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The Quest for Competitive Sustainability: From Technology Sourcing to Knowledge Management

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Abstract

This study undertakes an analysis of external sourcing of knowledge by biotechnology companies. It suggests that biotechnology companies need to be more realistic about R&D operational models in a context where technological changes are only incremental and companies based solely on single technology platforms are highly inefficient. It is argued that in order to build, preserve or enhance their knowledge creation capabilities in a fast changing environment, firms increasingly combine internal "core" capabilities with externally acquired "complementary" ones. Knowledge creation requires in reaching the right balance between exploration and exploitation. It consists of activities within the firm in order to create knowledge from its own experience and from the experience of other firms, and on the exploitation of that knowledge to fulfill the mission of the firm. Thus, a biotechnology company's ability to choose technologies wisely will have a large impact on the performance of its R&D organization in terms of time to market, productivity, and product quality.

Keywords: technology sourcing; organizational learning; competitive dynamics; innovation; biotechnology; knowledge management.

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1. Introduction

Sophisticated techniques such as genomics, combinatorial chemistry, bioinformatics, functional genomics, proteomics and automated target validation have revolutionized the biotechnology industry's approach to drug discovery. The constant creation of new fields within the biotechnology field has been a key driver with respect to the aggressive growth experienced by this sector. The development of cutting-edge technology and know-how in academic research institutions has created a favourable environment for the creation of early-stage biotechnology companies (Figure 1). However, such changes in the drug discovery process have considerably disrupted the competitive dynamics in the drug discovery industry by dispersing innovation activity (Audretsch and Feldman, 2003; Chesbrough, 2003). In effect, the number of biotechnology companies reached 4,275 in 2006 of which 710 were public companies. Europe accounted for 1,465 private and 156 public companies while the US accounted for 1,116 private and 336 public companies (Lawrence, 2007).

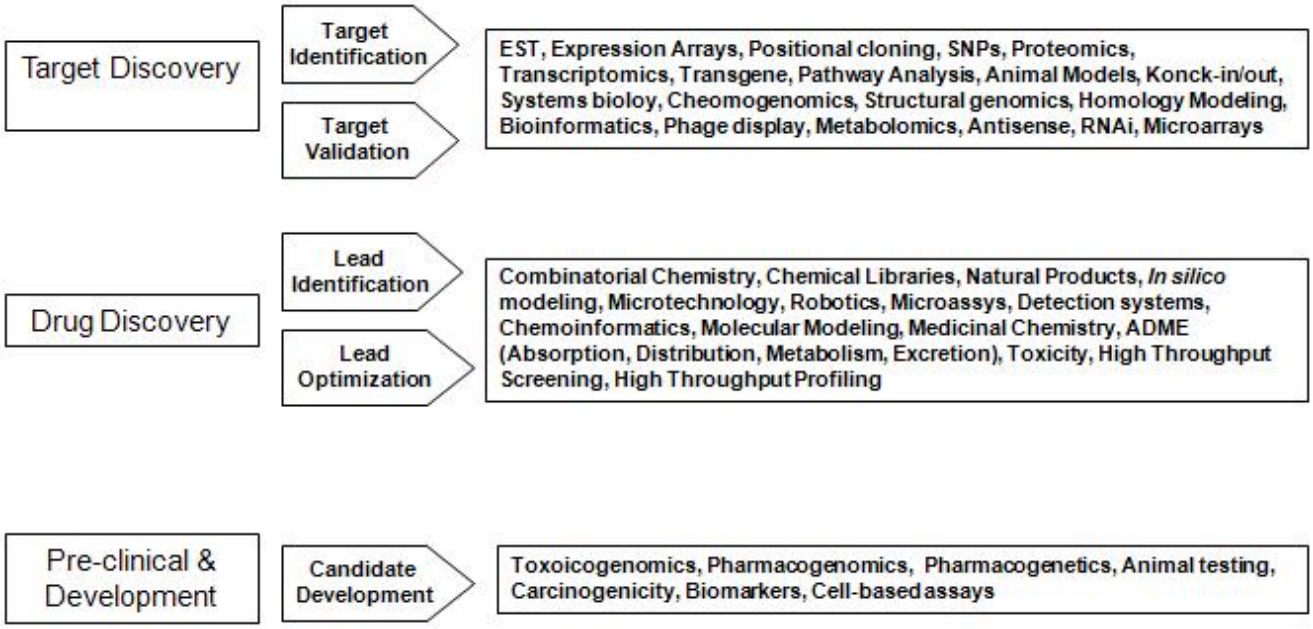

Figure 1. Biotechnology sector's knowledge base

Figure 1. Sophisticated novel approaches and technologies in the discovery and design of new drugs have replaced the traditional methods of discovery and development. However, such high technology methods in the field of biotechnology have mainly contributed to the complexity of the drug discovery process through the generation of a gigantic amount of data. Furthermore, the incremental value-added nature of each technology favours strategies capable of better integrating processes and managing resources through a range of different technologies.

