2 Inventors and creativity

This chapter discusses the generative phase of innovation, analysing certain issues relating to inventors and creativity. The first part outlines various historical modes of organisation and regulation of the inventive process, with particular reference to the USA: the 'golden age' of independent inventors in the phase of liberal capitalism; the birth of the great industrial research laboratories in the Fordist phase; and the development of social and territorial systems of innovation in the post-Fordist phase. The second part presents the observations of social psychologists regarding individual and collective creativity.

2.1 Genius or puppet?

As we saw in the previous chapter, the theme of innovation has returned in recent years to the centre of reflection on economic development. Studies, however, have focused mainly on its economic valorisation while little has been said about the actors and *generative mechanisms* that underlie it. In the wake of Schumpeter's observations, innovative entrepreneurs have received the lion's share of the attention, and the inventors far less.

Who are the protagonists of invention and innovation? In answering this question, the approaches present in the social sciences oscillate between two opposing visions: an *individualistic perspective*, which tends to attribute a prominent role to particularly creative subjects with specific personal characteristics, and a *holistic conception*, which assigns almost exclusive importance to the conditions of the context that determine the emergence of innovation (the functional requirements of the market or society; the cultural, territorial and organisational features of specific environments).

The first view has deep roots in Western culture, which has so often celebrated great innovators and creative genius. For example, to limit ourselves to the modern era, such figures occupy a special place in the social representations that accompany the first industrial revolution, when technological change started to affect economic growth in a more systematic way. In the writings of the time, in fact, the pioneers of technological innovation, such as James Watt, inventor of the steam engine, are celebrated as heroic characters, representative of an emerging industrious middle class (MacLeod 2007).

The importance attributed to particularly creative individuals has also been fully consecrated through the so-called 'Lotka law'. In 1926, while working for the Metropolitan Life Insurance Company in New York, the statistician Alfred Lotka made the discovery that most scientific production depended on a small number of men. Starting from an analysis of publications in the field of chemistry and physics, Lotka developed a generalisation according to which scientific productivity follows a distribution based on the inverse of the square. Two results emerge from the analysis: the number of scholars who publish n articles is approximately $1/n^2$ of those who publish only one; and the share of the latter is around 60 per cent of the total (Lotka 1926). In other words, taking 100 as the number of scientists who publish in a given field, 60 publish only one article, 15 publish two (equal to a quarter of the first 60: $60/2^2$), seven publish three (equal to a ninth: $60/3^2$), 4 publish four ($60/4^2$), and so on down the scale. The *inverse square law of scientific productivity* was subsequently tested and confirmed in several creative fields: humanistic sciences publications (Murphy 1973; Coile 1977); the patents of a sample of American inventors (Carr 1932); the inventive productivity of the researchers of some American semiconductor companies (Narin and Breitzman 1995) and of a number of German companies in the electric, chemical and mechanical engineering sectors (Ernst *et al*. 2000). Historiometric research (the quantitative study of historical phenomena), relaunched by Dean Simonton in the seventies, shows that half the innovation in every field is generated by 10 per cent of its practitioners (Simonton 1999).

All these studies show, therefore, a highly asymmetric distribution of scientific productivity and creative capacity. This tends to give credence to the idea that invention and innovation can be attributed to individuals endowed with exceptional qualities and gives rise to the tendency to study inventor creativity as a kind of personal trait. Certain personality aspects surely play a role in the creative process but these must be properly contextualised. This does not mean committing the opposite error, however – typical of holistic approaches and the functionalist variety especially – which explain the emergence of invention and innovation as a predictable (necessary and automatic) answer to market and society requirements or to the characteristics of particular contexts. As we shall see in the next chapter, with reference to the sociology of inventions that developed in the thirties, such precepts come to assume a deterministic approach that deprives social actors of all space and relevance. What is needed, instead, is an integrated analysis approach, which in addition to the individual aspects (the social attributes and personal characteristics of the inventors) also takes into account the relational (social networks) and contextual (territorial, sectoral and organisational factors) aspects that structure the inventive processes. This chapter will deal primarily with the historical process of the *professionalisation of inventive activity* and the research carried out by psychologists on creativity. The subsequent chapter will discuss sociological approaches and the latest research regarding inventors.

2.2 On the shoulders of giants

There are few systematic studies dealing with inventive activity. Above all it has been psychologists who have analysed creativity, and for a long time they tried to measure it at an individual level, using tests similar to those used to assess intelligence. Economists have focused mainly on innovation in companies, and inventors and inventions have been rather neglected. This underestimation is partly related to the 'decline of independent inventors' (Lamoreaux and Sokoloff 2005) that characterised the Fordist model of development, and the great socialisation and formalisation of innovative processes that followed: collective research teams, an increase in education and codified knowledge, standardised procedures for the evaluation of project costs and benefits, and routinisation of research. Although with national, sectoral and territorial variations – often neglected – during the twentieth century the growth of corporate research (i.e. the laboratories of large industrial companies), universities and public funding led to a downsizing of the role played by individual inventors on the one hand and of the technological innovation 'market' on the other.

In fact, the social and professional figure of the inventor came to the fore during the nineteenth century, following the advent of the industrial revolution and the institutionalisation of a market for technological discoveries. A large part of the increase in productivity seen in England in the late eighteenth century is linked to the progressive improvement of technology applied to the production process. Historian David Landes (1969) describes the industrial revolution as a complex mix of innovation that transformed an economy based on agriculture and artisanship into one dominated by industry and the machine. Those were years that witnessed the introduction of the factory system and the invention of new materials that made it possible to expand the range of products available: iron, for example, gradually took the place of wood. Two aspects deserve to be highlighted. Machines were employed in the activity of production, increasingly replacing artisanal skills. In addition, the toil of men and animals was alleviated by the use of inanimate energy sources: fossil fuels and the steam engine. Technological innovation, in other words – that is, the growing use of new knowledge in the production process – was one of the most distinctive features of the new industrial society.

The invention of the steam engine well embodies one of the founding myths of this 'industrial modernity': faith in limitless progress driven along by science and technology – the idea that human creativity would pave the way for a growing dominance over nature and a decisive improvement in human living conditions. Although intellectual curiosity and the creative effort of gifted individuals can be detected behind the invention of the steam engine, it is difficult to ignore the constellation of interests and the collective commitment that formed the background to each stage of the discovery process. The introduction of the steam engine was, in fact, linked to the need to solve a practical problem that was hindering Britain's further development – that of pumping water out of coal mines. Towards the end of the seventeenth century there emerged a huge demand for fossil fuels. Due to the massive deforestation caused by the use of wood for both private heating and productive activity, coal became one of the biggest alternative energy sources for the nascent British industry. This entailed the need to dig deeper mine shafts and solve the problem of draining the water that formed therein.

