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In search of the origins of novelty:
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IN SEARCH OF THE ORIGINS OF NOVELTY: EXPLORING NOVEL COMBINATIONS IN ALLOPATRIC SPECIATION

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ABSTRACT

Innovation theory tends to focus on the carrying of invention into innovation rather than the emergence of an invention itself. In evolutionary terms, innovation theory focuses on selection and retention rather than on the creation of new variety. This paper aims to develop an understanding of the mechanisms that generate variety. To do so, we will make use of the insights provided by the evolutionary concept of 'allopatric speciation' in order to inform us on how and under which conditions novelty comes about. We interpret this notion in the context of interfirm innovation networks and discuss the emergence of two new industries in the Netherlands, the multimedia industry and the pharmaceutical biotechnology industry. The empirical analysis indicates that novelty indeed originates in allopatric speciation, although how this occurs differs between the two industries.

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1. Introduction

In the organisational and economic literature there is a stream of thought suggesting that innovation proceeds according to a cycle with two stages. An initial stage of volatility, with the creation of Schumperian novel combinations, and a later stage of consolidation, with dominant designs (Abernathy 1978, Abernathy and Utterback 1978, Abernathy and Clark 1985) and efficient production systems that employ economies of scale and experience. The cycle is generally held to imply a shift from product to process innovations, as product forms settle down and competitive pressure shifts to efficient production. The life cycle theory of innovation has met with empirical contradictions. Often process innovation precedes rather than follows product innovation. A more fundamental objection is that that this cycle is not really a cycle (Nooteboom 2000). A genuine cycle leads back to the beginning. Innovation theory tends to focus on the 'working out' of novelty, towards a 'dominant design', neglecting the emergence of novelty. In other words, it focuses on the carrying of invention into innovation rather than the emergence of invention. The origins of novelty remain a mystery. It remains unexplained how the discovery process works. In the literature on innovation this issue is not addressed either. In the 'mainstream' approach of this literature, a deterministic stance dominates of an exogenous institutional structure that unilaterally determines learning and innovation (see e.g. Pavitt 1984, 1995, Dosi e.a. 1988, Lundvall 1992, Nelson 1993, Malerba and Breschi 1997, Mowery and Nelson 1999).

In evolutionary terms, innovation theory focuses on selection and retention rather than on the creation of new variety. Also, it neglects co-evolution, i.e. the possibility that outcomes of learning and innovation can substantially affect the selection environment of institutions and markets, causing it to change from within In terms of the three evolutionary mechanisms, most of these studies strongly focus on how selection processes take place but do not investigate how this relates to variety, nor how variety affects selection again. We consider that to be a major limitation in the innovation literature thus far. There is increasing empirical evidence that firms through path-creation strategies can also shape the institutional environment and exert considerable influence on the broader structure in which they are embedded (Mowery and Nelson 1999, Carlsson 2002, Gilsing 2003). So, we argue that firms are not only shaped by their institutional environment but are also shapers of this same environment.[2]

This paper aims to go beyond the selection bias as present in most innovation studies by developing an attempt to acquire an understanding of the endogenous origins of novelty in networks of firms. To do so, following Nooteboom (2000) we will make use of the notion of 'allopatric speciation' that originates from biological evolution and explains the origins and development of new species. In the context of technological change and innovation this notion of allopatric speciation may be useful in order to inform us on how and under what conditions novelty comes about. It also helps to explain the 'punctuated equilibria' in cycles of technical development postulated and empirically documented but not explained by Tushman & Romanelli (1985), Tushman and Anderson (1986), Gersick (1991) and Romanelli & Tushman (1994). To sum up, this paper addresses three issues:

- What does the evolutionary metaphor of allopatric speciation entail and how we can use it to develop an understanding of the endogenous origins of novelty?
- How does this work in practice and specifically in the context of networks of firms?
- How effective is the use of such a metaphor for understanding technological change and innovation?

The paper is built up as follows. In section 2 we provide a summary of a theory of learning as developed in earlier work by Nooteboom (2000). This theory entails a 'cycle of discovery' that goes beyond life cycle theory by explaining how exploitation is broken up and evolves into a next stage of exploration of novel combinations. A key element in this process is the evolutionary notion of allopatric speciation. We discuss where it originates from in biology and how it may possibly inform us in understanding the emergence of exploration from exploitation. We then discuss two case-studies of two newly emerging industries in the Netherlands that provide an illustration of how to interpret

[2] This goes back to Veblen who took an interactionistic stance in the sense that actor and structure interact and mutually condition each other to the degree that explanation based on either actor or structure alone are unwarranted : 'both the agent and his environment being at any point in time the outcome of the past process' (Veblen 1898: 391)

this notion of allopatric speciation in the context of interfirm innovation networks. In section 3 we discuss the multimedia industry and in section 4 we analyse the pharmaceutical biotechnology industry. Next, in section 5, we provide a further analysis of the differences between multimedia and biotechnology in how allopatric speciation occurs. Finally, in section 6, we draw a number of conclusions and reflect on the benefits and risks of using evolutionary metaphors for studies of technological change and innovation.

2. A cycle of discovery: the need for allopatric speciation in exploration

Nooteboom (2000) described a ‘cycle of discovery’ that does not treat innovation as an ‘exogenous shock’, like life cycle theory, but yields an elaboration of how change originates from within the innovation process itself. See figure 1.

(Insert figure 1 about here)

This cycle indicates how exploration and exploitation may build on each other. This distinction between exploration and exploitation goes back to Holland (1975) and was later further developed by March (1991). Exploitation can be characterized as routinized learning, which adds to the existing knowledge base and competence set of firms without changing the nature of activities (March 1991). This requires sufficient stability that is made possible because dominant designs have emerged and technological and market uncertainty have decreased. As a consequence, exploitation can be planned and controlled for, which is important as competition has emerged and considerations of efficiency have become crucial. In contrast to exploitation, exploration can generally be characterized by breaking with an existing dominant design and a shift away from existing rules, norms, routines, activities and so on, in view of novel combinations. Hence this type of learning is not about efficiency of current activities and can not be planned for. It is an uncertain process that deals with constantly searching for new opportunities (March 1991). Since exploitative and explorative learning are fundamentally different in nature, they may be difficult to combine and may need to be separated in time or place.

