Optimizing the discovery organization for innovation

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Strategic management is the process of adapting organizational structure and management principles to fit the strategic goal of the business unit. The pharmaceutical industry has generally been expert at optimizing its organizations for drug development, but has rarely implemented different structures for the early discovery process, where the objective is innovation and the transformation of innovation into drug projects. Here, a set of strategic management methods is proposed, covering team composition, organizational structure, management principles and portfolio management, which are designed to increase the level of innovation in the early drug discovery process.

For the past 15–20 years, our understanding of the molecular basis of drug actions, as well as disease and biological processes, has burgeoned, which has resulted in a considerable increase in the number of potential targets that can be pursued by the pharmaceutical industry for disease treatment. However, instead of seeing a steep rise in the number of new molecules entering clinical development, the industry has experienced a steady decline [1–5; www.fda.gov/oc/initiatives/criticalpath/whitepaper.html]. The cause of this decline is unlikely to be an increasing inability of companies to move drugs through development, because, during this period, most companies have been able to improve the efficiency of their screening, lead optimization and development processes even further. A more probable explanation is that the industry has been unable to take advantage of this new biological knowledge in terms of transforming the information into drug projects, an explanation supported by the tendency of many companies to pursue the same non-proprietary targets. These trends, therefore, strongly indicate that the industry suffers from an innovation deficit in the early drug discovery process and has problems with the transformation of ideas into feasible drug programmes [6–9; www-1.ibm.com/services/us/index.wss/ibvstudy/imc/a1001099].

Strategic management is the process of adapting organizational structure, management principles and control methods to fit the strategic goals of the business unit [10]. For example, in recent years, it has become common to divide the R&D organization of a pharmaceutical company into separate 'R' and 'D' units, because their strategy and, therefore, their requirements in terms of organization and people skills are considerably different. In most companies, the research environment is organized into departments by discipline with a traditional line structure and a formalized meeting structure. This is an organizational format that is highly suitable when tasks can be categorized based on discipline and are similar across most drug programmes. However, the process of conceiving new ideas for disease treatment and converting them into feasible drug programmes is an ever-changing process and it is known that this type of innovation is not favoured by rigid structures or highly formalized routes of communication, requiring instead a more fluid organizational form

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1359-6446/05/$ – see front matter PII: S1359-6446(05)03539-7

[10–14]. Therefore, by implementing a different strategic management form for the early phase of the drug discovery process, it could be possible to increase the level of innovation in the industry.

Organization

Recently, a new model for the drug discovery path at the level of the individual project was proposed (Figure 1a) [15]. In this model, the goals of strategy determination, exploratory screening and proof-of-principle approach are based on biological, medical and chemical information to identify and validate new targets and approaches for disease treatment, together with suitable lead structures. By contrast, the goals of lead optimization and development are within the framework of an existing and validated drug project that contains lead structures to which a set of known tools can be applied to develop one or more drug candidates suitable for clinical testing. The drug discovery path (Figure 1b) can therefore, in terms of tasks, be divided into a discovery phase, in which there are continuous interactions between research, strategy determination, exploratory screening and proof-of-principle, followed by a linear process consisting of lead optimization and development. Defining innovation as any change relative to existing products and approaches, and novelty as the degree of change [16], it can be said that the goal of the discovery phase is project innovation, whereas for the lead optimization phase it is product innovation.

In terms of strategic management, the goals for lead optimization and development are rapid and effective product innovation and development, and the tasks associated with this process are generally similar across drug programmes and can be divided based on discipline. Therefore, these areas should maintain the organization with discipline-based departments, for example, chemistry, ADME and toxicology, and fixed line structures (Figure 2a). For the discovery phase, the goal is project innovation, which is a variable process with a high level of uncertainty requiring the identification of new approaches to disease treatment and the transformation of these ideas into realistic drug projects. The degree of novelty in the innovation can range from completely new approaches to disease treatment to much simpler ideas, such as a drug that relieves a specific side effect resulting from the primary treatment or that has improved pharmacokinetic properties. However, to be able to generate such ideas, it is necessary to assemble a team where each of the members knows the indication and the unmet medical needs in depth and where there are representatives of all the disciplines required on a regular basis to perform effective drug discovery in the indication, for example, chemists, computer modellers, biologists, pharmacologists and biochemists. The advantage of combining disciplines in the same building with neighbouring offices is that the interaction between people with different types of knowledge and training frequently leads to the generation of completely new concepts and approaches

