of men from each detector congregated at lunch in the cafeteria and after hours at local pubs to build friendships and exchange ideas. The same was true of theoretical physicists, who, unlike experimental physicists, were expected to be 'solo artists' because they experienced few technological or financial incentives that might divide the labor of a project among a workgroup of fellow scientists.

Watson apart, the informal social relations of science usually go unreported in the history of scientific achievement. The news sections of *Science* and *Nature* do not yet have a gossip columnist to chronicle who was seen with whom at a meeting or to note new collaborative partnerships. Ironically, a solitary existence has been assumed to be the mode of scientific life. Consequently, an examination of the effects of isolation on scientific careers goes against the grain of popular expectations that 'scientists work alone, in silence' (Traweek, 1988: 57).

Nevertheless, news is routinely transmitted among colleagues, locally and at a distance through informal channels, third-person gossip, phone, and e-mail. There are times, such as when two groups make simultaneous discoveries, when gossip among scientists is intensely conspicuous. But ties among scientists not only permit information flow, they increase the probability of finding scientific partners with complementary skills, a shared commitment to a particular line of work, and the conviction to stand by their recommendations and convictions.

Consider the case of Rosalind Franklin, Watson and Crick, and the discovery of DNA's helical structure. Why wasn't Rosalind Franklin included among the recipients of the Nobel prize for this achievement? Owing to her untimely death, the inevitability of her exclusion can never be proven. Rosalind Franklin produced the first photographs containing the crucial evidence of DNA's helical structure. But she worked in an isolated research environment apart from the assistance of a single junior colleague.

Franklin lacked membership in a group of colleagues who might have supported riskier inferences and encouraged her to publish her findings more fully and quickly. Instead, in the prototypical fashion of an isolated female scientist, she built up her battery of evidence slowly and precisely before she was willing to draw strong conclusions. She lacked the social capital needed to locate persons with particular scientific information that was outside her expertise that could have allayed her hesitation about the speculative nature of her findings. In addition, she lacked contacts to researchers who could have mobilized support for her insights.

In contrast, her competitors Watson and Crick set forth ill-supported hypotheses on the chance of hitting the mark, despite the risk of being shot down, because of the support furnished by their large and well-connected network. After announcing a theory that was quickly found to be empirically wrong, they were ordered to cease and desist from this line of work by the Institute's head. Nevertheless, Watson and Crick obtained informal support and expressions of interest from colleagues and soon geared up for another assault on their goal.

Watson and Crick also used informal social interaction with scientists outside their new laboratory to complement the knowledge that was shared among scientists and technicians in their own laboratory. For example, the chance presence of a structural chemist at the Cavendish laboratory helped confirm the validity of Watson and Crick's helical model by revealing an error in another published work that was the foundation of Watson and Crick's insight. This was the same information that had eluded Franklin.

Watson reported that the discovery was due in part to the 'unforeseen dividend of having Jerry share an office with Francis, Peter and me.' He also noted the opposite effect on one of his competitors, a scientist working on the same problem: '... in a lab devoid of structural chemists, [he] did not have anyone to tell him that all the textbook pictures were wrong. But for Jerry, only Pauling would have been likely to make the right choice and stick by its consequences.' Had it not been for the network ties with chemists at the Cambridge

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pub, the misunderstandings of the chemical structure induced by the inaccurate pictures in chemistry textbooks might have never been uncovered – or at least not in so timely a fashion. Similarly, the large and diverse network of personal contacts possessed by Watson and Crick enabled them to mobilize resources and to effect a quick recovery after an initial failure.

A related example of the effects the lack of social capital is seen through the eyes of Evelyn Fox-Keller and in her analysis of Barbara McClintock, a future Nobel Laureate who, like Watson, was associated with the Cold Spring Harbor Laboratory. Evelyn Fox-Keller's graduate school experience in physics in the late 1950s and early 1960s shows the dark side of networks – isolation. She described how a lack of a supportive network negates motivation and lowers levels of aspiration in ways that undermine an individual's ability to realize their potential at a crucial point in the maturation of a scientist (Shapiro and Henry).

Fox-Keller almost dropped out of her Ph.D. program after being systematically excluded from participation in the informal social relations of her department. 'She was making a name for herself indeed, but the process was a nightmare. She was completely isolated . . . She was going to get out of physics' (Horning, 1993). Fox-Keller told her interviewer, 'My real world began to resemble a paranoid delusion. Many people in Cambridge knew who I was and speculated about me. None of them offered friendship.' After two years of such treatment, she 'was a wreck – defensive, weepy and unapproachable. She passed her orals but decided not to do a thesis.' Fox-Keller eventually completed her doctorate after a revivifying visit with biologists at Cold Spring Harbor Laboratory whose 'attitude to her was a lot more accepting than that of most members of the Harvard physics department' (Horning, 1993).