Before elaborating on this, we first provide a summary of how, according to the cycle, exploration and exploitation build on each other. Next we consider why they need to be separated and how this can be done. In exploitation, after an innovation has settled down into a dominant design, there are strong pressures to conform to it. There are psychological pressures to be an insider in dominant groups, and social pressures to acquire legitimation. Dimaggio and Powell (1983) argued that apart from effects of evolutionary selection of the most successful practice, there are pressures towards 'organisational isomorpism', by mimesis of established practices and conformance to norms, established by professional organisations, suppliers, customers, competitors and regulatory agencies, in an 'organisational field'.[3]

To escape from all these forces of conformism one may need to take refuge in an outside niche, where there is less threat to the integrity of existing systems, to gain opportunity to be different. This is consonant with the fact, in the history of technology, that initially innovations are developed not in areas where they could achieve their full potential, but in areas where they could be tolerated. A familiar manifestation of such escape is the 'spin-off' of entrepreneurial ventures from long established firms. Another is the move into a foreign country.[4] In the novel context (application, market, institutional environment), one runs into limitations of existing practices (processes, products). This generates motive for change, which at first is sought in proximate change, with minor adaptations, in 'differentiation', to maintain exploitation as much as possible. Next, if this does not suffice, the motive arises for more drastic change. Meanwhile, one has gained insight into similar or related processes or practices in the novel niche, which are seen to perform better in respects in which one's established practice seems to fail. This leads to 'reciprocation', where

[3] An example of such herd behaviour, or bandwagon effect, is the drive to engage in mergers and acquisitions, in spite of the fact that it is well known that they fail more often that they succeed.

[4] Nooteboom (2000) proposed that like crime discovery requires motive, opportunity and means. One needs an accumulation of unsatisfactory performance to generate motive, to overcome one's own inertia or that of others, in an organisation or wider institutional setting. One needs opportunity to deviate from the sway of existing institutions. And one needs means in the form of insights into where and in what directions to look for change, what novel elements to obtain from what source, and how to incorporate them in present competency. One can obtain such conditions mostly by moving one's present competencies across a variety of contexts ('generalisation'), subjecting them to new challenges, adapting them to local conditions ('differentiation'), interacting with others in the novel context, adopting elements of novelty from them ('reciprocation' or hybridisation). That is how we obtain motive, opportunity and means for change.

one builds in elements from such local practice into one's own, or tries to adopt local practice while maintaining elements from one's own.[5]

For the next step towards exploration the condition is important that the potential of novel elements is constrained by the architecture of the system in which they need to fit. Such structure may be the architecture of the practice itself, or structures of use, or superordinate structures of distribution channels, legal acceptance, vested interests etc. Thereby, as success of novelty emerges in the niche, pressures arise for more radical architectural innovation (Henderson & Clark 1990), or 'accommodation' to allow the novelty to fully realise its potential. Such architectural change is not random: one indication for it is to design architecture such that novel elements that were proven useful in the preceding stage of reciprocation can better realise their potential. Here the niche that served for the incubation of novelty is expanded, and novelty creates its own new selection environment and corresponding institutions. Such more radical architectural innovation, on different levels of structure, creates confusion, creative destruction and a great deal of uncertainty. Here we are back at the beginning of the cycle: a process of consolidation is needed. Completion of the cycle explains, among other things, that while process innovation may follow product innovation, the reverse can equally be the case.

In this scheme, one can recognize the principles of evolutionary thinking: consolidation entails selection among novelty, generalization entails transmission, and differentiation, reciprocation and accommodation generate new variety of forms. As argued, this process of variety generation has been neglected by evolutionary economics and innovation theory, which have taken the generation of novelty as random (by analogy to evolution in biology) or not amenable to explanation. In this respect, the present cycle of discovery gives more detail of what stages of development arise, and how they lead on to each other.[6]

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[5] A famous example of reciprocation is how Henry Ford's idea of an assembly line in car manufacturing was inspired by the procedure, at a mail-order company, in which boxes on a conveyor belt passes successive stations, to be filled according to order slips.

[6] It is related to the learning cycle of Kolb (1984), in an 'activity theory' of learning: learning (exploration) emerges from practice (exploitation). On a deeper level of analysis, this is consistent with the emerging stream of 'embodied cognition', mentioned before. In Kolb's cycle, learning comes about from 'concrete experience', 'reflective observation', 'abstract conceptualization and 'active experimentation'.

The present cycle is also similar, up to a point, to the ‘technology cycles’ proposed by Tushman, Romanelli and Gersick, mentioned before. In particular, it shares the basic principle that the discovery process arises from an alternation of variety of form and variety of context: variety of form is reduced (in dominant designs) and replaced with variety of context (outside niches) that generates novel variety of form (innovation). The added value of the present heuristic of discovery is that it specifies by what process and steps ‘discontinuity’ and punctuated equilibria come about, on the basis of allopatric speciation.

The role of a secluded niche

Crucial in this process of discovery is the role of a secluded niche that isolates exploration from the existing selection environment with its focus on exploitation. This notion of ‘escape’ to an outside niche, in generalisation, is an important one. New species often arise outside, or at the periphery, of the parent niche. After a lengthy process of such outside experimentation, a breakthrough, including invasion into the parent niche, can occur relatively fast, yielding punctuated equilibria. This links with the notion of ‘allopatric speciation’ in evolutionary theory (Eldredge and Gould 1972, Nooteboom 2000).

Allopatric speciation is a concept that originates from evolutionary biology and deals with the role of isolation in speciation. It implies that a new species emerges because a geographical boundary yields a separation from a parent population. The central idea is that without this geographical barrier the two species would soon melt into one homogeneous population again (Eldredge and Gould 1972, Dunbar 2003). When applied in the context of innovation, we claim that to the extent that in a given niche the existing selection environment is rigorous, with strict regulation, one has to escape to a niche that is more or less secluded from the parent niche. There, one may deviate from the institutions of the home niche, while being subjected to new institutions of the host niche. In this way one has the scope to deviate from familiar routines, carried from the parent niche, and one builds up insight in their limitations, as well as the motivation to differentiate them, in order to survive in the host niche. This raises the question why the existing institutional environment can be so highly selective and may hamper variety generation so that exploration needs to operate in relative isolation from existing exploitation.

The exploration of novel combinations may ‘violate’ institutions in the existing institutional environment. As a consequence, vested interests are threatened. Firms that occupy a central position in these existing networks, and whose interests are under threat, may then try to undermine the legitimacy of the new technology (Aldrich & Fiol 1994) and may block new entrants so that novel combinations may not be further explored. There are economic, psychological and social arguments for that. An economic argument has to do the fact that incumbent firms have large sunk costs in existing technologies through investments in R&D, production equipment, training of people and so on. The more these investments are specific for the existing technology, the higher the chance that they become obsolete once the new technology proves to be superior to the existing technology.