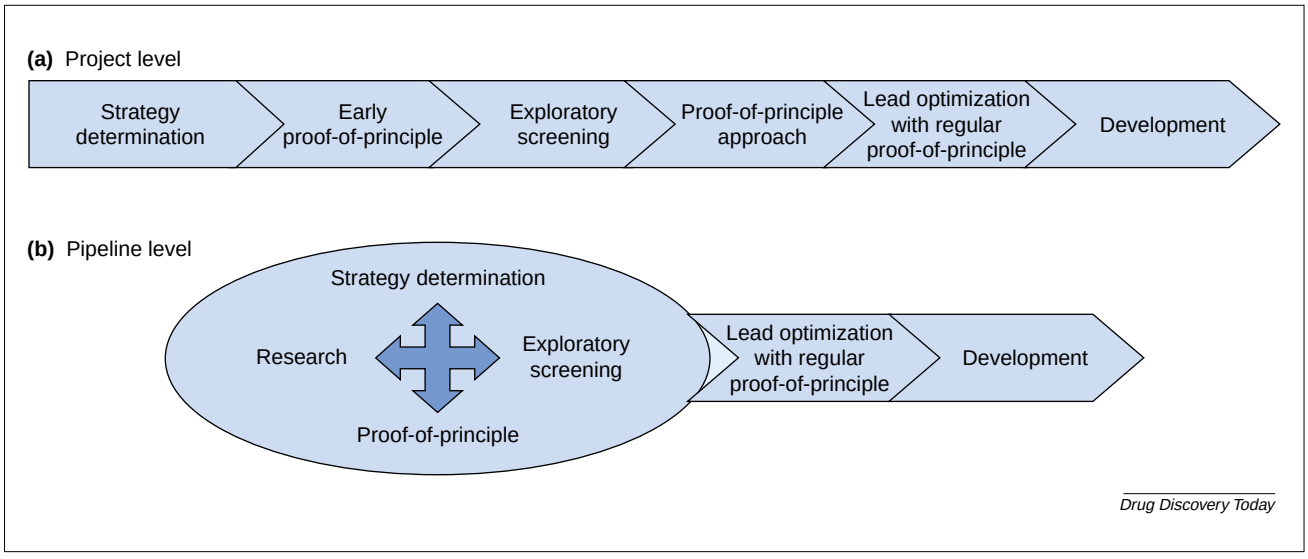

FIGURE 1

Drug discovery model. (a) The model [15] consists of: (i) strategy determination, where information regarding the biological function of the target, clinical manifestations of the disease, screening strategy and proof-of-principle criteria are determined; (ii) early proof-of-principle, where the therapeutic value of the target is determined if suitable reference compounds are available; (iii) exploratory screening, where the initial screening is conducted using, for example, HTS assays and HTS or disease models, together with small-scale exploratory chemistry; (iv) proof-of-principle approach, where the identified lead structures are tested in the chosen disease model; (v) lead optimization with regular proof-of-principle studies, where lead structures are optimized for target affinity and selectivity and where they are tested on a regular basis in the chosen disease-model. **(b)** The drug discovery path can, in terms of organization, be drawn as a discovery phase containing a circular process of research, strategy determination, exploratory screening and proof-of-principle studies, followed by a linear process consisting of lead optimization and development. The goal of the discovery phase is innovation – identifying new approaches for disease treatment – whereas the goal of lead optimization and development is product development – the identification of a suitable drug candidate for clinical testing based on a validated drug project.