In the second half of the seventeenth century, several inventors had already started using steam energy to build mechanical systems to extract water from wells. The first pump for domestic purposes, based on steam pressure, was invented by Thomas Savery and patented by him in 1698. Subsequently, in 1712, Thomas Newcomen developed the first engine designed for use in mines. Only 50 years later, in 1765, did James Watt make a fundamental improvement – a separate steam condenser – that made it possible to reduce the cost of steam engine use by three-quarters. The new system – patented in 1769 – was the origin of the famous firm Boulton & Watt, which, founded a few years later, continued to operate until the early nineteenth century. In 1783 Watt built a new version of the engine based on a rotary rather than a reciprocating motion, which allowed steam power to be used far more extensively. It was an immediately popular solution. Of the approximately 500 examples produced by Boulton & Watt, over 60 per cent were of the rotary type, and most of them were absorbed by the textile industry, which in those years was the beating heart of the industrial revolution (Furfery 1944, 148). Later, in the early decades of the nineteenth century, other inventors applied the steam engine to land transport, building the first locomotive and laying the foundations for a modern railway system.

The history of the steam engine is a good illustration of two elements: its discovery is linked to a complex socio-economic dynamic; and James Watt's invention follows a socio-cognitive development of a supra-individual kind. His steam engine was the latest in a long series of other inventions, developed over more than a century by a number of particularly creative and industrious figures. In other words, *invention does not take place everywhere*, but rather in specific areas and contexts, and is not produced as the work of an isolated individual. But *it is not created by just anyone* either: it requires the knowledge, passion and determination of specific figures. Many of the technological breakthroughs that have altered the contours of our modern age derive from the work of men of great talent; yet these men have been making good use of *already available* knowledge and mechanisms, often by improving upon existing designs (ibid., 152). In doing so, however, they have sometimes produced innovation of a fundamental kind. The best discoveries – as Isaac Newton stated[1] – take place on the 'shoulders of giants': many inventions, although produced by one individual (or a few individuals), are the result of a collective, and not merely an individual, endeavour.

2.3 The 'discovery' of inventors

But who were the main figures involved in the technological innovation that accompanied Britain's industrialisation process? As the chronicles of the time make clear, most invention came from *operatives*, i.e. people belonging to the working class (MacLeod 1999). These were mainly artisans and skilled workers, or foremen, supervisors and managers employed by a company. Some of these inventors were able to achieve substantial improvements in their conditions of employment: wage increases, profit sharing, even shares in the company. Most of the time, however, patenting costs and lack of adequate funds did not allow workers to adequately exploit their discoveries.

Although many of the 'first' inventors were employees, the era that started with the first industrial revolution and continued until the beginning of the twentieth century has rightly been portrayed as the '*golden age*' *of the independent inventor* (Hughes 2004). The emergence of inventors as an independent social group which followed an auto-entrepreneurial logic, was based on the institutionalisation of a real market for technological innovation and is intertwined with the history of patent systems. British patent legislation is the oldest in the world: its origins are rooted in the grants of rights on the part of the Crown. They were first established in 1624 with the *Statute of Monopolies* (Dutton 1984; MacLeod 1988). In the first half of the nineteenth century, in the UK, a market was already established for the purchase of technological innovation that had been developed by independent inventors (Dutton 1984, 122–49). However, it was only in the second half of the century – alongside the explosion of an intense debate concerning the patent system (the so-called *patent controversy*) – that a process of patent simplification and cost reduction was started in order to facilitate their use by elements of the working class, and to strengthen the contractual capacity of 'ingenious workmen' (MacLeod 1999).

In fact, uncertainty about the possibility of enjoying the benefits of their inventions made employee workers and artisans unwilling to reveal their findings. They feared their inventions would benefit their employers rather than themselves, given that it was the employers who possessed the means to develop and patent innovations. The reform of the British patent system was also inspired by the American example. In the US in the first half of the nineteenth century, a large market of technological knowledge had been established. Since the drafting of the constitution, and through several successive reforms, the US had created a particularly effective mechanism for protecting intellectual property. The American patent system also had very low access costs in comparison to Europe (Kanh and Sokoloff 2004). It was, moreover, based on more transparent procedures that guaranteed the ownership of the patent exclusively to those who were actually responsible for an innovative discovery (i.e. the *first and true inventors*). Furthermore, its provisions covered inventions from anywhere in the world. The invention was certified by the prior examination of a technical committee, which ascertained its innovativeness and lawfulness. The vast majority of European countries, in contrast, employed a registration system that only required formal verification of the correctness of administrative procedures.

The American system worked well and considerably reduced the transaction costs of technological innovation. Rigorous verification of the invention's originality, together with effective protection of the rights related to intellectual property, greatly reduced uncertainty regarding a patent's value. This in turn facilitated funding for the inventor's research and, above all, the commercialisation of their discoveries. Despite the delay in the process of industrialisation, the number of patents per capita in the United States in the early years of the nineteenth century exceeded that of Great Britain, and trade in technology patents reached far greater levels than in European countries (Lamoreaux and Sokoloff 2007, 5). The system also encompassed the working classes. Studies carried out on samples of patents granted at the beginning of the nineteenth century show that the social background of inventors was quite varied in the United States, and the percentage of those from the socio-economic élite much lower than in Britain (Khan and Sokoloff 1998). Even the typical profile of the 'great inventor' – a figure responsible for the most significant discoveries – is marked by his lack of formal education and modest social background (Khan and Sokoloff 1993, 2004).

With the increase in technology transactions, the number of specialised professionals operating in the field of patents grew rapidly. These professions expanded to include journalists and publications dedicated to the subject; lawyers specialising in the protection of intellectual property; and consulting agencies and intermediaries to assist inventors with the submission of their applications and the marketing of their licences, etc. In the US, therefore, the increasing mechanisation of production and the creation of a modern patent system encouraged the institutionalisation of a real market for technological innovation and, alongside this, the emergence of a *social group of independent inventors*: that is, professionals specialised in research who, through patenting their discoveries, could earn an income and often create a path of upwards social mobility for themselves.

The number of patents surged from the 1840s on, and continued to increase until the end of the century. At the same time there were a growing number of inventors who specialised exclusively in research and patenting. The number of inventors who managed to take out ten or more patents during the course of their careers (i.e. specialised inventors) rose from 3.5 per cent at the beginning of the nineteenth century to 35.9 per cent by the end of it. By contrast, those who took out only one patent (i.e. occasional inventors) fell from 51 per cent to 19.5 per cent (Lamoreaux and Sokoloff 2007, 10, Table I.1). The way in which inventions were used also changed. In the early years of the nineteenth century inventors often exploited their discoveries directly, by founding new companies. In some cases – and as a complementary activity – they marketed their patents on a limited scale, licencing them in regions other than those in which their own businesses operated.

The second half of the century, however, witnessed the growing *professionalisation* of the figure of the inventor. There was not only an increase in the number of those who specialised in inventive activity, there was also a rise in the commercialisation of patents. On the one hand, inventors became more skilled at mobilising ex ante funding for their research in exchange for the granting of rights to future discoveries; while on the other they became more willing to sell rights to companies with which they did not have a stable relationship (ibid., 6–7). So, in the nineteenth century – and especially in the US – a professional group of independent inventors began to take shape. These were figures who specialised in research and 'discoveries', entrepreneurially deft in the technology marketplace, and showing – especially the most productive of them – a high level of geographical and contractual mobility thanks to the legal protection obtained for the results of their ingenuity. There was a dense agglomeration of such activities in the more economically developed regions of the north-central Atlantic coast (ibid.), with the great inventors tending to operate mainly in the southern part of New England and New York State (Khan and Sokoloff 1993).