Despite the promise of new technologies and tools drug development and discovery has not changed significantly in the past three decades and the sector's initial impact for new therapies has involved a limited class of products characterized by therapeutic proteins and monoclonal antibodies (Walsh, 2003a; Walsh, 2006). Undoubtedly, the introduction of such technologies to improve R&D productivity by such research intensive companies has contributed to our better understanding of the molecular mechanisms of diseases. However, the biotechnology industry is confronted with the same obstacles faced by the pharmaceutical industry in terms of long development times ranging from 10 to 15 years for novel therapeutics reaching the marketplace; high attrition rates; increasing costs and low R&D productivity. Moreover, the introduction of a wide range of

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automated high-throughput technologies has mainly contributed in increasing the complexity of drug discovery and the sector's overall R&D productivity remains low (Biocentury Extra, 2000). This has resulted in an abundance of drug candidates which does not necessarily mean a marked increase in productivity as the number of new active compounds launched each year by the industry has stayed roughly the same (Hughes, 2008).

Also, the environment of drug discovery and development has rendered innovative capabilities of a biotechnology company further uncertain since it is influenced by financing and competitive constraints requiring enormous R&D investments with uncertain pay-offs. Moreover, innovation is essential to the competitive survival and lays the foundation of a biotechnology company's strategy formulation in transforming knowledge-based assets into marketed products (Nicholls-Nixon and Woo, 2003; Schweizer, 2005). However, in a constantly changing environment, implementing a successful strategy depends to a significant degree on learning with new directions and on recognizing opportunities that materialize during the process. In such a context, external sourcing helps multiply opportunities of discovery, provide the requisite flexibility that enables the firm to win the race against time and to increase the chances of product success.

Some explanation has been provided notably through the resource-based view of the firm (Peteraf, 1993) that stipulates that heterogeneity of resources and capabilities is essential for achieving competitive advantage (Dierickx and Cool, 1989; Newbert, 2007). Authors have mainly highlighted the acquisition of externally complementary assets by securing inter-firm strategic collaborations (Cockburn and Henderson, 1998; Coombs and Hull, 1998; Pisano, 1990; Rigby and Zook, 2002) and M&A transactions (Ahuja and Katila, 2001; Prabhu, Chandy and Ellis, 2005). Others have examined how variations in innovation performance by the firm affect the strategic positioning of firms competing for resources (Gulati, Nohria and Zaheer, 2000).

Although there now exists a body of work on external knowledge acquisition in the innovation literature, much of it tends to focus mainly on the scientific division of labour between major pharmaceutical companies and biotechnology companies, universities and public research institutes, (Henderson and Cockburn, 1996; Owen-Smith et al., 2002; McKelvey et al., 2004). It has been argued that strategic alliances may be the preferred choice of external technology acquisition over other modes of collaborations such as mergers & acquisitions as only desired resources are acquired (Das and Teng, 2000).

The particular challenge facing early-stage biotechnology companies is that a wide range of tools, technologies and approaches need to be combined and applied to the search for new and improved therapeutics. To complicate things further a high proportion of these technologies and related intangible assets have unproven R&D productivity. In a R&D outsourcing environment, due to discrepancies in data integrity and harmonization strategic alliances contribute mainly to the dispersion of the product information flow from one stage to another within the value chain of the drug discovery process. This presents a dramatic challenge for an early stage biotechnology company since the largest value to be captured resides in innovations that affect the later stages of drug development. The main issue that needs to be resolved is improving the probability of success of clinical trials which only manifest itself only many years later. Firms need to avoid misconceptions about accelerated drug development that has compromised the completeness of development and favoured diminished quality.

Moreover, the increasing pace of biological discoveries has shifted the productivity bottleneck downstream in the drug development process. Even with greater efficiency in lead identification and optimization, improvements will also need to be made in clinical development and the overall speed to market. In this environment, biotechnology companies need to focus on their future markets in order to stay ahead of the game. Ultimately, the objective for a drug discovery company is not necessarily to provide definitive answers in early preclinical stages. The definitive answer is really at the end of the clinical trials. What a drug discovery company needs to achieve early on is to proceed to a rank-ordering exercise and select the candidates with an optimal efficacy and toxicology profile before entering clinical trials.

Considering that the biotechnology sector's knowledge base is both complex and expanding, with widely dispersed sources of expertise, the innovation process will be found in networks of learning rather than at the

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enterprise level. Concepts such as open innovation (Chesbrough, 2003) imply that firms enjoy permeable boundaries. Creativity and innovation can be both spun-in and -out to and from a firm respectively and thus offering a better complementarity with the innovation strategy.

Recent literature on inter-firm collaborations and innovation provides mixed evidence on the effects of externally acquired assets on firm innovative performance (Cockburn and Henderson, 1998; Coombs and Hull, 1998; Ahuja and Katila, 2001; Prabhu, Chandy and Ellis, 2005). This study is based on the assumption that the integration of processes of technology sourcing, management of information and knowledge creation help increase the likelihood of reaching exploitation and securing competitive sustainability for the firm (Figure 2). We believe because of the uncertain and incremental nature of the value added of an early stage technology it is essential for biotechnology companies to identify, validate, harmonize and integrate complementary and mutually supportive technologies in order to improve substantially the quality of candidate drugs that enter the development stage. The greater ability to identify and bring in external technologies enhances a firm's flexibility to adapt to uncertain changes in the environments.