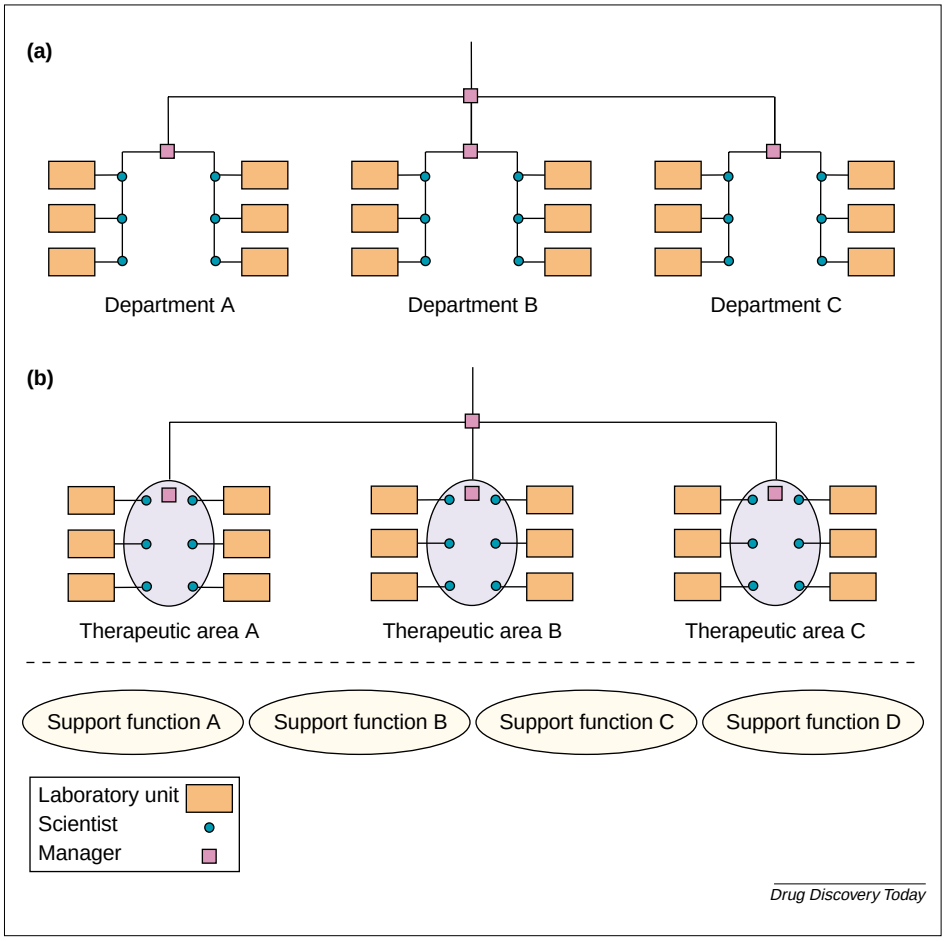

FIGURE 2

Departmental organization of drug discovery. (a) Organizational structure for lead optimization and development with departments organized by discipline. This organization is currently used by most companies. **(b)** Suggested organizational structure for the discovery phase. Departments are organized by therapeutic area as autonomous units, where each unit contains the necessary expertise to perform drug discovery in the indication (e.g. chemistry, cell biology and pharmacology). Tasks not needed on a daily basis or that cannot be replicated (possibly as a result of high costs) for each therapeutic area are organized as support functions.

[17,18]. For disciplines not required regularly or that primarily deliver a result based on an already conceived idea (e.g. HTS), these should participate in the discovery process on an *ad hoc* basis to minimize the size of the group and to avoid too many replications of functions across therapeutic areas. The discovery phase (Figure 2b) should therefore be organized by therapeutic area, with each team including representatives of all the disciplines that are required for the project innovation process, and informal routes of communication should be established within the team.

Management

For lead optimization and development, most companies have successfully implemented a formal hierarchical structure with clear reporting lines and meeting formats to ensure effective product development, either using a discipline-based department structure in combination with a project organization or matrix-type organization. However, for the discovery phase, where the goal is to facilitate innovation management studies, the use of a combination of process- and value-based management is recommended.

In process management [10,19–21], the manager directs the strategy and resource allocations of the group instead of controlling the specific tasks each researcher has to perform. This means less direct control of the team members, who are thus more autonomous and able to pursue their own ideas and to act on their initiatives. In value-based management, specific values and principles are promoted as 'being the right way' and this method is particularly important in an organization where members have a high degree of autonomy because it ensures that they always act in a manner that supports the company strategy. Peters and Waterman [22] studied several large companies known for being able to maintain a high level of innovation over many years and identified eight key values that characterized them and are also relevant to the pharmaceutical industry. These were (abbreviated versions): (i) a bias for action (i.e. do something instead of discussing forever and producing long reports); (ii) staying close to the customer (i.e. understand the medical need); (iii) autonomy and entrepreneurship (i.e. break the organization into small units and encourage people to think independently and competitively); (iv) productivity through people (i.e. create in all employees the awareness that their best efforts are essential and that they will share in the rewards of the success of the company); (v) hands-on, value-driven (i.e. upper management should stay in touch with the business); (vi) 'stick to the knitting' (i.e. remain within the business the company knows best); (vii) simple form, lean staff (i.e. few administrative layers and the minimum number of people at the upper levels); and (viii) simultaneous lose-tight properties (i.e. foster a climate where people accept the core values of the company combined with tolerance for all employees who accept those values).