A second type of argument is more of a psychological nature. As a matter of cognitive psychology, incumbent agents, embedded in existing institutions, may not be able to see the sense and significance of radical novelty, simply because its falls outside their absorptive capacity. Nelson and Winter (1982) noted the phenomenon of ‘local search’: firms search for new knowledge that is less likely to conflict with their existing cognitive and mental models.[7] The cognitive argument against radical change entails that in order to develop requisite motivation and insights one needs to operate outside the reach of incumbents to have room to manoeuvre and to experiment freely, and to obtain novel inspiration and insights.

As a matter of psychology, incumbent agents, especially management, have generally made their careers and earned their positions on the basis of existing technology and paradigm. The threat of a new technology, breaking with this existing technology and paradigm, is likely to cause loss of power, status and reputation, all undermining their position on the longer term (Aldrich and Fiol 1994).

[7] Underlying this is the idea of the relative inertia of firms, as advanced by population ecologists such as Hannan and Freeman (1984) that firms are better at doing more of the same than at adapting tot change.

A social argument, especially relevant in the context of interfirm relations, relates to the role of the existing networks that may exert strong inertial forces, preventing incumbents from entering into more innovative new relationships. The implicit expectation of loyalty to alliance group members may prevent them from allying with firms from competing groups (Gulati et al., 2000) as they experience implicit or explicit social pressure from their partners to replicate ties within the group. The risk of negative reputation effects when group members engage in an outgroup-orientation will not be offset by the potential rewards provided by engaging in the new windows of opportunities these innovations offer (Duysters and Lemmens 2003). As a consequence, the close ties and commitment the block members share in their technological community can develop into a collective blindness to the outside, which makes them vulnerable to disruptive changes in the environment.

So, the potential threat of novelty for vested interests, which may try to undermine the development of such novelty, forms a first argument for a secluded niche that separates exploration from existing exploitation.

In sum, a secluded niche is needed for three reasons. The first is that established capabilities arisen and consolidated in a given niche, and therefore performing well there, and are taken for granted, so that new conditions of technology, demand, infrastructure and institutions are needed to gain new *insights in limits* of validity. The second reason is to build *motivation* for change, resulting from such misfits, in the novel context. The third reason is to yield *insight into potential novel content* of practice, for which inspiration is found in the novel context.

A fundamental aspect of allopatric speciation in biology is that there is a real physical geographical barrier between species (e.g. such as a mountain range, desert or sea). Theorists in biology have not been able to show convincingly how speciation might occur without physical separation of the founding populations, except in certain rather specialized circumstances (Dunbar 2003).[8] The question now, in the context of innovation, is how to create such separation so that the exploration of novel

[8] If in the biological world two separated species come back together, we speak of "sympatric speciation". Sympatric speciation refers to the formation of two or more descendant species from a single ancestral species all occupying the same geographic location. Some evolutionary biologists don't believe that it ever occurs. They feel that interbreeding would soon eliminate any genetic differences that might appear. But there is some compelling (albeit indirect) evidence that sympatric speciation can actually occur (Dunbar 2003).

combinations can to some extent be isolated, or secluded, from the selective effect of the institutional environment with its focus on exploitation. As we will show there are two structural forms for creating a secluded niche, namely separation in time and separation in place. To further study this, we discuss two newly emerging industries in the Netherlands to analyse how exploration of novel combinations in these two industries has developed. Section 3 deals with the multimedia industry and section 4 with the pharmaceutical biotechnology industry.

3. The emerging multimedia industry

In this section we analyse how the multimedia industry in the Netherlands has emerged through the 1990's and the early years of the new millennium. In this analysis we will take the moment of the adoption of Internet (around 1990), as the worldwide standard for on-line communication, as a starting point. Three Dutch industries formed the basic building blocks for the emerging multimedia industry around the early 1990's, namely the telecommunication industry, the information technology industry and the media industry. These various industries were 'worlds apart' in the off-line era, but were strongly affected by rapid technological advancements in the fields of micro-electronics, miniaturisation, compression-technology, leading to increasing possibilities for digitalisation of information and technological convergence. So, this technological convergence fuelled an industrial convergence process in the gradual merging of telecommunications, IT and media industries, resulting in a newly emerging multimedia value chain (Directie EDI 1996, Dialogic 1998, 1999). In figure 2 an overview is given of this newly emerging multimedia value chain and the positioning of two learning regimes along it, one with a focus on exploration and the other with a focus on exploitation.