Her own experience of isolation turned Fox-Keller's scientific career from physics to molecular biology and eventually to the history of science. Years later, preparing for a colloquium, Fox-Keller experienced the converse of Watson's epiphany, recalling to consciousness the effects of her isolation. She had repressed her painful experiences, including the haunting image of a distinguished female scientist seen on solitary walks at Cold Spring Harbor. Fox-Keller wrote, 'Barbara McClintock represented everything that I was most afraid of – that becoming a scientist would mean I'd be alone . . .' (Horning, 1993). This realization led Fox-Keller to refocus her career on the analysis of gender issues in science, starting with a biography of Barbara McClintock, a Nobel prizewinner who shared with Watson an interest in genetics and for a time a research home – the Cold Spring Harbor Laboratory.

And what she showed was that despite being Nobelists and having exceptional scientific minds, the career trajectories and networks of McClintock and Watson were vastly dissimilar. McClintock was an outsider who, on the fringe of key networks of communication and support, operated at a competitive disadvantage relative to Watson. While a few persons like Barbara McClintock turn social capital disadvantages to advantage (Fox-Keller, 1980), most fall behind in professional attainment or decide to change careers.

RAISING SOCIAL CAPITAL

In this chapter, we have described the nature of social capital, how it forms, and the ways in which it can influence scientific achievement. We drew an analogy between social capital and the kula ring. Both are defined by membership, the special logic of exchange that governs resource trades within the group, and the revolving 'credit' and investment nature of the exchanges that tends to enrich the network over time.

We placed social capital in context by reviewing literature that showed how the change in the way scientific work and practice is conducted – from graduate school recruitment to the conceptualization and marketing of scientific goods – revolves around interdependencies among scientists that are best managed through social capital. Our point was not to discount the importance of human, cognitive, or financial capital in career success. Rather it is to show the effects of social capital, particularly in how it enables scientists to find

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Social capital develops out of interaction with prior contacts and network structure in several ways.

First, reciprocity governs exchanges between contacts. New faculty members who are invited into a network feel indebted to the others in the network for bringing them into a supportive and status-enhancing social group.

Second, the new members' initial indebtedness and reciprocity expand as members exclusively share tacit knowledge on how to get ahead or allocate discretionary resources to each other. For example, contacts can help one to find out about jobs, pass on information about research areas that might receive special funding consideration, locate unpublished material, or make introductions/referrals between formerly unacquainted persons who share similar interests (Kenney, 1986; Seashore *et al.*, 1989; Powell *et al.*, 1998).

Third, the right social network configurations not only get access to but also increase the speed and veracity of the information transferred. These outcomes are also important for the university. In decentralized systems, non-bureaucratic systems, informal connections provide a by-way by which information is accumulated and imported from other institutions (Powell *et al.*, 1998).

Fourth, networks provide social support to their members. Close working relationships with experienced network members help new members interpret critical feedback and motivate commitment to a long-term program of scientific study, which is often punctuated by few immediate rewards. Emotional support and group affiliation create an identity that enhances feelings of self-worth ('I know others feel the same thing'), generate commitment to goals that have delayed pay-offs (Ibarra, 1992), and provide a group mechanism for legitimating claims or counteracting against discrimination (White, 1992; Podolny and Baron, 1997). As an individual's portfolio of contacts grows over time, resources and opportunities also accumulate, facilitating success (Coleman, 1988).

Scientists at central positions in scientific networks function as repositories for social capital because they have a large number of connections to diverse persons in and outside the department. Those at central positions in a network can be thought of as 'social capital banks' which accrue gifts or loans from other senior scientists with similar reservoirs of relationships. The members of the network gain special access to information that is not available to non-network members, and to information before it becomes available to the 'market', namely scientists outside the network.

Moreover, these connections facilitate the match between a person's human capital (i.e., a person's specific skills, talents, or motivation) and various situations in which opportunities appear to use and expand one's capital. Thus, the network is the organizing structure of interpersonal ties in which social capital accrues and, depending on their network access, individuals with equal human capital experience different rates of success based on their social capital (Coleman, 1988; Burt, 1992; Ibarra and Smith-Lovin, 1997).

In the next few chapters, we turn to an in-depth analysis of the experiences of women faculty and the ways in which different departmental structures affect their ability to succeed in science and for science.