But the beginning of the twentieth century saw the golden age of independent inventors fall into decline, in the United States as well as elsewhere. Their autonomy became rapidly reduced as they began to establish long-term and exclusive relationships with certain companies, to whom their ideas would be 'sold'. This was a very varied kind of process, however: in the north-east inventors accepted employment in large companies, while in the Midwest they tended to create their own enterprises or, more frequently, go into partnership with companies that made use of their discoveries. This territorial variability was related to differences in the institutional context of the various states, particularly with regard to local financial market conditions. In the north-east there was a vigorous hierarchisation of access to venture capital, with the main stock market in New York favouring larger, more established companies. In contrast, in some smaller Midwestern cities, such as Cleveland, the presence of a vibrant local market of venture capital, with local investors willing to support new technology companies, conferred a greater slice of entrepreneurial autonomy to persons endowed with inventive talent (Lamoreaux and Sokoloff 2005, 27–30; 2007, 15–18).

Besides these regional variations, however, the fact remained that from the early years of the twentieth century the number of independent inventors was shrinking, and with them the number of patents (Schmookler 1957; Lamoreaux and Sokoloff 2005). In parallel, the role of the *employee inventor* expanded, with an increasing amount of research being carried out by highly educated staff working for large private or public organisations. This is not to say that independent inventors vanished altogether – far from it. In the early fifties in the US they still made up an estimated one-third of the total (Schmookler 1957, 325, Table 2). The first decades of the twentieth century, however, saw a substantial change in the social organisation of invention. Science and technology played a more important role in development and became more receptive to economic requirements. The production of new knowledge became more directly connected to decisions made by actors responding to market stimuli (Rosenberg 2007, 80). Companies, especially the larger ones, began investing in research, creating *large industrial laboratories*. This new organisational set-up saw its first applications in the German chemical industry of the late nineteenth century, but the model was subsequently applied extensively in the US. In part this was also the result of particularly strict antitrust legislation, which pushed US companies to merge and intensify their innovative efforts to beat the competition.[2] Large diversified companies such as General Electric and DuPont in the chemistry field, IBM in data processing systems, Westinghouse in the electricity sector, and General Motors in the automobile industry, are the best-known examples of companies that became leaders in their respective industries through a process of massive investment in R&D. Their laboratories were used to test a wide range of innovations, using large amounts of capital raised from private investors (Lamoreaux and Sokoloff 2007, 19).

The emergence of industrial research had important consequences not only for new technology, but also for the scientific advances that, in some cases, resulted from these activities. The best-known example is provided by Bell Labs. From 1925 Bell Telephone Laboratories (Bell Labs) – owned by the American Telephone and Telegraph Company (AT&T) and Western Electric (the manufacturing arm of AT&T) – was actively involved in research that achieved considerable success. Bell Labs' primary task was to produce systems and equipment for telecommunications, which would then be marketed by AT&T – but it was also engaged in basic and applied research. These activities resulted in many technological innovations (e.g. the fax, sound film, long-distance transmissions, and so on). A number of truly revolutionary discoveries were made (in the fields of radio astronomy, laser technology, information theory, software operating systems, etc.), bringing a total of seven Nobel prizes to company employees. Bell Labs became best-known for its invention of the transistor, a device which opened the way for the miniaturisation of electronic circuitry. In years to come this would revolutionise the world of electronic devices and computers. The invention was developed in 1947 by three researchers at Bell Labs – John Bardeen, William Bradford Shockley and Walter Houser Brattain, who were awarded the 1956 Nobel Prize for Physics.

But industrial laboratories not only carried out research, they also provided companies with the necessary skills to explore the knowledge being produced by the scientific community, and to monitor any possible repercussion on the market. Scientific and technological research was also carried out in universities and research centres funded by the government or other private philanthropic institutions (the Rockefeller, Guggenheim and Carnegie foundations in the USA, for example). Public and private-social funding was another major force that influenced the direction and intensity of inventive activity in the post-war period. This was especially so in areas where public benefit heavily outweighed any possible private gain. In the United States in the early fifties, for example, the federal government reached the point where it was financing more than half of the national investment in R&D (Lamoreaux and Sokoloff 2007, 19; see also Chapter 5 on this point).

The emergence of large private and public research techno-structures cast a shadow over the social figure of the inventor and the generative mechanisms of invention. Studies focused on large research organisations and on economic and organisational aspects: funding, the division of labour, knowledge specialisation and the economies of scale of the research – in other words, on the 'visible hand' of the organisation and the pre-eminence of the large public and private techno-structures in scientific and technological innovation.

From a theoretical point of view, moreover, 'knowledge' was conceptualised by economists as a pure 'public good', characterised by high costs of production and low costs of reproduction and circulation: i.e. a good that would be difficult to be regulated through market rules and incentives. This aspect, it was believed, disincentivised private actors – especially smaller ones – from investing in research, due to the low appropriability of its results.[3] An emblematic case of 'market failure', then, that justified intervention in research activity, first, by public institutions (Arrow 1962) and, second, by large diversified firms (Nelson 1959), with a clear distinction between 'public' and 'private' knowledge: the 'scientific community' – based mainly in universities and driven by reputational incentives – promoted open knowledge and the free circulation of research results; while the 'technological community' – based in private companies and driven by economic incentives – promoted proprietary knowledge, through secrecy and patent protection of inventions (Dasgupta and David 1994).

Other authors have pointed out different reasons for the spread of the great industrial laboratories. David Mowery, for example, notes that it was not the lack of private appropriability of results that led to a push towards the corporatisation of research. The reasons must rather be sought in the special characteristics of industrial know-how and the difficulties encountered in the negotiation and implementation of market contracts (Mowery 1983, 351). First, Mowery draws attention to the high specificity of industrial research which, to be useful, must be closely integrated with productive activity and adapted to the specific needs of individual companies. Second, he emphasises the need for the latter to have a high provision of human capital to monitor and exploit knowledge arriving from the outside. And third, he indicates difficulties relating to the definition and enforcement of research contracts awarded to third parties in order to ensure the confidentiality of the results. In short, the need to provide adequate internal *absorptive capacity* (Cohen and Levinthal 1990) – together with the high transaction costs associated with the use of the market – induced companies to internalise much of their strategically valuable research. This did not completely rule out the use of external agencies, but rendered their use more limited.