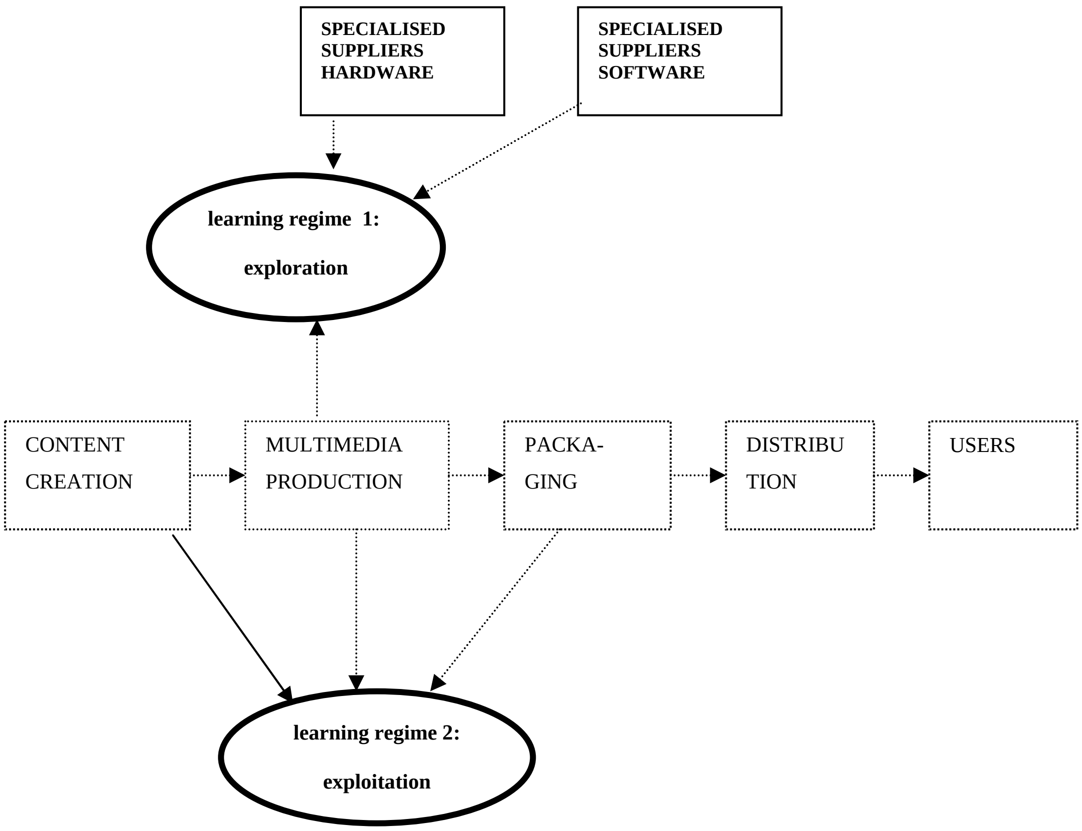

Figure 2 : Emerging value chain and learning regimes in the multimedia industry

Learning regime 1: technological exploration

Before the advent of Internet, the existing knowledge base was compartmentalized in separate technologies that co-existed: information -, communication - , audiovisual – and data-transmission technologies. These technologies were mostly stand-alone and most exploration was done by large, R&D-intensive firms. These firms were specialized suppliers of hard- & software such as Lucent, Ericsson, Philips, and Sony, which explored within the scope of their own knowledge domains (Directie EDI 1996, Bouwman en Jansen 1996, Bouman and Bouwman 2000). The arrival of Internet yielded the insight that for its full utilization a more fundamental restructuring was required, in technological convergence. Digitalisation provided a technical incentive and opportunity for this integration of technologies.[9] Thus, Internet, together with perspectives for digitalisation, provided powerful incentives to actively search for convergence of these technologies, in new applications (Condrinet 1998). This led to the entry of new firms that were small in size and formed by people with technological knowledge and a keen interest in exploring the potential for this technological convergence process. In doing so, these new entrants complemented the search activities of the large, R&D-intensive firms. So, exploration developed between small specialized multimedia firms and specialized suppliers of hard-& software. In this respect, this exploration emerged largely outside the sight of the established players in the media, telecommunication and ICT industry. Many of these existing firms remained very aloof as they did not understand or recognize the potential impact of Internet on their business in the early 1990's nor much more later on.

[9] Digitalisation made information easy to combine and to manipulate. The major implication was the change from analogue to digital representation, manipulation, storage and transportation of information (Bouwman and Propper 1994). In addition, digitisation spurred the convergence of three different technological fields that dealt with information processing, namely telecommunication technology, information technology and media technology (Dialogic 1998). More specifically, this technological convergence could be described as a process of the convergence of transport utilities such as cable and telecommunication networks, interactive storage, manipulation and processing of information as well as devices to use or consume the information (Bouwman and Hulsink 2000).

> An example of this is formed by KPN, the national Dutch telco. At the time, their main focus was on making money out of their existing telecommunication network, i.e. in selling distribution capacity. They were hardly interested in the Internet except for its potential to sell more of their existing capacity without any interest in the content going through their telecommunication networks. Quoting the then chairman: “Wij hebben geen boodschap aan de boodschap” (= We have no interest at all in content).
> (Source: statement by Wim Dik, former CEO KPN, during press-conference of presentation of 1994 annual report)

These new entrants were formed by spin-offs from the established firms as well as by new start-ups. In general, spin-offs were created by individuals, formerly employed by these existing firms, who were denied the possibility to explore these newly arising opportunities. Start-ups were mostly created by a new breed of university graduates with no relevant antecedents in existing industries whatsoever (Schaffers 1994, Beam-it 1999). Both types of firms were driven by what may be considered as ‘push’ and ‘pull’ forces. The ‘push’ force consisted of insights in the growing limitations of existing ICT, telecommunication and media technology. Application of these technologies in firms and organisations led to automation and digitisation of parts, so called ‘ island-automation’, and their separation made it impossible to exchange this isolated information electronically let alone to communicate among people. This was more and more considered as a bottleneck, not only for geographically dispersed firms but also for professionals and smaller firms given the growing need for communication in an increasingly knowledge-based economy (Directie EDI 1996, McKinsey 1997). The force ‘pulling’ these start-ups and spin-offs into the newly emerging field of multimedia was their shared, professional fascination for the new technology and its promises of an on-line, interconnected world that enabled to communicate freely with no consideration of time and place (Bouwman and Propper 1994, Condrinet 1998). Initially, the outcomes of their exploration activities were formed by creating all kinds of new combinations of technology, however, without any feel for user-oriented features (Smeulders 1999). So, in the multimedia industry exploration was isolated from the existing selection environment in two ways: away from incumbent firms in the media, telecommunication and ICT industry as well as away from potential users in more downstream industries.

Learning regime 2: technological exploitation

This absence of the role of users in exploration changed when some first applications like simple e-mail applications, websites and electronic games started to propel demand. As a consequence, some first professional users started to become involved, especially in information-intensive industries such as banking and finance as well as large firms with dispersed activities like multinationals (Directie EDI 1996, Condrinet 1998). These first users needed to invest in specialized personnel with the ability to deal with specific multimedia technology and its applications. Increasingly exploration started to focus more on user-oriented features such as different kinds of user-interfaces, speak-& language technology and image processing. Thus, technological exploration changed in nature as its object shifted from a sole focus on technological convergence in the early 1990's towards more user-oriented technologies from the mid 1990's onwards.

This led to the emergence of a second learning regime, pursued by networks with a focus on exploitation. The emergence of this learning regime 2 was further stimulated by a broadening customer base, built up of a growing mass-market which exerted a relatively simple, more homogeneous demand (Directie EDI 1996, Dialogic 1998, 1999)[10] This market was served, from around 1995 onwards, by a rapidly developing, new type of network. The vast majority of firms making up this new type of network were very small in size (often employing less than 10 people) and disposed of average technological capabilities, all of them trying to take advantage of the growing market for on-line applications (Leisink e.a. 1998).[11] Compared with the firms engaged in exploration, learning in this network was more oriented to exploitation with a dual learning object: the understanding of customer needs as well as keeping up-to-date with the constantly changing technological knowledge as explored in learning regime 1.[12]

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[10] Exact data on the market size are not available although there are various indications. The Internet Almanac estimated the total number of users at 1,4 million in 1997 and predicted the number of users to have more than doubled to nearly 3 million users by the year 2000. Booz Allen & Hamilton (1997) estimated the total market for on-line services through Internet in the Netherlands at somewhere between euro 410 and 450 million in 1997 with an expected annual growth rate between 1997 and 2001 of around 65%.