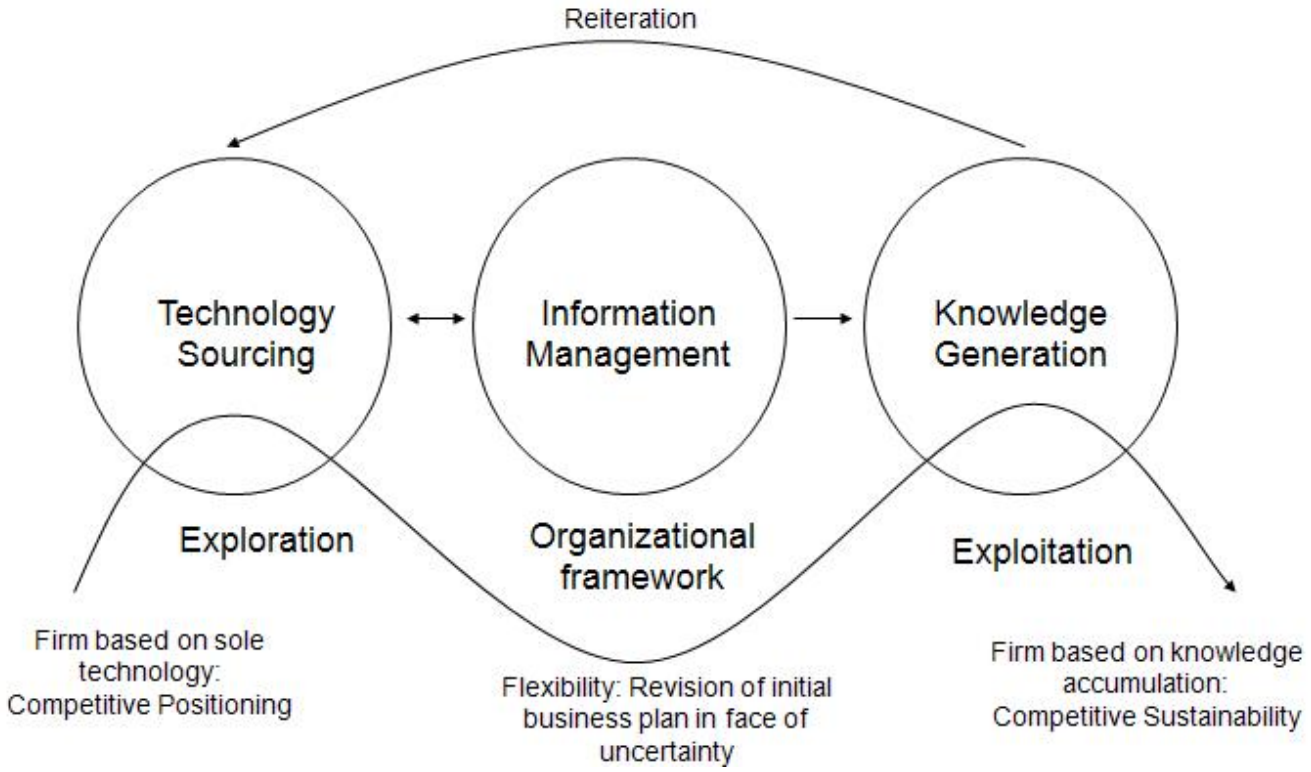

Figure 2. Organizational learning process in the drug discovery process

Figure 2. The key to achieving superior R&D productivity and speed and superior products takes into account a firm's technology sourcing, information management and knowledge creation capabilities. This requires an intra-firm organizational framework capable of bridging the gap between a firm's explorative and exploitative capabilities.

Many biotechnology firms have turned to external sourcing strategies and learning alliances in order to gain access to novel knowledge and reduce uncertainty in R&D. However, we believe in order to strike the adequate balance between exploration and exploitation, mergers & acquisitions (M&A) may be the preferred choice of external technology acquisition for the discovery and pre-clinical phases of the drug discovery process. Other modes of collaborations such as strategic alliances collaborations would be more appropriate for the development phase of the process. Previous studies fail to capture the growing importance of the dynamic

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nature of such relationships between biotechnology companies, engendered by the low R&D output.

The research outlined in this study suggests that the best approach for a research intensive company to overcome the dilemma of technological uncertainty is to implement an organizational model to combine diversity in exploration and integrative capabilities for exploitation.

2. Literature on external sourcing of knowledge

The implementation of strategies requires a thorough understanding of the external environment in terms of technology, competition and demand. This perspective has underpinned the development of new concepts, such as dynamic capabilities (Teece et al., 1997; Deeds et al., 2000; Eisenhardt and Martin, 2000; Zollo and Winter, 2002). Moreover, the concept of technological learning as the process that allows the firm to enhance, expand and/or renew its knowledge base and competences as a response to changes in technology, competition and demand has been highlighted (Hitt et al. 2000). Eisenhardt and Martin (2000) refer to dynamic capabilities as "the firm's processes that use resources to integrate, reconfigure, gain, and release resources to match and even create market change".

External technology acquisition has been viewed as an important method by firms to achieve higher economic returns (Tsai & Wang, 2008). Firms engage in external technology acquisition in response to a number of strategic incentives such as enhancing their knowledge base (Ahuja and Katila, 2001; Henderson and Cockburn, 1996; Rothaermel and Deeds, 2004), adding technological elements that increase opportunities for new scientific search (Kim and Kogut, 1996; Rosenkopf and Almeida, 2003), or altering their development trajectories (Mathews, 2003). The learning-based strategy can also provide higher visibility in financial markets (Walter and Barney 1990).

The organizational learning literature has recognized that formal inter-organizational alliances (ranging from licensing, equity participation, R&D consortium, R&D agreements to joint ventures) can provide access to the knowledge of a partnered organization (Inkpen 2000). According to innovation studies, knowledge contributing to the development of innovations is regularly obtained from outside organizations (Mansfield, 1995). The interaction between biotechnology companies has mainly taken forms of strategic alliances and M&A transactions.