Mowery, in fact, detects the presence of a dualistic structure in American industrial research throughout the first half of the twentieth century. In addition to the companies' internal laboratories, numerous private research institutes sprang up (about 350 in total) which came to employ up to 5,000 researchers and engineers (Mowery 1983, 353). A relationship of great complementarity was formed between these two sectors. The research institutes specialised in routine, standardised activities (such as materials testing), exploiting the economies of scale to be had. These institutions catered to a wide range of industries, offering generic services that did not require cognitive input tailored to individual companies. In contrast, company in-house laboratories specialised in more complex and strategic projects that were tuned to their own particular needs – *firm-specific*, in other words. The difficulty and idiosyncratic nature of such projects made it difficult to use external institutions or to determine appropriate contracts under which they might be carried out: the activities required to achieve the outcome of the projects presented a high level of uncertainty in terms of success and were (in formal contractual terms and conditions) difficult to define *ex ante*. Given the specialised nature of these services, the supply structure was far from competitive and, in the event of counterparty default, objective difficulties arose in enforcing agreements. As the economic theory of transaction costs showed, all these factors made the use of the market difficult, since they exposed both parties to the high risk of opportunism – in other words, to non-compliance with established agreements.

Other research carried out by economic historians, however, seriously challenged the idea that the corporatisation of research, at least in the initial phase, could be attributed to these factors. The studies of Lamoreaux and Sokoloff (1997), for example, show that during the nineteenth century companies were perfectly able to use the market for these kinds of transactions. That said, they did for a long time have problems in regulating relations with their staff with regard to the discoveries that they made – as is evidenced by the many disputes that arose between the two parties concerning patents. To ensure that inventions made during working hours were assigned to the company, they resorted to specific employment contracts that contained detailed provisions. Prior to this, however, they had to legitimise the idea that discoveries made in the workplace were the exclusive property of the company. This involved a huge set of difficulties: overcoming worker resistance; limiting the mobility of 'ingenious' employees; obtaining their cooperation in the event of discoveries (e.g. informing the company), and so on.

In short, then, even the in-company (*intramuros*) organisation of inventive activity and research required a complicated process of negotiation and regulation. Contrary to the argument put forward in much of the economic literature, 'Economic actors at that time had a great deal of experience with contracting for new technological ideas in the market; what they did not know how to do, and had to spend a great deal of time and energy learning, was *managing creative individuals within the firm*' (ibid., 51, my italics). These difficulties in regulating *intramuros* inventions – related to the organisational costs and conflict over intellectual property rights – were not only present in the American case, but also in the British one, where the external technology market was developed on a much smaller scale (MacLeod 1999).

In brief, entrepreneurs had to convince *independent inventors* and *employee inventors* that cooperation with the company would carry less risk and healthy economic opportunities. The basis for this organisational breakthrough developed between the late nineteenth and early twentieth centuries at the precise moment when technological innovation was becoming central to certain sectors (e.g. communications, transport, electricity, iron and steel, the chemical industry etc.); and at a time when its economic and organisational costs were starting to grow. The increase in resources required and the uncertain outcome of projects at the frontier of technology thus tended to redirect the preferences of all those involved in innovation activity, i.e. the *entrepreneurs*, the *financiers* and the *inventors* themselves.

Technological innovation was becoming increasingly *capital intensive*. This provided a competitive advantage to those large companies that were beginning to organise and diversify their own research, and to embark upon a number of projects entrusted to their own in-house technical staff. This created the socio-organisational structure that, in the private sector, led to the *institutionalisation of the employee inventor*. In this way, large companies became privileged collectors of both the human and economic capital required for innovation. They were able to attract independent inventors (who saw an opportunity to continue their research in what were often well-funded industrial laboratories), and to create a job market for the technico-scientific figures produced by the university system. But they also attracted financiers, who felt better protected in this environment than in investing in high-risk individual projects carried out by small companies or independent inventors.

The growth of these huge industrial techno-structures was not, however, without its drawbacks. Research found itself hampered by *a process of bureaucratisation* that in many cases limited the ability to make truly innovative discoveries or failed to exploit them to their full potential. One classic example was Xerox PARC in Palo Alto, a research centre located at Stanford University and funded by Xerox, a leading manufacturer of office machines (photocopiers in particular). Founded in 1970 and endowed with great human and financial resources, in its first five years the centre produced a number of high-impact discoveries: the first prototype personal computer; the mouse; icons and drop-down menus; local area networks; and the laser printer. Xerox, however, only commercialised this last innovation, leaving the rest to be exploited by other companies. The whole story is told in a book with a highly significant title: *Fumbling the Future: How Xerox Invented, and Then Ignored, the First Personal Computer* (Smith and Alexander 1988).

As has been noted, the geographical and cultural distance of the Californian laboratory from its parent company (which had its headquarters in Connecticut) meant that many revolutionary innovations were undervalued by Xerox's management, who saw the company as one that dealt exclusively with photocopiers. The hierarchical model of the management team also clashed head-on with the informal and horizontal organisational set-up at PARC. The west coast style of life and work of the creative staff served to hinder the transfer of technology to the parent company on the east coast (Rogers 2005, 155). However, Steve Jobs of Apple Computer – who visited Xerox at the end of 1979 – was very impressed by the potential he saw in the PARC research team, and hired several of them himself. In 1985, after five years of further research, Apple launched the Macintosh – an innovative personal computer for business purposes – on to the market. It was a huge success.

Most of the time, however, the problems that arose in industrial laboratories were of a different type. Routinisation of research, management imposition of greater constraints and financial controls (including making cost-benefit assessments of the various projects under study) progressively tended to reduce the ability of corporations to carry out truly cutting-edge projects. This is the argument put forward by William Baumol, who says that most of the key innovations produced during the twentieth century were the work of independent inventors or of small- and medium-sized companies.[4] There did exist, however, a strong complementarity with the large companies. With a few rare exceptions, the large companies were not responsible for fundamental innovation; rather they carried out the subsequent (significant and indispensable) work of developing and fine-tuning products to make them commercially viable (Baumol 2002, 2004).

Most research conducted in the US is carried out by large companies. In early 2000, private companies accounted for almost 70 per cent of the expenditure on R&D, with 46 per cent of these funds coming from just 167 huge companies (those with 25,000 employees or more). This rises to 80 per cent with the addition of the approximately 2,000 companies who employ more than 1,000 workers (Baumol 2004, 10–11). According to Baumol, however, most of the big laboratories are responsible for routine activities and incremental innovation. Post-World War Two studies show that about 80 per cent of the funds for industrial research are used to *improve* existing products (Rosenberg 2007, 84). Such figures enable the conclusion that although the majority of R&D is carried out by large companies, most of the truly innovative activity is the prerogative of medium- and small-sized firms (Baumol 2004, 14).

Baumol cites studies conducted by the US Small Business Administration into the most important innovations introduced by small businesses over the course of the twentieth century. These include the aeroplane, FM radio, the helicopter, the pacemaker and the personal computer. The studies also highlight the high patent productivity and greater innovative impact of small- and medium-sized companies (up to 500 employees) compared to larger ones: the probability that the former will take out highly innovative patents (1 per cent of the most-cited patents) is twice that of the latter (ibid., 15–16).

These studies, however, must be placed in context, and against a background of transformations that have affected the most advanced economies and specific productive sectors. With the advent of post-Fordism and the knowledge economy (Snellman 2004; Rullani 2004) the role of small- and medium-sized companies regained momentum – first in traditional sectors (involving incremental innovation), and then in high-tech sectors and the field of more radical innovation. Examples include development in the areas of telecommunications, IT, personal computers and biotechnology.