[11] Around 40% of them were new entrants, the majority (approximately 60%) had their major chunk of business in more traditional industries such as printing, advertising, audio-visual production, IT or pr/advertising (Bakker and Jonkheer 1999, Dialogic 2000). In this respect, they had more familiarity with those aspects of multimedia that were closer to their traditional business (Dialogic 1999).

[12] Clear empirical indications for this dual learning object were that, based on an extensive survey on multimedia firms by Peelen e.a. (1998), between 65 - 70 % of all multimedia firms especially invested in a better

In general, customers were professional users that were formed by firms in a wide variety of industries that increasingly adopted multimedia-devices and its related services such as e-mail, websites, intranet-applications and so on. In this respect, this second learning regime basically formed the 'move back' into the existing institutional selection environment, as can be noted from the growing presence in this network of (larger) firms from existing industries that mostly acted as users of the new multimedia technology. A further indication that the existing institutional selection environment started to absorb the newly developing technology, was that these large firms were increasingly prepared to make substantial investments in this newly arising field (Dialogic 2000).

Separation between exploration and exploitation

In the multimedia industry the separation between exploration and exploitation occurred through a niche that was created by separation in place as well as in time. Separation in place was created by (1) start-ups that explored in isolation from incumbent firms in the media, telecommunication and ICT industry as well as by (2) spin-offs that were generally formed by people who were denied such opportunities for exploration within these firms. Insights in the growing limitations of existing technologies and the common challenge to explore the new promises of multimedia technology made these firms work together in this niche. This niche, created through separation in place, enabled both types of firms to explore with no or only limited considerations for exploitation from the viewpoint of the existing selection environment. This was important as it enabled them to move beyond local search and to access sources of knowledge at a larger cognitive distance, outside the absorptive capacity of incumbents. In doing so, these new firms initially also ignored future exploitation as they neglected the potential needs and applications from the side of future users to a large extent. This was important as such novel applications required sufficient systemic integrity to convince potential users of their novelty value and viability, whereas such integrity was certainly not within immediate reach. Exploring in a niche that was isolated from potential users enabled to create this systemic integrity sufficiently. So, a niche was created through separation in place to remain isolated from *existing*

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understanding of customers (through improvements in marketing, communication and customer focus) as well as in knowledge on (adjacent) technologies.

exploitation and through separation in time to remain isolated from *future* exploitation. In this way, the isolated niche enabled these firms to explore freely the potential of the new technology and to assess in how far its promises were within reach, technologically speaking. With the first indications around 1995 that this was the case, learning regime 2 developed from the mid 1990's onwards. On the one hand its focus was on the continuous influx of knowledge spill-overs originating from the exploration activities in learning regime 1, whereas on the other hand its focus was on the identification of customer needs. This dual learning object of learning regime 2 made it possible to fine-tune the new multimedia practice as explored in learning regime 1 and to make full use of its potential. This then formed the basis to 'invade' the domain of established industries such as printing, publishing, audio-visual production, IT, media and telecommunication (Condrinet 1998). As the effect of this technological convergence for their business and organisations became increasingly apparent throughout the second half of the 1990's, these actors increasingly started to adopt and use the new technology. So, the creation of a secluded niche through separation in place and in time required a subsequent, transitional process from exploration to exploitation in order to 'transfer' novelty into the existing selection environment.

4. The emerging pharmaceutical biotechnology industry

In this section we analyse how the pharmaceutical biotechnology industry has emerged throughout the 1990's and the early years of the new millennium. Over this period, the Netherlands occupied a 12th position in the overall ranking of nations, based on number of biotechnology companies (Ernst and Young 2002)[13]. Four medium-sized multinational firms were clearly involved in pharmaceutical biotechnology, namely AKZO Nobel (Organon, Organon Technika and Intervet), DSM-Gist Brocades (largest global manufacturer of penicillin), Yamenouchi and Solvay Pharmaceuticals. In addition, foreign pharmaceutical firms had clinical research being carried out in the Netherlands and had

[13] From the early 1990's towards 1998-1999 the number of entrants by DBF's per annum increased from 4 in 1994 to 10 in 1998, making 50 in total (Biopartner 2001, 2002). Around 50% of these firms in the pharmaceutical industry in the Netherlands were active in the field of pharmaceutical biotechnology. This indicated that a pharmaceutical biotechnology industry in the Netherlands was emerging in this period.

relations with local Dedicated Biotechnology Firms (DBF's). Some of these DBF's also had relations with large pharmaceutical firms outside the Netherlands.

Over the period that we studied, the majority of this 'new breed' of Dutch DBF's was engaged in research on general platform technologies with a potential for applications in the pharmaceutical industry such as e.g. genomics, combinatorial chemistry, high-throughput screening and bio-informatics (Degenaars and Janszen 1996, Ernst and Young 2001). In these application areas, time-to-market was shorter and there was less risk involved as compared with therapeutics. These latter required lengthy and costly clinical trials and had a higher chance of failure. In our analyses of the Dutch pharmaceutical biotechnology industry we will further focus on firms active in these general platform technologies.[14]

Over the course of the 1990's a 'knowledge exploration value chain' was emerging in the field of general platform technologies, which is schematically depicted in figure 3:

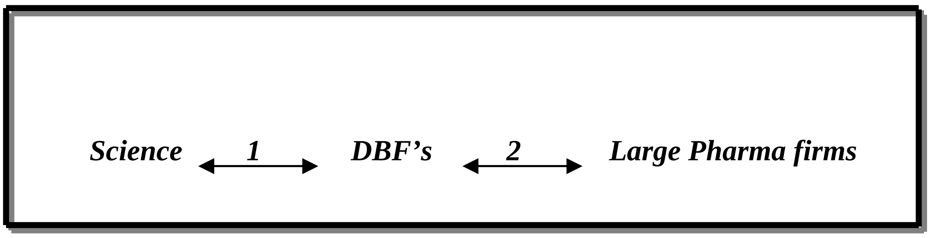

Figure 3 : Emerging knowledge exploration value chain and learning regimes in the field of general platform technologies

Within this value chain we can discern between 2 main types of learning regimes, namely:
- Learning regime 1 : exploration embedded within a network of DBF's with academia.