2.1. Strategic Alliances

The field of biotechnology represents a sector with most alliances. Biotechnology companies have long relied on pharmaceutical partners using alliances in order increase their survival prospects and experience rapid growth (Niosi, 2003). Previous studies have highlighted the importance and characteristic of strategic alliances in a context characterized by technological changes and emerging new technologies (Grant and Baden-Fuller, 2004). In effect, early-stage biotechnology companies secure backward vertical alliances with academia to get access to basic knowledge and state-of-the-art technologies and forward vertical alliances with large pharmaceutical companies to access to complementary assets, expertise and financial resources (Galambos and Sturchio, 1998; McKelvey et al., 2003). As such, competencies and expertise in key technologies have been rapidly developed in biotechnology companies through cooperative alliances.

Strategic alliances have provided biotechnology companies with a less costly, less risky and more flexible approach of accessing new technologies without incurring excessive costs. In effect, in the eventuality that the outcome of an alliance is unsuccessful the biotechnology company can terminate the collaboration in a flexible and cost-effective manner.

Shan, Walker and Kogut (1994) have demonstrated that strategic alliances have a positive impact on firm innovativeness. There can be no doubt that alliances are not only significant but also acquire an increased strategic importance for all new entrants concerned. If anything, the high number of alliances reflects first and foremost a division of innovative labour in the drug market. Firms utilize alliances as learning vehicles for matching its competences with the evolving technology, competition and demand.

For small and medium sized firms, the main implication is that a strategy focused on learning through alliances can significantly reduce the interval between the production of scientific knowledge and the commercializa-

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tion of products (Gambardella 1995). A strategy based on strategic alliances also helps defray costs and alleviate technological and commercial uncertainty (Das and Teng, 1996). Perhaps unsurprisingly, firms using alliances increase their survival prospects and experience rapid growth (Niosi 2003). However, studies have demonstrated that 30 to 70% of alliances are not successful (Kogut 1989; Bleeke and Ernst 1995)

2.2. Acquisitions

As a complementary strategy to internal learning and learning through alliances, companies may also acquire, or merge with other companies (Wernerfelt 1984; Van Rooij, 2005) and thus improving long-term survival rates (Vermeulen and Barkema 2001). On acquisitions and innovation, Prabhu et al (2005) argue that acquisitions can be a "tonic" for firm innovative performance. Consolidating complementary competences and technologies has been suggested as an explanation to decrease inertia and create synergies through economies of scale and scope.

Zahra (1996) has reported that external technology acquisitions is positively associated with firm performance in terms of sales and market growth. Furthermore, Jones at al. (2001) has reported that internally available resources enhance the effect of external technology acquisition on product performance.

M&As have often been triggered by the belief that the combined value of technology platforms are greater than the sum of their parts, in part because the combination of these competences often allows technology platform companies to reduce rigidities by becoming fully-integrated drug discovery firms, and in part because the very business of conducting innovative activities in chemistry, informatics, biology and instrumentation can synergize to achieve economies of scope and scale.

A relevant stream of research has examined complementarity effects of internal resource development and external resource acquisition by arguing that it is such complementarities that impact firm innovative performance (Duysters & Hagedoorn, 2000; Cassiman B, Veugelers R. 2006.). Recently, Tsai & Wang (2008) highlight the importance of internal R&D investment accumulation for firms wishing to gain competence. Also, it has been previously demonstrated that accumulating internal R&D investment over time, firms can expand their technological knowledge or capability (Cohen & Levinthal, 1990; Duysters & Hagedoorn, 2000). From a drug discovery perspective, a critical capability may be the leveraging of diverse knowledge both within and across therapeutic areas in the combined firm. (Jung, 2002).

Moreover, Mathews (2003) has argued that firms may not have the organizational capabilities to realize potential benefits from the technology acquired thus they are confronted with low levels of financial and product performance. This aspect was further developed by Smith & Sharif (2007) where they highlight the important role of human expertise, organizational structure and information assets in the acquisition of technology assets.

3. Drug discovery R&D productivity and its implications for technology sourcing

The former head of Smithkline Beecham in 2000 claimed that biotechnology had been a bad investment citing 1,900 clinical failures and only 137 products reaching the market for the period between 1985 ad 2000 (Biocentury Extra, 2000). However, several academic studies have concluded that drugs developed in an alliance are more likely to reach the market than drugs developed independently by an originating company. One study examined 1,900 compounds developed by over 900 firms between 1988 and 2000 concluded that drugs developed in alliances had a 9 to 14 percent point higher probability of successfully completing phase 2 and phase 3, respectively, than drugs developed by a single company (Danzon etal., 2005). These positive effects were even stronger when the in-licensing firm had considerable experience in drug development. Dimasi (2001) also arrived at similar results using slightly different samples and time periods.

More recently, Czerepak and Ryser (2008) observed for the 2 year period spanning from January 2006 to December 2007, that 103 products were approved by the FDA with 47(45%) originating from the biotechnology sector; 16 (16%) were developed through partnerships between biotechnology and pharmaceutical companies and 40 (39%) were covered by pharmaceutical companies including 4 that were in-licensed from biotechnology companies. However, only 31 of all FDA approvals

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were novel drugs or new chemical structures with 9 coming from the biotechnology sector and 5 through partnerships and the remaining from the pharmaceutical sector. The authors further reported that for each FDA approval, there was on average one Phase III failure with 95% of these failures were products originating from the biotechnology sector. When only novel drugs were considered the failure rate was even higher with 1,6 Phase III failures for every approval. Novel drugs developed by biotechnology companies fared worse, on average, with 4.7 failures for every approval. Also, the authors further observed that the pharmaceutical sector had a much better success rate than the biotechnology sector in getting drugs approved. Also, it was noted that biotechnology-pharmaceutical alliances had significantly fewer failures.