The question now is how can this work in real life? With respect to the values, these are usually most effectively propagated through the power of example, that is to say, the managers act in accordance with the values and emphasize them in the evaluation of the actions of an individual. One example can be the process of initiating a new project in the discovery phase. Most projects will begin as an idea originating from one or more indi-

TABLE 1

Mapping of the drug discovery pipeline

	Research		Strategy determination		Exploratory screening		LO-1		LO-2		Milestones		
Project name	**Type**	**Resource**	**Risk**	**Resource**	**Risk**	**Resource**	**Risk**	**Resource**	**Risk**	**Resource**			
Project A			Low	1.0									
Project B			Mid	2.0									
Project C					High	3.0							
Project D					Mid	2.0							
Number of projects	**Research**		**Strategy determination**		**Exploratory screening**		**LO-1**		**LO-2**		**Discovery**	**LO**	**Dev/Clin**
Research projects													
Technology projects													
Drug projects			2.0		2.0						4.0		
Attrition rates (%)			50.0		50.0		50.0		50.0				
Capacity limitations													
Average duration			1.0		1.0		1.0		1.0				
Required projects			16.0		8.0		4.0		2.0		24.0	6.0	Goal = 1.0
Risk distribution	**Research**		**Strategy determination**		**Exploratory screening**		**LO-1**		**LO-2**		**Discovery**	**LO**	**Dev/Clin**
Low			1.0								1.0		
Medium			1.0		1.0						2.0		
High					1.0						1.0		
Resource allocation	**Research**		**Strategy determination**		**Exploratory screening**		**LO-1**		**LO-2**		**Discovery**	**LO**	**Dev/Clin**
Total per stage			3.0		5.0						8.0		
Average per project			1.5		2.5								
Needed per project			2.0		3.0								
Needed for existing project			4.0		6.0						10.0		
Needed for required project			32.0		24.0						56.0		
Indication average	**Research**		**Strategy determination**		**Exploratory screening**		**LO-1**		**LO-2**		**Discovery**	**LO**	**Dev/Clin**
Indication X													
Indication Y													
Indication Z													

Abbreviation: Dev/Clin, drugs in development or clinical testing.

viduals in the discovery team or from someone outside the team. In accordance with the values, all ideas must be treated equally independently of who generated them, for example, in many companies, it is a standing joke that only proposals made by upper management and supported by an external expert will ever be pursued. Furthermore, the ideas must be judged based on their feasibility and the availability of supporting data, not personal beliefs and assumptions. 'Sticking to the knitting' will mean the company has experience in the therapeutic area and a small group of team members can therefore rapidly determine the feasibility and value of the idea (i.e. a bias for action). If supporting data for the idea can be obtained through a simple experiment, such as the testing of a reference compound in a suitable disease model, they will initiate the study without further discussions. Alternatively, if the proposal requires full-scale assay development (i.e. HTS), they will prepare a short strategy outline that forms the basis for the decision concerning whether or not to proceed, which can be discussed at the next team meeting.

In this drug discovery process, the role of the scientist is to perform research and drug evaluations in his or her laboratory unit, to generate the new ideas for disease treatment and to support constructively the ideas of others. The role of the manager [23–27] is also to participate in this process, but his or her key tasks are to support the innovative process, to ensure that all aspects are considered in the course of transforming an idea or a finding into a project, for example, patenting, medical and marketing aspects, to ensure that projects advance at an acceptable pace, to use his or her experience in drug discovery to

guide the process in the right direction and to ensure the team has the necessary facilities to perform their work. It is evident that the success of this process will be highly dependent on the composition of the team and the manager. The team should be assembled to cover the skills needed, as well as types of personality, such as a combination of highly creative people with people who understand how to transform an idea into a concrete project. Although it can certainly be advantageous to have a highly recognized scientist in the position of team manager, his or her primary function is to encourage and support the innovative skills of the team and to ensure an effective drug discovery process. Therefore, the team manager should be selected based on these skills and not a publication record. Finally, important aspects to consider (but which will not be covered here) are the management of scientists and those factors that motivate them to perform high-level and creative research within the boundaries of the company strategy. Several studies have shown that although monetary incentives are important, individuals cannot function without 'softer' factors, such as recognition, autonomy and responsibility [28].