[14] Research in these platform technologies could be considered as an important 'engine of knowledge' (Allansdotir e.a. 2002). There were many technological spill-overs by means of licences to different parts of biotechnology. Especially platform-technologies generate such spill-overs by providing platforms also in non-pharma applications such as plant breeding, food-processing (e.g. diagnostic kits), speciality chemicals, bioinformatics and biological catalysis. DBF's that specialised in platform technologies aimed to provide tools and services to pharma firms that were involved in drug discovery and development. The advantage of this strategy was its potential for relative rapid commercialisation with (hopefully) fast cash-flows (Casper 1999).

- Learning regime 2 : exploitation embedded within a network of one or more DBF's with a large pharma firm.

Learning regime 1 : technological exploration

Learning regime 1 focused on technological exploration and was embedded in a network that was made up of relations between DBF's and (public) research institutes such as universities and academic hospitals. The focus in this learning regime was on exploring the knowledge base on general purpose, platform technologies. This knowledge base had a mainly stand-alone nature due to its strong basis in molecular biology. In contrast with this new scientific field of molecular biology, the existing knowledge base on organic chemistry did not provide an understanding of the interaction of drugs with the human body. Its focus was on understanding the properties of chemical entities and producing them reliably in large quantities (Santos 2003), not on understanding the biological underpinnings of specific diseases, as provided by molecular biology (Pisano 2002). So, for the pharmaceutical industry this biotechnological revolution opened up completely new areas for innovation as it altered the drug discovery process in profound ways and opened up fundamentally new ways to define search spaces, identify promising targets and develop potential heuristics (Pisano 2002, Santos 2003).

However, very few of the Dutch incumbent pharmaceutical companies jumped into these opportunities, for two reasons. One was the unwillingness of the existing labour force of mainly organic chemists to 'give up' their powerful positions to pharmacologists and biotechnologists that understood this new technology (Degenaars and Janszen 1996). Moreover, the cognitive distance with the existing knowledge base of organic chemistry was large ((McKelvey and Orsenigo 2001, Reis e.a. 2000, Roijakkers 2003, Enzing and Kern 2002) and it changed the locus of innovation away from incumbent firms (Santos 2003, Roijakkers 2003). Without exception, new entrants formed by small start-ups that specialised in biotechnological research, were at the leading edge in transforming the highly scientific knowledge created at universities into potentially commercially useful techniques and products (Reis e.a. 2000, McKelvey and Orsenigo 2001, Pisano 2002, Roijakkers 2003). This applied to the Netherlands as much as elsewhere, and provided the basis for the emergence of learning regime 1.

Technological exploration in this learning regime 1 between DBF's and public research institutes focused on the discovery of the new scientific field of molecular biology. This search process was characterized by a lot of trial & error and highly specific to individual persons and research communities (Enzing 2000). In this learning regime a clear spatial concentration could be observed, especially around universities such as those in Amsterdam, Groningen, Leiden, Utrecht, Wageningen and Delft. The mainly tacit search process meant that personal contacts and frequent interaction were necessary to accommodate an effective transfer of this tacit knowledge (Geenhuizen and van de Knaap 1997). In addition, physical closeness facilitated easy access to a talent pool of skilled workers, facilitating knowledge spill-overs through the mobility of researchers. In addition, opportunities were generally diffuse, requiring regular checks and adaptations of the search process into the most promising search direction (Geenhuizen 1999). So, these exploration networks were formed by dense networks of strong relations between universities and DBF's that enabled them to develop an in-depth understanding of key scientific issues (Enzing and Kern 2002).

Learning regime 2 : technological exploitation

Learning regime 2 was concerned with technological exploitation, being embedded in a network made up of relations between DBF's and large pharma firms. The rationales underlying this network were as follows. Large pharma-firms needed to keep up to date with a rapidly changing knowledge base as the continued exploitation of the existing knowledge base of organic chemistry made its limitations increasingly visible, first slowly but towards the end of the millennium increasingly more apparent. These limitations became manifest by the increasing number of existing patents by pharma companies which was expiring in combination with a lowering number of potential 'blockbusters' in the pipe-line.

However, opportunities pertained to niches and were difficult to define upfront, making it difficult to decide for pharma firms in which fields of knowledge to invest and which to ignore (Ernst and

Young 2000, 2001 (2)). Therefore, large pharma-firms made use of alliances with various small DBF’s which enabled them to explore various opportunities at the same time, without making substantial specific investments. From the side of DBFs such alliances were attractive as large pharma firms provided them complementary assets such as access to marketing and distribution channels and to capabilities in the field of regulatory approval procedures.

An important governance instrument in this network was formed by research contracts, possibly complemented by minority equity arrangements (Ernst and Young 1999, Enzing 2000). These contracts regulated contract research, contract manufacturing, custom synthesis and very importantly, preclinical and clinical testing (Reis e.a. 2000). In essence, the contract provided DBFs with two key resources, time and money, which guaranteed DBFs a secluded niche that enabled to explore them in relative isolation. In this way DBF’s could maintain a sufficiently academic orientation and comply with relevant selection criteria such as achieving scientific excellence and publishing in academic journals as well as to maintain their embeddedness in regional networks around universities and research institutes. On the other hand, for DBF’s a core performance-yardstick was ‘time-to-patent’ (Ernst and Young 1999), in view of exploitation.

From the viewpoint of a large pharma firm, the contract provided access to new technology developed by DBFs and universities. So, although the cognitive distance with its existing knowledge base of organic chemistry was large, a pharma firm did not need to understand the complexities of the search process, and could maintain its focus on exploitation. In other words, the value of such a contract was mainly in the assurance of a large pharma firm contributing to the costs of doing research, in return for the ‘first-right-of-refusal’. This entailed the rights to have first, exclusive access to the results upon which he could decide whether to use these or not.

Separation between exploration and exploitation

In contrast to multimedia, we clearly see exploration and its subsequent exploitation going on at the same time, throughout the whole period studied from the late 1980’s towards the late 1990’s. Instead, our empirical analysis reveals that in the biotechnology industry exploration and exploitation were separated in place. This was created through a clear division of labour. DBF’s specialised in exploration whereas incumbent firms in the pharmaceutical industry specialised in exploitation. This separation was created through a contract that guaranteed DBFs a secluded niche in which they could explore relatively freely but also required that they take up an intermediary position between universities and large pharma firms, in view of the transfer from exploration to exploitation.