According to Recombinant Capital, an online database service monitoring the biotechnology sector, biotechnology companies enjoyed the following trend of strategic alliances ever since the year 2000: 534 (2000), 623 (2001), 640 (2002), 641 (2003), 594 (2004), 642 (2005) and 669 (2006). Interestingly, the percentage of late stage deals had increased by 10% from 21,5% when comparing mean values for years 2001/02 and 2005/06.

The better success rates obtained for FDA approvals from the pharmaceutical sector and alliances result mainly because of a pharmaceutical company's prior experience in clinical development and regulatory expertise that can help them to better evaluate the probability of success of clinical trials and approval. In effect, pharmaceutical companies have the financial strength to undertake safety tests in large populations prior to market approval. This allows them to avoid misconceptions about clinical development that can compromise the development and favour diminished quality.

The biotechnology industry's low R&D productivity can be explained mainly by two reasons: 1) The complexity of the drug discovery process and the sector's incapacity to plan and integrate processes, enforce data integrity, and better manage resources through a range of different technologies; 2) Biotechnology companies business models attempt to link technological capabilities to future market needs in a resource constrained environment and high investor expectations. The investment community's short-term focus and disappointment regarding the sector's R&D output has forced biotechnology companies to bridge the gap between technological potential and commercialization in order to meet those expectations. However, this has forced the greatly of them to embark on ill-prepared, accelerated and incomplete clinical trials with low quality products that ultimately experienced failure further down the development process.

4. Coping with a turbulent environment

Companies deeply involved in outsourcing their research efforts with a variety of different partners, even though each being coherent, due to discrepancies in data integrity will not be able to fully capitalize on the product information flow from one stage to another within the value chain of the drug discovery process. Furthermore, many of the biotechnology companies may not have the organizational capabilities to realize potential benefits from the technology acquired.

But all those companies share common challenges: a novel base of technology and a complex context in which that the technology must be applied. The positioning of a technology within the overall drug discovery value chain is unique. At the time a drug discovery program is initiated, limited data is available regarding the R&D project, resources and time required to successfully realize the future payoff. However, completing successive stages will incrementally reveal data related to these matters with increasing visibility regarding the barriers to completion.

Thus, an efficient management of information, knowledge, and organizational learning appears as the principal source of competitiveness. In order to secure competitive sustainability biotechnology companies need to source and evaluate information; organize and harmonize information, integrate data and process information in order to generate knowledge (Figure 3).

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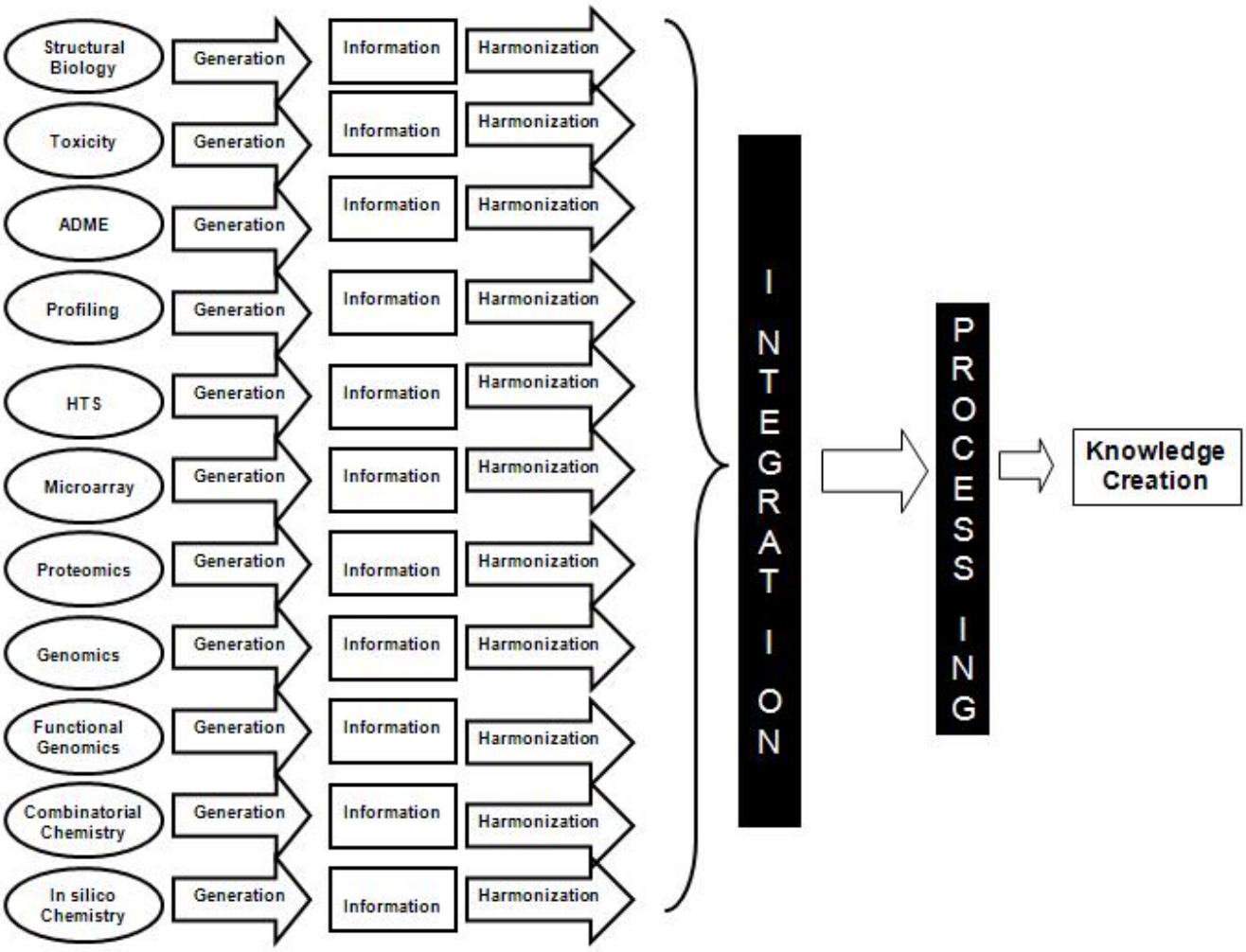