The number of venture capitalists who have been willing to support highly innovative companies has grown in more recent times. Independent inventors and the innovation market have thus, once again, begun to attract scholarly attention. In many areas large research laboratories have been downsized, while small firms specialising in research in cutting-edge activities (notably the so-called technological start-ups) have mushroomed. Such companies have gone on to sell the rights related to the intellectual property of their discoveries.[5] And so patenting activity, and market transactions involving technological breakthroughs, have taken off once again (Lamoreaux and Sokoloff 2007, 35).

This evolution brought about a reorientation of studies on innovation, which today focus more on its relational dimensions, with interest tending to concentrate on the flow of information and territorial agglomeration of innovative companies. The creation and learning of new knowledge are seen as collective processes based on interaction between companies and institutions in specific geographical areas (Silicon Valley being the classic example[6]).

From a theoretical perspective, highlighting tacit aspects of knowledge, information asymmetries, and the complexity of innovation processes tend to reduce the emphasis previously placed on the low appropriability of research results. There is now more stress on the fact that knowledge, including public knowledge, requires a capability of use that encourages private actors to invest in R&D, to enhance the 'absorptive capacity' of knowledge and of the information produced outside individual companies (Cohen and Levinthal 1990). In addition, changes occurring in the cognitive bases of some sectors – especially those related to information technology, life sciences and biotechnology – involve increasing integration between different types of knowledge, as well as between companies and universities. The boundaries that once separated the scientific community from the technological community, and 'academic inventors' from 'company inventors', have thus tended to become less rigid.[7]

After the transformation inspired by Schumpeter in the middle of the last century, we now have another – both factual and analytical – sea change in Innovation Studies. The *locus of innovation* alters once again, passing from the innovative entrepreneur, through the great innovative companies, to the *social and territorial systems of innovation*. The importance of the relationship between economic enterprises and 'non-economic' institutions is thus brought to light. The role of the inventors, however, remains in the shadow. Inventors, who became invisible during Fordism, only partially emerge as subjects to be studied in the subsequent phase of post-Fordism.

As we shall see in the next section and in Chapter 3, creative individuals and inventors have been the subject of several studies, not always with very satisfactory results. The literature has contrasted individualistic and holistic approaches, projecting an 'undersocialised' and 'oversocialised' vision of inventors. They have been studied as 'creative individuals' and 'men of genius', with reconstructions of their biographical journeys and personal and social characteristics. Conversely, they have been analysed as the mature and inessential fruit of historical circumstances. They have also been seen as 'actors of an innovation system', in order to understand how modes of governance, organisational culture and incentives provided by universities and host companies influenced their inventive activity and capacity to patent. The social dimension that permeates discovery processes has, however, often been overlooked. Even when networks of collaboration have been analysed, the processual dynamics that link inventors to their research groups, and to the contexts in which they operate, have been little investigated.

The analysis of inventive activity, on the other hand, requires an integrated perspective of analysis that is capable of seeing invention as the outcome of a complex process of social construction.[8] The paths that lead to the discovery of something new are, in fact, highly socialised. They are the result of effort not only by single individuals or companies, but of effort that is collective in nature – effort that varies according to technology sectors, territories and different forms of *social embeddedness*. The analysis of the generative mechanisms of innovation requires, then, an interdisciplinary approach. In the remainder of this chapter, and in the chapter that follows, the focus will therefore be on the topics of creativity and invention, reviewing contributions from a variety of disciplines. To start with, the next section presents some studies from the field of social psychology.

2.4 The psychology of creativity

What is meant by creativity? In social psychology studies, reference is made to a specific skill: *the ability to generate new and appropriate products or ideas* (Sternberg and Lubart 1999, 3; Hennessey and Amabile 2010, 570). In other words, it is the ability – individually or in groups – to develop original solutions that are proven to be useful, or at least influential (Mayer 1999). The presidential speech given in 1950 by Joy Paul Guilford (1950) at the American Psychological Association (APA), marks the official start of a specific line of research on this subject – one that had hitherto been neglected by the theoretical approaches prevalent in academic psychology, in particular those of a behaviourist kind.

In reality, some ideas had already been developed, but in the context of non-mainstream approaches. The psychology of form (*Gestaltpsychologie*), for example, had devoted some attention to certain aspects of creativity, such as *insight* (intuition/illumination), considering it as an adaptive response to situations perceived as unusual. In particular, *Gestalt* psychologists identified two styles of thinking employed in different conditions. When faced with routine problems, *reproductive thinking* prevails: a way of thinking that applies solution procedures that have already been tried in the past. Conversely, when unusual problems emerge, for which no ready-made solutions exist, *productive thinking* – a form of creative reasoning – can take over (Mayer 1995). On the basis of experiments conducted on the perceptions and responses provided for practical or mathematico-geometrical dilemmas, *Gestaltists* defined insight as a phenomenon of sudden and discontinuous learning, resulting in a restructuring of the cognitive field in the face of situations perceived as problematic. In short, creativity involves the ability to analyse data deriving from external reality in an original way, reorganising the properties of phenomena in order to provide a more appropriate behavioural response to the problematic situation (Rossi and Travaglini 1997, 18–21).

In the psychoanalytic approach, on the other hand, creativity is attributed to impulses with a strong emotional value for the subject (Sternberg and Lubart 1999, 6). Creative thinking is a way of expressing unconscious desires in socially acceptable forms through an activity of sublimation that finds its most obvious manifestations in artistic phenomena or in the work of great inventors and artists such as Leonardo da Vinci – to whom Sigmund Freud devoted a famous essay (1910). At base, there is the ability of certain individuals to exploit the regressive tendencies of the ego in functional forms, allowing desires and the deepest kind of psychic energy to flow freely at a conscious level. This makes it possible to satisfy latent impulses by reconciling the two principles of reality and pleasure (Rossi and Travaglini 1997, 59–62).

It is only from the fifties on – after the official legitimisation bestowed by Guilford's speech – that research on creativity began to develop in a more organic way. This took place at the height of the Cold War. It is no coincidence that a book containing the proceedings of three conferences held between 1955–59, and dedicated to the question of the 'identification of creative talent in the scientific field', opens with an essay written by a White House advisor. The essay in question explicitly links studies on creativity to economic, technological and military competition with the Soviet Union – a competition, according to the essay, that in the long run will be decided by the supremacy of scientific knowledge and the ability to use the greater number of its citizens in applying the creative work of science (Golovin 1963, 22).

At first, psychologists sought to study creativity as an aspect of individual personality, measuring it with tests used for intelligence. In the early sixties, however, it was shown that intelligence and creativity traits were – to a large extent – independent. Creativity presupposes a certain level of intelligence (*threshold theory*), but this in itself is not enough (Sawyer 2006, 44). Guilford had in fact, in his first essay (1950, 447), already pointed out that the usual systems used to measure individual IQ did not identify creative abilities. Intelligence tests measured, above all, what academics would later define as *convergent thinking*, a mode of reasoning that exploits the logico-rational capabilities of the human mind to find the correct answers to the questions put by the researchers. At the basis of creativity, however, lay *divergent thinking*, which seeks to determine not the *one right answer* to a question, but rather the *number of potentially viable solutions* (Guilford 1967).