For teams working intensely on projects, there is always the risk that 'group thinking' evolves, thus it is important to have external boards questioning the drug discovery strategy in detail. One instrument is regular portfolio meetings where medical and marketing teams, as well as upper management, participate together with the research team to evaluate the direction of the drug discovery efforts. Another instrument is external scientific and drug discovery advisory boards that can assess the rationale of the research groups and provide input to the process. A scientific advisory board can question and contribute to the scientific aspects of the drug discovery programmes, whereas a drug discovery advisory board can act as a sparring-partner to evaluate the strategic and commercial aspects. The board members should exclusively have an advisory role, because they will only be in contact with the company on an irregular basis and their main activities are elsewhere. The boards should be assembled to provide expertise in the therapeutic area, as well as to complement the knowledge of the team in areas where they are perhaps not as proficient. The most common approach for selecting board members is to examine publication lists and latest titles, but this does not mean that the selected individuals will contribute to the development of the company in a productive manner, and thus advisory board meetings are frequently more for show than for substance. One method for appraising the suitability of potential members is to ask them to evaluate a specific project or set of activities and to provide a written report with their recommendations. This will enable the company to appraise their ability to contribute to the company strategy and their willingness to work seriously. Finally, another instrument is small workshop-like meetings to discuss specific topics that are important to the company at that point in time.

Control

Process management is the method of managing the activities and priorities of a group through strategy settings and resource allocations. On a daily level, this will be the responsibility of the manager, but determining the long-term strategy of the therapeutic area should also involve people outside the team to ensure that the directions taken are realistic and in line with company strategy. An effective instrument for the performance of such a process is portfolio analysis [29,30]. In most companies, detailed portfolio analysis is only performed for late-stage projects, but the analysis can be equally productive for early pipeline analysis if parameters, such as risk assessment, resource allocation, resource constraints, indication coverage and desired output, are included.

For the process of mapping the pipeline, the drug discovery model in Figure 1a has been converted into table format (Table 1). The research category has been added to ensure a continuous focus on target discovery and the implementation of new technologies, and the lead optimization (LO) phase has been divided into two parts based on the consideration that the attrition rate might be higher during the early phase of lead optimization.

Project level

Within Table 1, the individual projects are listed under 'project names' and the estimated risk level and allocated resources are entered for each project, according to its stage in the development path. The risk factors depend on the actual project and for this reason it is initially necessary to establish clear goals and criteria for each project and then, based on these criteria, to identify project-relevant risk factors. These will change depending on the goal of the project, for example, whether the aim is to develop an antidepressant or an antidepressant with fast onset of action. The stage of the project will also have an impact on the risk factors, for example, during the early stage of a project the biological risks might be most important, whereas, in the LO-phase, it could be chemical risk factors. The number of factors should be kept at an absolute minimum and the analysis should only include those that have a direct impact on the decision process to keep the procedure manageable. The risk factors can be entered into the table as a number (e.g. 1 to 3) or as a category (e.g. low, medium or high). In addition, they can be represented as a composite measure for each project, for example, average risk or the highest risk level, or they can be entered as 2–3 different values indicative of, for example, biological, chemical and medical risk factors (Table 2).

For the purposes of the analysis, it is important to distinguish between risk and priority. Risk denotes factors that are not understood or cannot be controlled at the time of portfolio analysis, such as the true therapeutic value of a novel target or whether a novel anxiolytic compound has a faster onset of action (if a suitable animal model is not available to evaluate this parameter). Priority is a question

TABLE 2

Risk factors that could be relevant to a given project

Risk factor	Low	Medium	High
Biology			
Target	Clinically validated	Validated in animal model	Novel target
Disease models	Available	Available, but low validity	Not available
Unmet needs	Can be measured	Measurable, but low validity	Cannot be measured
Chemistry			
Target	Standard target (e.g. receptor)	Ion channel modulator	Protein–protein interactions
Structures	Many	Few	One
Medical			
Cause of disease	Known	Theories available	Unknown
Disease definition	Well-defined disorder	Poorly defined	New unrecognized disease
Clinical trial	Standard	High placebo response	Not previously performed
Other factors			
Experience in indication	Good	Medium	Low
Competitive situation	Same as competitors	Some competitors ahead	Lagging far behind
Market size	Known	Could change in near future	Uncertain

of the value attached to the information. For example, the clinical testing of a disease-modifying treatment for Alzheimer's disease is expensive and complicated, but, at the company level, it is feasible and possible to decide *a priori* whether the company is willing and able to make the necessary investments to address this question.