5. Comparing separation in time and separation in place

In this section we reflect on our empirical analysis by making a comparison between the two types of separation. Moreover, we analyse how in both arrangements a linkage was still being maintained between exploration and exploitation, although in fundamentally different ways.

Comparing separation in time versus in place: the role of the knowledge base

Our empirical observations point to an interesting issue, namely the profound difference between these two industries in the way in which a secluded niche was created, either through separation in place or through a combination of separation in time and place. The key to explaining this lies in the nature of the knowledge base that underlies both industries. The knowledge base on multimedia is a highly systemic one (Teece 1986). It forms a sort of technology system that is built up of different types of technologies such as hardware technology and different kinds of software technology such as middle-ware, speak-and language technology, image processing technology, communication technology, content management technology and so on (Smeulders 1999). In other words, strong mutual dependencies existed between these different

Although not a Dutch firm, Eli Lilly may serve as an exemplary case for all pharmaceutical firms including Dutch ones. Eli Lilly's patents for its very successful Prozac (against depressions) which expired from the beginning of 2001. The turn-over of 2.3billion US$ in 2001 has halved in a few months and could not be compensated for by increasing sales of other new medicines (FD, January 2002). According to Jan Leschly, former CEO of SmithKline Beecham, "Big pharma cannot afford to rest on its laurels. If today's successful pharma companies do nothing then their sales will be halved within ten years from now" (E&Y 2001) technologies so that to develop a multimedia-application required the integration of different technologies for which change in one required adaptations in others.

This also created complexity in the exploration process as firms needed to consider all relevant technologies simultaneously, making it difficult to take a structured approach (Smeulders 1999). As a consequence, newly developed knowledge on technological convergence was of a highly tacit nature, creating a need for geographical proximity that enabled an easy transfer of this knowledge among the involved firms.[15] Given the systemic nature of multimedia technology, the effects of radical change in one type of technology could have highly disruptive for adjacent technologies, making that the costs for adaptation became substantial. Firms with interests and investments in such adjacent technologies were only be prepared to adopt the new technology when the benefits of novelty clearly outweighed the costs of change. That was difficult to prove in such an uncertain and unstable setting of exploration with search activities going on in all directions. To test the viability of the new technology and to develop convincing arguments for change then required a secluded niche. Such a niche offered the possibility to build on the acquired insights in the growing limitations of existing technologies by exploring the potential of the new multimedia technology. To maintain a clear connection then with incumbents and potential users cannot be done. Given the systemicness of multimedia technology, the risk of inconsistencies and the disruptive consequences for existing or adjacent technologies inhibit this. So, a niche was needed that was secluded from both *existing* exploitation through separation in place, and from *future* exploitation through separation in time.

In contrast to multimedia, the knowledge base on general platform technologies in pharmaceutical biotechnology was more of a stand-alone nature (Teece 1986). It was firmly rooted in a specific kind of scientific discipline such as molecular biology, genomics, combinatorial chemistry or others (Enzing e.a. 2003). In general, stand-alone knowledge coincides with more mono-disciplinary knowledge and yields innovations that require an in-depth understanding within a limited disciplinary or functional area (Malerba and Breschi 1997). Often such stand-alone knowledge originates from academia, generally being highly codified through publications. This combination of stand-alone and codified knowledge explains why in the pharmaceutical biotechnology industry a secluded niche was

[15] This regional concentration was particularly around Amsterdam/Hilversum and Eindhoven.

created through separation in place. Due to its stand-alone nature, exploration of new technology would not have highly disruptive consequences for adjacent technologies or other parts of the overall system. Moreover, the codified nature of knowledge, as an outcome of the search process, made that that it could be accessed fairly easy, even at distant locations, and when of potential value be absorbed by means of a license agreement or a contract. This means that large pharma firms did not need to be directly involved in the search process but merely needed to engage in a once-off transaction. This also explains why there was no need for geographical proximity and why relations could take place over large distances in exploitation.

In this organisational arrangement though, it was very important that exploration was not separated in time from exploitation. One of the key-issues in the contract were the activities related to preclinical and clinical testing. Such tests generally entailed issues such as toxicity, undesirable side-effects of drugs and so on (Reiss e.a. 2000). When a new drug did not meet the requirement of one or more of such tests, it is critical to be able to modify the new drug or to explore in different directions. To be timely then requires that exploration on the one hand and such (pre)clinical trials on the other hand take place simultaneously, or at least that time lags are limited. So, given the stand-alone and codified nature of knowledge and the specificities of testing new drugs in pharmaceutical biotechnology, a niche for exploration is created through separation in place.

So, from the nature of the knowledge base we are able to understand the profound differences between the two mechanisms through which a secluded niche was created. In this respect, we may conclude that separation in time is a stronger form of seclusion than separation in place. The latter form still enables to coordinate between the discovery process and the existing selection environment. Through separation in time such dependencies are decoupled in order to avoid the risk of inconsistencies among elements of a systemic knowledge base.

Maintaining a linkage between exploration and exploitation

As argued in section 2, the essence of allopatric speciation in the context of innovation is to escape from the dominant selection forces consisting of vested interests and existing cognitive models, by exploring in a secluded niche. Only in this way novelty can originate and develop. However, a crucial point here is that some sort linkage between exploration in a secluded niche and exploitation needs to be maintained: in separation in time there is a transformation from exploration to exploitation over time whereas in separation in place there is an ongoing transfer of knowledge between exploration and exploitation. There are two reasons why maintaining such a linkage is important. A first reason has to do with the fact that exploring novel combinations departs from the existing dominant design: you need to have insights in how the existing dominant design fails and why it fails in order to obtain hints for directions where to search for novel combinations. These are the phases of differentiation and reciprocation as we discussed in section 2 on the move from exploitation to exploration. The cycle of discovery aims to show a path of exploration while maintaining exploitation. Elements of the old exploitation structure are carried along, but to a decreasing extent: one first maintains both the architecture and the elements of old structure, then introduces new elements, then changes architecture, while still maintaining some old elements.

A second reason to maintain a linkage is the need to regularly assess the level of progress made when exploring. At lower levels of exploration, in differentiation and reciprocation, the existing knowledge base and dominant design may function as adequate benchmarks, clearly marking the starting point of your exploration efforts. However, their relevance decreases more and more so that it becomes difficult to compare the standards of old exploitation with the outcomes of new exploration. Increasingly though, potential lead-users may serve as a new guidance for these exploration efforts by testing and experimenting with novel applications such as demos and the like. So, the linkage with existing exploitation diminishes in importance and makes room for an emerging linkage with new exploitation. This forms a key issue in view of the need to convince potential users, suppliers and other stakeholders that the benefits of novelty will outweigh the costs of change.