Indicating the mental abilities that recur in creative subjects, Guilford specifically refers to 'the scientist and the technologist, including the inventor', assuming that different types of creativity exist and that the underlying cognitive abilities might be different for various fields of activity (Guilford 1950, 451). Subsequent research identified the main dimensions of divergent thinking (Mumford 2001, 267–9): (1): *fluency*, the ability to generate a large number of ideas quickly; (2) *originality*, the ability to provide new answers – unusual perhaps, yet still acceptable – in situations where one single answer is not possible, and; (3) *flexibility*, the ability not to become embroiled in a single pattern of reasoning and instead to be able to take alternative models into consideration.

That said, Guilford also takes into account other issues that influence the various stages of the creative process: the 'upstream phase', for example, is affected by individual sensitivity towards the discovery of problems – the variable capacity to perceive dilemmatic situations worthy of further investigation; the 'ideation phase', the ability to analyse situations and synthesise various solutions and the degree of complexity of the conceptual structure that the subject is able to elaborate; and, finally, the 'downstream phase', the ability to evaluate and refine the solutions generated, subjecting them to the selective evaluation of critical reasoning.

Guilford proposes appropriate tests for each of these aspects, with the aim of measuring divergent thinking. The novelty introduced by the American scholar is in fact the idea that creativity can be studied in ordinary people – and not exclusively in so-called 'geniuses' – using a psychometric approach (Sternberg and Lubart 1999, 7). Guilford also believed that intellectual and creative abilities could be improved through special training processes (Rossi and Travaglini 1997, 36–7). This led to the design of a number of tests and scales for the comparative assessment of individual creativity. The best known are the *Torrance Tests of Creative Thinking*, which were used for over 40 years to assess divergent thinking ability among individuals (Hennessey and Amabile 2010, 570). Despite their success, and the popularity gained from educational creative thinking programmes, this type of study also attracted a great deal of criticism. Mental abilities indicated by Guilford were deemed unsuitable for defining and delimiting the concept of creativity. It was also claimed that, given their sectoral specificities, the tests proposed to evaluate them were inadequate (Amabile 1983; Baer 2008; Mumford *et al*. 2008). This first wave of psychometric studies and, more generally, the personality studies that were so very fashionable during the sixties, lost momentum over the following decades as other approaches gradually came into favour.

From the seventies on, cognitive psychologists – winning out over the old schools of behaviourism and psychology of the personality – opened a new phase of studies. This involved in particular the analysis – through both research on people, and using computer simulations – of the mental representations and cognitive processes underlying creative thinking. One argument put forward was that creativity emerged from the normal mental procedures used in everyday activities. Studies by Weisberg (1993), for example – based on laboratory experiments and research carried out on highly creative people – showed that insight is derived from the use of conventional cognitive processes that exploit knowledge already stored in the memory. Creativity, in other words, involves 'ordinary' cognitive processes that lead to 'extraordinary' results (Sternberg and Lubart 1999, 8).

The first studies on creative processes provided some noteworthy results that brought such phenomena more clearly into focus (Sawyer 2006). Creativity: (1) is not a special mental process, rather it involves cognitive activities of an ordinary kind; (2) is not a distinct personality trait but derives from a combination of basic mental abilities; (3) is the result of hard work; (4) is specific to a field, and – contrary to the often held idea that equates genius with a sense of wild indiscipline – is associated with those who are well-balanced and successful in their own particular area. Research into personality also made it possible to define certain recurring traits possessed by creative individuals:

> high valuation of esthetic qualities in experience, broad interests, attraction to complexity, high energy, independence of judgment, autonomy, intuition, self-confidence, ability to resolve antinomies or to accommodate apparently opposite or conflicting traits in one's self-concept, and, finally, a firm sense of self as 'creative'.
>
> (Barron and Harrington 1981, 453)

These early studies, however, also served to focus on how psychology provides only *part* of the explanation; and how individualistic approaches, concentrating on personality traits, are insufficient for an understanding of creative processes (Sawyer 2006, 74).

Over the last three decades, studies regarding creativity have become highly institutionalised in the psychology field, and there has been a proliferation of journals and research topics. Until the eighties, studies tended mainly to focus on a few major issues – in particular on the relationship between personality, creativity and intelligence. In subsequent years, however, topics, methods of enquiry, and theoretical perspectives mushroomed, accompanied by a marked division of labour with compartmentalisation in specialised sub-sectors.[9] Some authors, however, attempted to build integrated analytical approaches that were open to interdisciplinary collaboration. This created more than a few opportunities for dialogue with sociology. In fact, psychologists began to study the social and cultural contexts of creativity, connecting them both with personal and motivational traits and with the processual aspects of these phenomena. Awareness gradually emerged that previous studies had tended to decontextualise and desocialise creativity; whereas creative individuals, even when working alone, are always in some relation of influence with others (Hennessey 2003, 181). Social dynamics, in fact, permeate the rules, motivations, knowledge and skills that – at both an individual and group level – condition creativity (Paulus and Nijstad 2003, 6).

The work of academic Teresa Amabile (1983) is emblematic of this new approach, starting with her simple definition of what being creative is: a product is creative when experts in a particular sector judge it to be so. Emphasis of the consensual and *domain-specific* nature of creativity opens up the possibility of a sociological perspective of analysis. In order for a 'creative intersection' to exist it is necessary to determine the convergence of a plurality of factors. The subject must possess: (1) specialised knowledge and abilities (*domain skills*); (2) specific abilities to generate new ideas, and to deal with complex situations and problems (*creativity skills*); and (3) appropriate motivations with regard to the objective being pursued (*task motivations*) (Hennessey 2003, 182). Several studies emphasised the centrality of the third factor, highlighting the variability of the motivations and their 'situational contingency'. The level of involvement and personal interest in the problem at hand represents an essential ingredient to explain the performance and the individual creative ability deployed in the execution of a task. These motivational aspects, however, are not only influenced by the individual's subjective characteristics and the objective nature of the task, but also by the socio-organisational context and the type of incentives provided.

Amabile (1983, 1996) identifies two types of motivation. *Extrinsic motivation* is linked to the achievement of some objective or external benefit other than that deriving from the work itself. This type of motivation is often related to sanctions or benefits distributed by an outside authority or organisational body (the market, an employer, an examination committee, a jury) and depends on an evaluation of the efforts or performance of an individual in executing a task.

In contrast, *intrinsic motivation* is connected to the interest and specific rewards that result from performing a certain task – it originates within the individual, therefore, and from the activity itself, rather than from the external environment. If a person feels interest in an activity and finds it stimulating because of the challenges it presents, then the probability of creative performance is increased. This type of motivation cannot be adequately replaced by economic incentives, sanctions or hierarchical control. Hence the idea develops that organisations must form an environment that is capable of engaging its members, offering tasks that interest them, and minimising control from above. In contrast, external pressures – such as rewards and objectives that are defined by superiors – tend to be associated with low intrinsic motivation. These will tend to limit creative performance. More recent studies, however, have shown that in the presence of strong subjective motivation, and in very specific contexts, incentives that are geared towards providing recognition of effort made and skills attained can increase extrinsic motivation without limiting intrinsic motivation, thus producing a positive influence on creativity (Amabile 1996; Hennessey 2003, 197).