Resources can be represented either as the number of full-time-employees (FTEs) per month or per year allocated to the project or as an amount indicative of the monthly or total costs of the project – if needed the resource allocation can be subdivided by functional area. The number should give a reasonable impression of the capacity allocated to the project and the estimation method must be consistent across projects. Finally, additional factors can be included, but the analysis should be kept as simple as possible to maintain the focus on strategic aspects and not to drown the process in detail.

Pipeline level

At the level of individual projects, Table 1 can now be used to set project milestones. The purpose of a milestone should be to advance the project to a stage where it is possible to reduce the risks associated with the project, thus enabling progression to the next stage in the drug discovery path and/or to receive additional resources. The most obvious criterion is a positive proof-of-principle study to proceed into lead optimization, but it can also be the definition of the exact patient population that could benefit from a treatment or the performance of a proof-of-principle study with a readily available reference compound to proceed from strategy determination into exploratory screening. Similarly, if the project does not reach its milestone, termination of the project or reduction in its resource allocation must be considered.

At the level of the pipeline, the interpretation of an analysis will depend on the specific strategy and situation of the company, thus the purpose here is only to demonstrate the types of information that can be obtained. The first issue is whether the number of drug projects is sufficient to support a continuous flow of drug candidates into the development phase and clinical testing. For this part of the analysis, the first step is to determine the number of on-going drug projects in each of the phases from strategy determination to LO-2. The second step is to determine at company level how many compounds per year must be forwarded to development, that is, the output goal of LO into development must be decided. The third step is to estimate: (i) the average attrition rate per stage (i.e. the percentage of drug projects that can be expected to proceed from one stage to the next in the drug discovery path), which will usually be determined from in-house data or external benchmarking information; (ii) identification of capacity limitations in the process (e.g. the HTS group can only handle four projects per year for this therapeutic area); and (iii) the average duration required for a project team to complete a stage in the pathway. Next, based on this information, it is possible to calculate the required number of concurrent drug projects in each stage to achieve the goal – the required projects. For example, if the average attrition rate is 50% and the average duration of each stage is one year, then the goal of delivering one compound into development each year will require two LO-2 projects, four LO-1 projects, eight exploratory screening projects and 16 strategy determination projects. However, if there is a limitation of four projects per year in exploratory screening, the pipeline will only be able to deliver 0.5 development candidates per year, meaning that the company will need to revise its strategy. A com-

parison of this information with the actual number of projects will, for the stages after the research phase, show how well the actual number of projects and their distribution across the pipeline fits with the plans of the company.

For the analysis of risk distribution, the number of low-, medium- and high-risk projects are determined per stage, and the question here is whether the distribution of risk levels across stages and projects match the risk willingness of the company. Factors to consider can be that attrition rates could increase if there is a large proportion of high-risk projects, whereby the company will not be able to supply its clinical pipeline or afford too many failures.

Calculation of the total amount of allocated resources per stage (to assess the distribution of resources across stages) is the first step in the analysis of resource allocation. An early-stage company might have a skewed distribution towards the discovery phase, whereas later-stage companies with established pipelines should be biased towards the LO-phase. The second step is to calculate the average amount of resources per project per stage – the 'total per stage' divided by the number of projects resulting in the 'average per project'. Comparison of the value generated with the risk levels and resource allocations of individual projects will indicate if the distribution of resources relative to the risk level is acceptable, for example, if a high-risk project receives much more resources relative to a low risk project. The third step is based on in-house information combined with, for example, external benchmarking information to estimate the amount of resources that is normally needed for a project at a given stage to proceed at an acceptable pace – needed per project (in cases where there are significant differences in resource requirement for different project types, Table 1 should be modified accordingly). The fourth step is the multiplication of the value of the need per project with the number of existing projects (drug projects) to give 'needed for existing projects'. Comparison of the value generated from this calculation with the actual amount of resources (total per stage) will indicate whether existing projects are properly resourced. The final step is the multiplication of needed per project with 'required projects' to calculate 'needed for required projects', which reveals the amount of resources required to support the goal of a particular output of the pipeline. A comparison of this value with 'total per stage' will identify whether the company is able to achieve this goal, whether it needs to revise its strategy and expectations or whether it must increase its in-licensing activities.

For each stage, the number of projects targeting a specific indication is determined (e.g. including primary indications and spin-off opportunities). This distribution will indicate if the pipeline is highly scattered or, alternatively, highly focused and whether this fits the experience, existing product line, life cycle management and the sales and marketing forces of the company.