Figure 3. R&D strategy based on the identification, validation, harmonization, integration and processing of internally coherent but mutually supportive technologies contributes to the convergence of innovation.

The biotechnology company as a learning organization must develop the ability to create, acquire and transform knowledge. Learning organizations are provided with a network of shared information where empowerment is valued as the capacity to transform new knowledge into innovations, as shared knowledge is processed and implemented. As such, if a firm is to increase its chances of survival in a turbulent environment, it must also achieve the right balance involving the exploration of new possibilities and the exploitation of old certainties (McNamara and Baden-Fuller 1999).

4.1. Sourcing

A company's ability to choose technologies wisely will have a large impact on the performance of its R&D organization in terms of time to market, cost-effectiveness, productivity and product quality. The advent of diverse cutting-edge science into biomedical research and drug discovery has necessitated a redesign of the drug discovery process in the direction of more industrialized processes. In effect, the emergence of "rational drug design" paradigm in the discovery process has created niches for focused and highly specialized firms where the expertise is based on a sole technology platform or disease indication. Biotechnology companies can typically only afford to cover a few technologies and therapeutic areas and often find themselves in a situation of losing their way in the labyrinth of options presented by the various technologies. In effect, because of the distinct disciplines within the industry, knowledge acquisition from the development process can be ex-

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tremely high. The explosion of new discovery technologies necessitates the formation of complementary organizational structures.

Moreover, the fact that much of R&D in biotechnology is based on incompletely understood living systems such as humans, animals, and plants implies that R&D programs are subject to drastic technological feasibility and uncertainty. Each technology is typically only part of the larger set of activities in the R&D value delivery system in which it participates. The lack of interaction and integration amongst the various technologies within the value chain will favour the development of many unpromising drug candidates.

Coordination of such-inter technology extensions at the level of the value chain represents the realistic vision of value creation learning within the drug discovery process. Otherwise in the absence of mutually supportive technologies enormous value gets lost. Implementing platforms that incorporate other value-adding technologies has become a pre-requisite for success. The option of ignoring such issues will undoubtedly compromise a company's long-term success.

Companies having a wider view of the drug discovery process will be in a better position to exploit external knowledge produced. This way companies will avoid any short sightedness by overseeing linkages upstream and downstream of their own technologies and capabilities.

4.2. Harmonizing

The challenges involve in the collection, storage and analysis of the large amounts of biological and chemical data being produced by high-throughput biology, screening, profiling and chemical library generation technologies.

Standardization is required in order to facilitate information exchange based on shared norms between various disciplines. Thus, for the advancement of R&D productivity, harmonization at multiple levels is essential. Minimum information standards for the description of data sets and common languages for the description of biological pathways as well as for the mathematical modelling need to be developed.

As a consequence, the assembly of large integrated models providing novel biological insights and the unified view of all relevant intelligence information will allow the development of techniques to aid scientists in making decisions based on accurate information. Most initiatives undertaken by biotechnology companies within the drug discovery value chain will need to focus on information sharing between disparate systems. Even though the bulk of current information contains large amounts of knowledge, however, it is extremely difficult if not possible to gain access to that information.

Additionally, most of the data models for these systems have evolved separately from different sets of requirements. To further complicate matters, many different companies have implemented systems using different products and information models. Thus standards for characterization, manufacture and sharing information about modular biological devices may lead to a more efficient predictable and design driven drug discovery process.

The biological interpretation of the data will be facilitated by various tools, which place the analysis results into context with existing biological knowledge. Thus, efforts to unify and standardize the way in which information is recorded should make the interpretation of large-scale data experiments easier.

4.3. Integrating

The combination of novelty and complexity makes a company's excellence in technology integration critical. This need has become even more acute for the technologies involved in the early phase of the drug discovery process. The integration of biological information from various sources, such as large scale data produced by various experimental techniques, provides a valuable platform for the drug candidate identification and selection.

In effect, various technologies utilized within the drug discovery value chain are mutually supportive. This implies that within the drug discovery value chain companies pursuing R&D activities generate knowledge as output that is in turn utilized as input to enhance and expand its value-added. The outcome of R&D endeavours of knowledge generation through learning and integration provides the right rational and infrastructure to sustain a competitive advantage.