These early studies analysed the motivational impact of the socio-organisational context in 'impersonal' terms. However, the various social environments influence the creativity and motivation of their components above all through the interpersonal relationships that are established therein (ibid.), giving rise to the recent trend of paying attention to the socio-relational dynamics that develop from the family, school and work experiences of the subjects. All this, however, without neglecting the influence of socio-cultural factors that act at a more impersonal level – such as different national and corporate cultures, etc. In these new approaches, therefore, the creative process is studied by linking individual characteristics to the various contexts of interaction, while also taking into consideration the social and cultural factors that shape them (ibid.). Frameworks such as these have therefore led psychological studies regarding creativity to increasingly assume a systemic perspective that is open to contributions from other disciplines (Hennessey and Amabile 2010, 571).

What has been defined as the 'socio-cultural approach' to creativity, for example, moves in this direction – aiming as it does to study creative people against the background of the different contexts in which they operate (Sawyer 2006). This is informed by the awareness that creativity incorporates a variability related to culture, society and historical epoch. Studies and definitions relating to creativity tend to oscillate between two different conceptions. On the one hand, there is what is commonly labelled as the 'big C': that rare and august kind of creativity that has a strong social and economic impact. On the other, there is the 'small c': that widespread form of creativity which is possessed to varying degrees by all individuals, and which is employed in everyday life to solve ordinary problems (Gardner 1993, 29). The socio-cultural approach refers to the former kind of creativity, which is conceived as 'a novel product that attains some level of social recognition' (Sawyer 2006, 27). To be innovative, an idea must not only be original but also appropriate – recognised, in other words, as socially valid within a community of reference.

Mihaly Csikszentmihalyi's systemic approach (1988, 1996) has made a fundamental contribution to this perspective. An academic of Hungarian descent, Csikszentmihalyi sees creativity not just as a psychological event, but as a social and cultural one as well. The creativity of a new product depends not so much on its intrinsic qualities as on the effect it has on others. In other words it requires public recognition, based on interaction between producer and audience: 'Creativity is not the product of single individuals, but of social systems making judgments about individual's products (Csikszentmihalyi 1999, 313). To understand creativity, therefore, one must also analyse the environment in which the individual operates, and this is composed of two elements: a symbolic-cultural aspect (*domain*) and a social aspect (*field*). More precisely, the creative process derives from the interaction of three elements (Figure 2.1): the person (source of innovation), the field (composed of experts of a creative field who select the ideas that are considered original and appropriate), and the domain (the area into which innovation, once it is recognised as such, enters and is diffused).

The domain consists of all products created in the past and all the rules and conventions accepted in a specific sector of activity. Creativity, in fact, without the sharing of certain specific conventions, is impossible. Innovation consists of the transformation of cultural practices in an appropriate manner with respect to the criteria recognised in a particular sector. Culture is composed of several domains (music, maths, religion, technological fields, etc.), each with its own

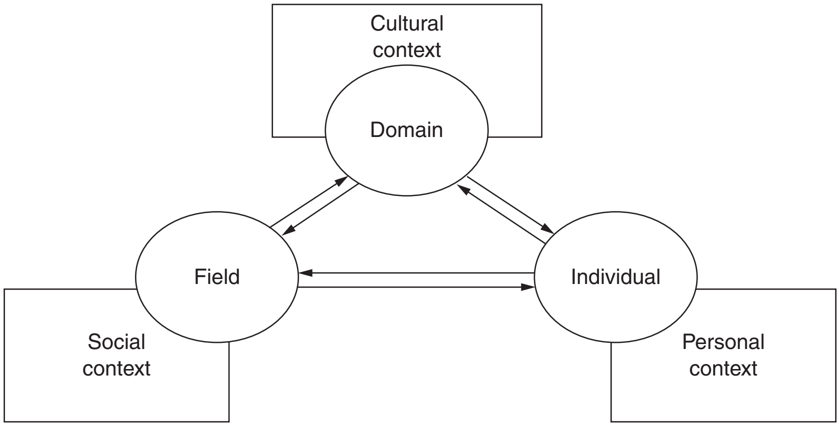

Figure 2.1 Systemic approach to creativity (source: adapted from Csikszentmihalyi (1999, 315)).

own rules, objects, representations and shared notation systems. The level of integration and of separation of the domains varies depending on the society and the historical epoch. Innovation takes place within each of the domains, thanks to the work of individuals who possess specific creative abilities.

Creative individuals make use of the information and knowledge in a particular field, introducing new ideas through the use of cognitive processes, personality traits and motivations that derive from both their own talent and their personal background (family, the social and territorial context in which they were educated and in which they work, etc.). The experts who make up the field – teachers, critics, the owners and editors of specialised journals, directors of theatres, museums, foundations that provide funding, etc. – represent the '*gatekeepers*' of a specific sector. They constitute a network of experts who have internalised the conventions of a domain and thus possess the shared criteria to evaluate and certify the creativity of a new product. In other words, they confer the recognition of novelty to a certain product and allow its diffusion throughout the relevant industry. After selection by the experts, the final acceptance test of the new idea comes from a wider audience, stratified according to a decreasing level of competence (Sawyer 2006, 126–7).

The levels of creativity present in a given area depend not only on the quantity of individuals possessing originality, but also on the characteristics of the domain and the field in which they operate. There are various ways in which the structuring of the sector affects the creative process: with regard to the domain, the clarity of its internal structure (i.e. the level of codification and integration of its constituent elements), its centrality within the culture of reference, and its openness and accessibility, are all important. As regards the field, it is essential to mention the level of institutionalisation and autonomy from other sectors, as well as its ability to attract social resources and to stimulate and implement the innovation proposed by the individuals who work within it. As we have seen, the first psychological studies analysed creativity as an aspect of the personality of particular individuals, neglecting the social dimension. Yet the latter permeates creative phenomena, both in the generative phase of new ideas and in the subsequent stages of their development – which pass through the dynamics of evaluation, elaboration and communication that take place within a specific sector. The socio-cultural approach goes beyond these limits, surpassing the individualist perspective and considering the social context in which the creative process takes place. This social dimension emerges even in a creation's most crucial and apparently individual stage, i.e. during *insight*: the moment when, quite suddenly, something new is discovered/created, when the solution appears to a long-considered problem. In this phase, a specific mental state is generated, involving a swift restructuring of the cognitive frame, with the emergence of an idea that is perceived as being able to provide a new understanding of a problem or phenomenon that has kept the subject busy for a long time.