The research stage is also included in the analysis (Table 1). The purpose of including this stage is to ensure

BOX 1

Portfolio mapping for a hypothetical medium-sized pharmaceutical company in the CNS field

With respect to the number of projects, the company has an estimated need of 0.5 development candidates per year, which translates into four concurrent LO projects using the indicated attrition rates and durations per stage*. The company has four LO projects, meaning that, in the LO phase, the company can achieve its goal. For risk distribution, it is acceptable for the LO projects with only one high-risk project, and with respect to the resource allocation, to be appropriately resourced to ensure their continuous development. For the discovery phase, there should be 18 projects to maintain the desired output. However, the company only has six projects, indicating that the company cannot supply its late stage pipeline long-term from only in-house projects. In terms of risk, there is a high proportion of high-risk projects, which could suggest further problems with the supply of projects to the LO phase, because high-risk projects are more likely to fail. Examination of the resource allocation reveals that existing projects are appropriately resourced, meaning that existing projects can at least be expected to proceed as planned through the pipeline, but the data also show that the company will not be able to resource the number of projects required to reach its desired output. Closer examination of the discovery phase indicates that the company needs six projects in the exploratory phase and 12 in strategy determination and the maximum capacities are four and 15, respectively. The company only has three projects in exploratory screening and three in strategy determination and can therefore increase the number of discovery projects without reaching its capacity limits. However, this would mean that either the existing projects will no longer be appropriately resourced or the company must increase the resource allocation to the discovery phase. Alternatively, the company must obtain projects from outside resources, through in-licensing activities. In addition, the company should address the number of high-risk projects in the discovery phase, either through efforts to reduce the risks and/or by replacing the projects associated with the greatest risk with lower risk alternatives. These changes could potentially also reduce the attrition rates, thereby decreasing the high number of projects required in the early stages. In terms of research activities, the company has four projects, and they use more than the expected amount of resources per project, thus the allocated amounts of resource per research project could possibly be reduced to include more discovery projects or additional research activities to extend the core competence of the company. Finally, the indication coverage is focused in the LO phase, which should ensure that a drug will proceed into development covering Alzheimer's disease or schizophrenia. By contrast, the discovery part is focused on the introduction of new indication areas without providing further support for the indications in the LO phase and, depending on company strategy, this could or could not be the optimal strategy.

* For the purposes of this theoretical analysis, the risk factors for biology, chemistry and others for each project have been listed separately to facilitate the determination of milestones; the overall risk factor for a project was based on the highest of the three risk factors. The factors 1, 2 and 3 correspond to the risk levels low, medium and high, respectively. The resources represent allocated full-time employees per month (see supplementary Table available with the online version of this article; data and calculations available from author on request).

a continuous focus on research and technology projects. These projects are a necessary investment in the future and they are the only method by which the company can secure a continuous flow of new drug projects and can improve, or at least maintain, its technological core competence.

Advantages of process management

Although the specific structure of the portfolio map, risk factors and the analysis depends on the company and its specific strategy (Box 1 provides an example of a pipeline analysis for a hypothetical company), the process itself can, in all companies, be used as a strategic management tool. Portfolio mapping should be conducted on a regular basis (e.g. every 6 or 12 months) and the participants should include the upper management responsible for the research area, middle management of discovery, LO and key support functions, all discovery-responsible researchers within the therapeutic area, key researchers involved in LO-projects and, finally, representatives of the medical and marketing teams involved in the therapeutic area. There are several advantages associated with portfolio mapping: (i) the process will force the discussion to focus on strategic issues and not scientific detail, and can therefore serve to bridge understanding between business and research functions; (ii) the process will require the clear formulation of strategic intent and expectations by all levels involved and this will ensure that all have the same understanding of the position of the company and its direction; (iii) the discussions and interactions across levels will remove barriers and will facilitate a better understanding of the perspectives and strategies of the other part, which will lead to the improved performance of the company; and (iv) for upper management, it is an excellent opportunity to practice hands-on management and to evaluate the function of the research unit, because the openness of the discussions and the dynamics of the interactions will clearly display any problems. Portfolio mapping is therefore a simple tool for analysing the pipeline that will lead to a productive and concrete outcome that can be used by all levels in the organization. However, perhaps even more importantly, it is an effective upper management tool for explaining company strategy and for evaluating the research team.