How was this linkage maintained in the multimedia and pharmaceutical biotechnology industry? At the very early stage of the emerging multimedia industry, professional users were stuck with investments in all kinds of separate IT and communication systems with limited or no compatibility. Insights in the growing limitations and misfits of these existing technologies provided the linkage between existing exploitation and new exploration that aimed to adresses these issues. For (potential) lead users, technological convergence increasingly provided an opportunity to solve the problem of this ‘island-automation’ in their organisations by moving to more uniform and compatible IT and communication systems. This explains why professional lead-users in information-intensive industries were among the first to adopt the new technology around 1995, rather than incumbent firms that supplied such tools based on existing, stand-alone technology. In this learning from lead-users, the new entrants in the industry were able to obtain further insights in which directions to search (such as more user-oriented technologies like speak-& language technology, image processing technology and so on). The increasing level of cooperation with some large R&D-intensive firms, specialised in various types of multimedia technology (e.g. Philips, Lucent, Ericsson, Sony and others), enabled to improve this technology further and to develop arguments for change. So, the linkage with existing exploitation was created through the carrying over of insights in its limitations and misfits, into the secluded niche. Increasingly, this linkage with existing exploitation made room for a linkage with new exploitation that was created through relations with some first lead-users and R&D-departments of specialised suppliers.

In the pharmaceutical biotechnology industry, this linkage was highly institutionalised through a contract between large pharma firms and DBF’s. While being confronted with the increasing failure of their dominant knowledge base on organic chemistry in existing exploitation, indicated by the increasing number of expiring patents, this linkage enabled large pharma firms to create access to new technology in exploration. Moreover, this formalised linkage enabled them to monitor the level of progress made in exploration by confronting its outcomes with the requirements set by new exploitation. This was done through (pre)clinical trials, the results of which were regularly fed back into the exploration process.

6. Conclusions

In this paper we studied the usefulness of the evolutionary metaphor of allopatric speciation in order to develop an understanding of the endogenous origins of novelty in interfirm innovation networks. A first conclusion is that our empirical analysis of the multimedia and the pharmaceutical biotechnology industry reveals the notion of exploration operating in a secluded niche. The analysis provides empirical evidence in support of the allopatric speciation argument that for novelty to develop, it needs to operate in some level of isolation from the existing institutional selection environment. In other words, our theoretical argument on the relevance of allopatric speciation when exploring novel combinations holds, for both industries.

A second conclusion is that the way in which this niche is created differs between these two industries. The exploration of a stand-alone technology like in pharmaceutical biotechnology requires the creation of a secluded niche through separation in place. This enables to coordinate between the discovery process and new exploitation at the same time. The exploration of a systemic technology like in multimedia requires a combination of both place and time. Separation in place is needed to explore in seclusion from *existing* exploitation, whereas separation in time is needed to explore in seclusion from *future* exploitation. Hence we may conclude that exploring such a systemic knowledge base requires a stronger form of seclusion when compared with a more stand-alone technology, due to its systemic nature and the potential disruptive consequences following from that.

A third conclusion is that although exploration needs to operate in seclusion, at the same time some sort of linkage with exploitation needs to be maintained. More precisely, in order to monitor progress in exploration and to further accommodate this process, an initial linkage is needed with existing exploitation. We see here an important commonality as well as difference with biological evolution. In the latter case there is also an initial linkage with the old selection environment through the carrying over of genes into the new niche. Once this niche becomes physically separated, this linkage with the old selection environment disappears and variety generation in this niche, through cross-overs and gene mutations, is random. The essence of random variation in biological evolution is that combinations of genes likely to fit the environment are as probable as combinations that are not likely to fit (McKelvey 1997). Herein lies the difference with economic evolution in which variety is not random, as firms have the ability, to some extent, to perceive, interpret and anticipate technical and economic selection criteria. This ability to generate novelty that is likely to fit the criteria by the selection environment makes that variety generation in economic evolution is not random. Although not random, firms can obviously not fully anticipate selection so that variety generation remains an uncertain process. It is this uncertainty that makes firms maintain a linkage with the selection environment of existing exploitation (to acquire insights in accumulated failures and develop arguments for change), which then makes room for a linkage with an emerging selection environment of new exploitation.

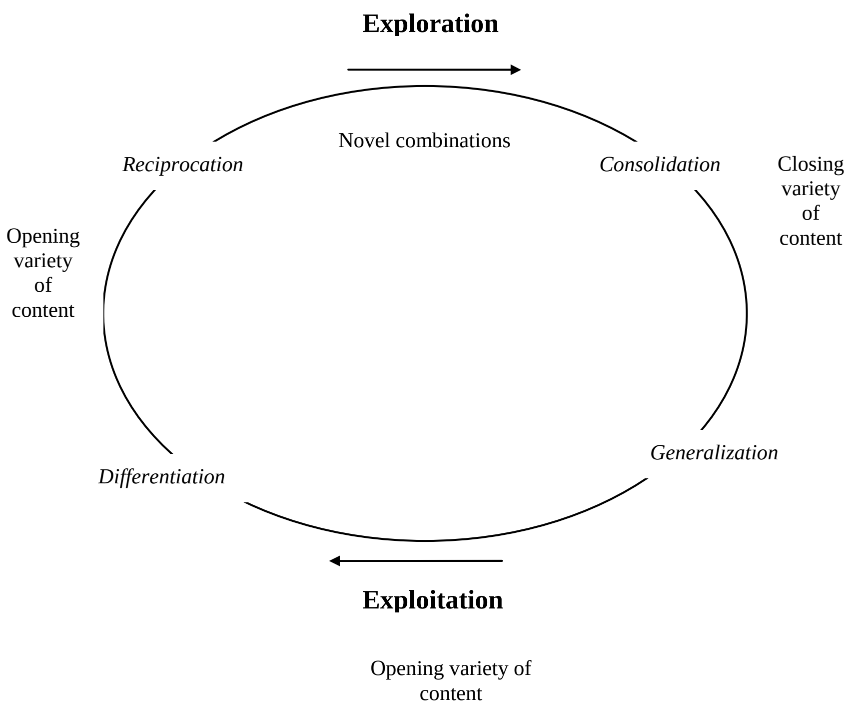

Figure 1 Cycle of Discovery (Nooteboom, 2000)

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