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Such integrated approaches will help the prioritization of preclinical drug candidates. As a consequence, drug discovery companies are concentrating their efforts on approaches to raise the "probability of success" of lead candidates in an effort to decrease the rate of attrition in the development process.

4.4. Processing

The biotechnology sector has been overwhelmed by the information explosion in the last several years. As such data processing has become essential in managing this information overload. The efficient management of information and knowledge generation consists of incorporating novel information, capitalizing on existing information and integrating novel and existing information in order to create knowledge, and finally putting that knowledge into exploitation.

These activities are executed through the implementation of technology and organizational structures in order to raise the yield of existing knowledge and produce new knowledge (Figure 3). Critical in this effort is in acquiring, harmonizing, integrating in order to generate knowledge for learning, problem solving, and decision making.

As such knowledge management highlights critical functions and potential bottlenecks which hinder knowledge flows to the stage of exploitation. It will ultimately allow the biotechnology to protect and enhance its intellectual assets, seeks opportunities to improve decisions, services and products through adding intelligence, increase value and provide flexibility.

5. Implications of technology sourcing on business strategy

The management of knowledge would be the systematic process of sourcing, validating, selecting, organizing, differentiating and generating knowledge. In other words, it attempts to generate and utilize spaces of technology interaction that allow the development of the intangible assets that support the firm in the achievement of its objectives. Thus, gaining and sustaining a competitive advantage requires that a company understands the entire value delivery system and not just the segment of the value chain in which it participates. This necessitates the management of competitive capabilities at a wider scale and no longer based at a firm level based on a sole technology.

As complex as it might seem to implement platforms that incorporate the role of other value-adding technologies, the option of ignoring these wider issues is quickly becoming unrealistic for biotechnology companies. This evolution requires a fundamental recasting of intra and inter-firm organizational frameworks, business models and strategic orientations. Firms can increase considerably their operational efficiency and R&D productivity by providing direction capabilities within the technology maze of the drug discovery process.

In the early stage of the drug discovery process innovation is based on an open network where firms engage in efforts to establish direct contacts with all their partners. This creates a situation that ultimately contributes to the dispersion of innovation and is characterized by high managerial involvement. In effect, different partners have access to different flows of information, whilst at this stage value is essentially created through a closed network where information is exchanged and transformed based on shared norms.

Achieving this goal is the primary objective of he biotechnology sector's efforts to renovate and reinvigorate its R&D. Developing technology internally meets the needs of capability building for the firm, but it requires more time and greater resources. Acquiring technology externally constitutes the best alternative for the sector which suffers from rapidly changing technology and high investor expectations. Such an approach will lead access to new knowledge and organizational structures that are essential in serving markets of unmet medical needs in the most cost-effective and rational way.

Thus, collaboration amongst biotechnology firms through M&A will enable them to diversify risk by securing options on different projects and allow them to deliver quality and innovative products entering clinical trials at a faster rate. M&A at the early stages of the drug discovery process helps implement an organizational structure based on a closed network favouring knowledge creation through the convergence of innovation which is achieved by the coordination of data collection, validation, screening and processing. Thus, a strategy based on M&A will be capable of coordinating intra/inter-firm extensions at the level of the value chain

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and of projecting the pragmatic vision of value creation planning within the drug discovery process.

Access to capital markets and strategic alliances with major pharmaceutical companies constitute the two major sources of financing for the biotechnology's sector. The extremely high financing needs of the traditional discovery to market business-model can leave companies orphaned if investors lose interest along the way. In effect, the pressure exercised by the capital markets has considerable influence on the nature of the dynamics characterizing the biotechnology sector. The lack of a financing opportunity from the capital markets can jeopardize the viability of a biotechnology company. As a consequence, biotechnology companies may find themselves in situations where they have to let go of value embedded in their R&D programmes or potentially become acquisition targets. To avoid such vulnerability companies need to adopt a business model based on M&A in order to optimize the time to market aspect of drug discovery and development. As such, they will be in a position of delivering an earlier return by fully capitalizing on their R&D portfolios and by prioritizing factors that are financially central in determining the long-term success.

Moreover, major pharmaceutical companies have the possibility of choosing among a vast array of technologies and products in development. As such, major pharmaceutical companies entering such collaborative arrangements, have the possibility of influencing their objective to technology sourcing. In effect, instead of managing numerous strategic alliances they prefer dealing with one company enjoying a wide technology platform capable of responding and adapting to their short- and medium term needs. The current trend of M&A amongst pharmaceutical companies has forced also the biotechnology sector to embark on a M&A trend and thus allowing them into re-organizing themselves and implementing new and more cost-effective resource allocation strategies. Recombinant capital reports the following figures regarding M&A activity within the biotechnology sector since 2001: 52 (2001), 36(2002), 48 (2003), 49 (2004), 50 (2005), 36 (2006) and 52 (2007). Such re-organizations are often accompanied by new technology portfolio management which could help many biotechnology companies access precious sources of capital particularly when financial markets are not so receptive to the sector.

If the biotechnology company is to achieve and maintain a position of superior productivity, it must also think strategically about long-term outcome and devote significant resources to R&D. Companies that have implemented strategic orientations in order to secure sustainability have shaped and clarified their choices within a competitive environment.