Conclusion

The goal here has been to present a model for the organization of the early drug discovery process that not only seeks to support innovation and entrepreneurship but also implements control structures to ensure that projects are terminated in a timely manner and that resource allocations are matched to the risk level and stage of each project. It is only a model and it must be adapted to the specific company and its strategy, but the model emphasizes particular aspects of innovation that are often not considered. For this reason, it might be valuable to compare the current organization in a company with the model to determine if the implementation of one or more parts of the model could be beneficial. However, it must also be realized that any organizational change will have little impact unless it is accompanied by management principles that truly encourage innovation and where people understand and feel responsible for the company strategy, because only in such a research environment can the maximal potential of the organization be reached.

Acknowledgements

I thank Professor Dieter Hinzen and Jeanette Sams-Dodd for their comments on the manuscript.

References

1 Van den Haak, M.A. *et al*. (2004) *Industry Success Rates 2004*. CMR Report 04-234R
2 Chanda, S.K. and Caldwell, J.S. (2003) Fulfilling the promise: drug discovery in the post-genomic era. *Drug Discov. Today* 8, 168–174
3 Drews, J. (2000) Drug discovery: a historical perspective. *Science* 287, 1960–1964
4 Drews, J. (2003) Strategic trends in the drug industry. *Drug Discov. Today* 8, 411–420
5 Handen, J.S. (2002) The industrialization of drug discovery. *Drug Discov. Today* 7, 83–85
6 Weisbach, J.A. and Moos, W.H. (1995) Diagnosing the decline of major pharmaceutical research laboratories; a prescription for drug companies. *Drug Dev. Res*. 34, 243–259
7 Drews, J. and Ryser, S. (1996) Innovation deficits in the pharmaceutical industry. *Drug Inform. J*. 30, 97–108
8 Brown, D. and Superti-Furga, G. (2003) Rediscovering the sweet spot in drug discovery. *Drug Discov. Today* 8, 1067–1077
9 Horrobin, D.F. (2003) Opinion: modern biomedical research: an internally self-consistent universe with little contact with medical reality? *Nat. Rev. Drug Discov*. 2, 151–154
10 Stacy, R.D. (2002) *Strategic Management and Organizational Dynamics: The Challenge of Complexity*, Prentice Hall
11 Minzberg, H. (1983) *Structures in Five*, Prentice-Hall
12 Sengre, P.M. (1990) The leader's new work: building learning organizations. *Sloan Management Review* Fall, 7–23
13 Leonard, D. and Straus, S. (1997) Putting your company's whole brain to work. *Harv. Bus. Rev.*, 111–121
14 Kreiner, K. and Schults, M. (1993) Informal collaborations in R&D. The formation of networks across organizations. *Organ. Stud*. 14, 189–209
15 Sams-Dodd, F. (2005) Target-based drug discovery: is something wrong? *Drug Discov. Today* 10, 139–147
16 Tidd, J. et al. (2001) *Managing Innovation*, John Wiley and Sons
17 Lombardino, J.G. and Lowe, J.A., III (2004) The role of the medicinal chemist in drug discovery – then and now. *Nat. Rev. Drug Discov*. 3, 853–862
18 Erickson, D. (2003) Wanted: drug hunters. *In vivo* 21, 45–52
19 Minzberg, H. and Waters, J.A. (1985) Of strategies deliberate and emergent. *Strateg. Manage. J*. 6, 257–272
20 Goold, M. and Campbell, A. (1987) *Strategies and Styles*, Blackwell
21 Miles, R.E. and Snow, C.C. (1978) *Organizational Strategy, Structure and Process*, McGraw-Hill
22 Peters, T.J. and Waterman, R.H., Jr (1982) *In search of excellence*, Warner Books
23 Farris, G.F. (1982) The technical supervisor: beyond the Peter principle. In *Readings in the Management of Innovation* (Tushman, M.L. and Moore, W.L., eds), pp. 337–348, MIT Press
24 Tushman, M.L. (1982) Managing communication networks in R&D laboratories. In *Readings in the Management of Innovation* (Tushman, M.L. and Moore, W.L., eds), pp. 349–362, MIT Press
25 Jensen, I. *et al*. (1995) Skilled incompetence in the management of R&D. *Drug Dev. Res*. 35, 1–6
26 Herzog, R. (1997) Managing the R&D staff. *DN&P* 10, 488–493
27 Adler, G. (1997) When your star performer can't manage. *Harv. Bus. Rev*. July–August, 22–36
28 Herzberg, F. et al. (1959) *Work and Motivation,* Wiley
29 Cooper, R.G. *et al*. (2002) *Portfolio Management for New Products*, Perseus Publishing
30 Aaker, D.A. (2004) *Strategic Market Management*, John Wiley and Sons