Intuition has been predominantly studied in isolation, and as a cognitive process that takes place in solitude. Mihaly Csikszentmihalyi and Keith Sawyer (1995, 331), on the other hand, making use of research carried out on a variety of creative subjects, analyse it within a sequence of stages that structure the creative process, integrating the *intra-psychic* and *contextual dimension*: 'When we look at the complete "life span" of a creative insight in our subjects' experience, the moment of insight appears as but one short flash in a complex, time-consuming, fundamentally social process.' It is true that from the interviews the crucial moment of discovery emerges as a solitary moment, but these moments are inserted into a narrative that depicts the effort and dynamics that precede and follow the insight, and the overall significance of these *narratives of discovery* tends to emphasise the salience of social and interactional factors. The creative process is divided into four stages:

1 the discovery *preparation* phase, which involves intensive study and research into a problematic issue;
2 the discovery *incubation* stage, which develops during a period of inactivity when the individual is momentarily detached from work on that specific issue;
3 the *insight* stage, during which time the new idea emerges;
4 the *development* phase, which follows the discovery and involves hard work elaborating and evaluating the new idea in order to develop and fine-tune it.

This division into stages refers to the models developed in social psychology with regard to the processes of *problem-solving* (for a critical review see Lubart 2001). The sequence of stages, however, should not be thought of as linear: the creative process is composed of multiple loops and involves continuous feedback (Csikszentmihalyi and Sawyer 1995, 344).

The work upstream and downstream of the discovery is profoundly influenced by social dynamics. The preparatory phase is stimulated by external pressure and/or internal motivation formed in a specific domain. There is in fact no 'creativity quotient' as there is an intelligence quotient. Creative people are not creative in general, but are so in particular spheres of activity; creativity, as we have said, is *domain-specific*. *Preparation* thus entails a long phase of learning specific knowledge related to a particular domain, and learning what knowledge has already been produced on the topic on which the person is working. Creativity often, after all, consists of a new combination of *already-known elements*. Precisely because it is necessary to know what already exists, formal education does not hinder creative work – although it is often possible to note an inverted 'U' relationship: both a deficit and an excess of formal education may be detrimental, since they generate a shortage or a surplus of socialisation with the domain, thereby rendering individual thinking, conventional (Sawyer 2006, 60).

The *incubation* phase is also important. Many creative figures recount that their best ideas occur to them during periods of inactivity and idleness, when they are involved in doing something else. At these moments, the gestation work is, more or less unconsciously, carried out for the discovery that takes place in the central phase of the creative process: the insight stage. The 'discovery' however, is often preceded by a series of minor insights, related to the work being performed. In this respect – as Sawyer has observed (ibid., 71) – the crucial moment of insight is overvalued. The interviews reveal two generative models of discovery. The shorter *presented problem-solving process* occurs when the problem faced is already known within the domain; it is thus a matter of finding and organising the correct solution. The longer *discovered problem-finding process* is deployed when faced with problems that are less known and which may even become problematic thanks to the insight itself. This second mode is associated with paradigm shifts and the more significant kinds of discovery (Csikszentmihalyi and Sawyer 1995, 337).

As we have said, innovation is the ability to combine various types of ideas and information in an original manner. Thus, eminently cognitive and more or less conscious processes come into play. Analogical thinking is very important in scientific discoveries. New conceptual combinations often use metaphors and analogies that hail from different sectors and activities (Sawyer 2006, 266). Following a variety of projects therefore increases the possibility of *cross-fertilisation*. Creative people often work on a variety of partially overlapping projects. Particularly revolutionary discoveries (and insights) are based on the 'casual' convergence of ideas coming from different domains, usually facilitated by interaction with individuals working in different fields (Csikszentmihalyi and Sawyer 1995, 337). Subjects capable of radical innovation, therefore, frequently occupy a position on the boundary between different disciplines. This does not make them marginal figures, however: rather they are *field-switchers*, exploiting analogies and knowledge from different domains, since a greater number of ideas and basic concepts makes innovative combinations easier.

The ability to work and productivity also play an important role. Creativity requires a great many ideas that are then selected and combined with each other and for this reason the more productive subjects – i.e. those capable of generating a high volume of work – are in general also more creative (ibid., 161). Peaks of creativity vary according to discipline, but there is evidence that creativity tends to be continuous throughout life. Finally, the last phase – the development of ideas generated during insight – is a period of intense, fully conscious work that relies upon the specialised knowledge of the domain (Sawyer 2006, 68). The development and evaluation of the original idea always require modifications, adjustments and critical reconsideration. The social dimension emerges even more clearly in the *collective kind of creative dynamics* that are gaining a prominent place in this field of study. Nowadays, in fact, the most important forms of creativity are related to cooperative activities that involve complex networks of highly qualified experts. Creativity requires distributed knowledge – the integration of many creative workers specialised in different fields. The most creative groups have specific features. They are composed of individuals who have worked together for a while, who share knowledge and conventions, but who also possess complementary skills. Studies also show a certain variability related to the type of tasks they are faced with: the variety of knowledge present in the group is more effective when it is a matter of dealing with unfamiliar problems. In contrast, integration and shared knowledge are better suited to solving more conventional problems.

It is evident that, in order to analyse these forms of *collective creativity*, the individualistic approaches of traditional psychology are not very appropriate. For this reason, psychological studies dedicated to 'creative group' (John-Steiner 2000; Paulus and Nijstad 2003; Sawyer 2003), and 'work team' (West 2003) collaborations focus to a large extent on the socio-interactional dynamics and organisational aspects that favour or hinder collective creativity (King and Anderson 2002; for a review of recent studies, see Hennessey and Amabile 2010, 581–5). These areas of study represent fertile ground for interdisciplinary collaboration in which the sociology and psychology of organisations, the new economic sociology (which pays attention to social networks), and the psychology of creative groups can be integrated to explain the collective and *open source* innovative dynamics (which will be discussed in the next chapter): not only in artistic fields, but also in research teams and industry and service workplaces.

Box 2 Self-study prompts

1 What is meant by the 'golden age' of independent inventors?
2 Why did the figure of the independent inventor decline in the early years of the twentieth century and why did large industrial research laboratories become more prominent?
3 Why, nowadays, do we speak of social and territorial systems of innovation?
4 What is creativity and how can it be 'measured'?
5 What are convergent and divergent thinking?
6 What is the difference between intrinsic and extrinsic motivation?
7 What are the essential features of the socio-cultural approach to creativity?
8 What is meant by insight and what are the four stages of the creative process?

Notes

1 The actual remark attributed to Newton was: 'If I have seen further, it is only by standing on the shoulders of giants'. For a reconstruction regarding the origins and complex history of this aphorism, see Merton (1965).
2 The impact of US antitrust laws on the innovation system is explained in section three of Chapter 5.
3 For a definition of the concept of 'appropriability', see Chapter 5, section 4.
4 As will be seen in the next chapter, this is quite a controversial viewpoint. A number of studies have tried to estimate the level of 'innovativeness' of discoveries made by inventors working as part of a team, as against individually.
5 Even the famous Bell Labs – now owned by Lucent Technologies and Alcatel – has undergone drastic restructuring and downsizing in recent years.
6 Silicon Valley is a highly innovative area of the US, located in the southern part of the San Francisco Bay area. The area corresponds mostly with the Santa Clara Valley and has over four million residents in the metropolitan area of the city of San José. Its nickname derives from the intense concentration of industries related to computers and silicon-based semiconductors.
7 All these issues will be taken up and looked at in detail with the analysis of innovation systems in Chapters 5, 6 and 7.