6. Conclusion

We argue that exploratory technological acquisitions help firms gain access to technical knowledge that could support innovation. Furthermore, they will lead to asset accumulation and the generation of new capabilities in relation to the firms' absorptive capacity. Biotechnology companies should support the development of those competencies that allow a more effective and significant utilization of the information and the knowledge available. In effect, too many companies start with the technology itself rather than what they are trying to achieve. They do not ask, 'What is our business strategy? What fundamental research questions are we trying to answer? What technologies do we need to answer those questions and how will this technology help us to answer them? Ideally, companies need to determine in advance technological process required to guarantee the success of the product development. In effect, the development of innovative therapeutic compounds is largely technology driven that necessitates on building upon existing technologies until new bottlenecks appear.

The main question that needs to be answered is to determine that how sustainable is the commercial development of drugs in drug discovery's uncertain environment where early-stage biotechnology companies only have limited expertise? The key to maintaining a superior performance here is not only a matter of technology value-added and differentiation is a matter of sustainable competitive dynamics. This is particularly true for an environment of great turbulence such as he biotechnology sector where technology is subject to obsolescence and its outcome uncertain and remote, where competition is intense and resources limited whilst markets being volatile. In such an environment, the firm may rapidly lose it competitive advantage (or positioning), so purposeful efforts to enhance, expend and renew its competences are often the key to survival.

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The organizations that look to manage knowledge generation within the firm must develop an organizational culture in which it is possible to share, integrate and transform knowledge. In other words, its business strategy that should dictate the technologies in which the company invests. This approach ensures the development of a technology platform that genuinely supports the product pipeline, which is balanced in terms of risk and will deliver a real return on investment (Figure 4). Biotechnology companies face difficult and complex decisions when identifying, evaluating and selecting new technologies to apply to their R&D. The majority of technologies that yield truly novel products originate in other companies and often in other industries. The most effective technological advancements often unite concepts and components from diverse areas including physics, chemistry, biology, electronics, engineering, computer science, material science, optics, microfabrication and information science.

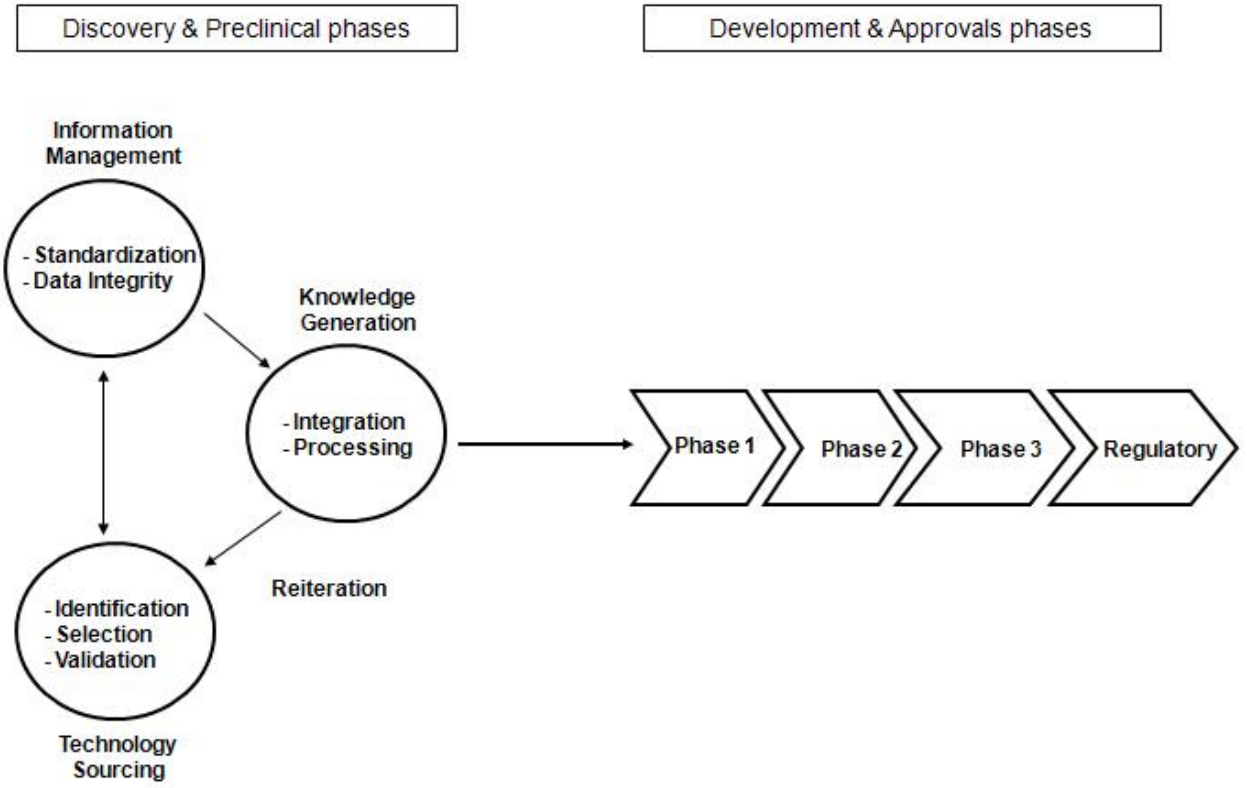

Figure 4. The objective for a biotechnology company is to provide definitive answers in early stages of the drug discovery process by increasing the attrition rates of low quality products and favouring the entrance of promising products into clinical development.

Considering the long product development time lines the contribution of external technology acquisition to firm performance cannot be measured using traditional performance indicators. Technology sourcing in the dynamic nature of the biotechnology industry can be used as learning vehicles for matching its competences with the evolving technology, competition and demand.

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