R&D and Financial Resources and Capabilities Development in Life Science Ventures: A Dynamic Capabilities Perspective

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Submitted in fulfilment of the requirements for the degree of doctor of philosophy

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Glasgow

July 2011

Abstract

Life science firms compete in rapidly changing environments that demand substantial resources and capabilities. Nevertheless, there are a growing number of small life science firms, and these firms are having a profound impact on innovation in the industry. However, little is known on how these firms overcome resource constraints to finance and develop R&D resources and capabilities. Consequently, the purpose of this thesis is to empirically explore how small life science firms develop R&D and financial resources and capabilities. A closely related area that this research is also fundamentally concerned with is how R&D and financial resources and capabilities affect firms' early growth.

The central aim of this research is to unearth insights on the motivations, assets and processes that lead to the development of R&D and financial resources and capabilities. To accomplish this, the research draws on the resource-based view and dynamic capabilities. The resources-based view is interested in the resources from which firms derive competitive advantages. Whilst dynamic capabilities focus on how firms in rapidly changing environments – especially high technology environments – configure and reconfigure their assets and capabilities to develop competitive advantages. Because this research is concerned with the development of key resources and capabilities of firms in rapidly changing environments, a resource-based view influenced dynamic capabilities framework is used to isolate the development of R&D and financial resources and capabilities of life science firms.

An in depth case study approach is used to examine the research questions. It draws on longitudinal data collected from six life science firms. Data has been collected from twenty interviews and over 3000 pages of secondary data. The interview data is abstracted using four techniques: 1) identifying repetitions, 2) looking for transitions, 3) identifying similarities and differences and 4) cutting and sorting notable quotes. Following Miles and Huberman (1994), the data is then analysed using a multiple step abstraction and condensing process. A unique triangulation technique is used at the end of the study where the key informants are surveyed on the results of the qualitative analysis.

Results from the study indicate that a unique set of past decisions, future opportunities, assets, capabilities and routines leads to the development of R&D and financial resources and capabilities. It is evident in all of the case firms in this study that scientific breakthroughs, partnership opportunities, the founders' experience and the firm's ability to integrate resources and learn from earlier paths are vital to the development of R&D and financial resources and capabilities.

The study makes several contributions to the practice and scholarship of management. It provides insights on how small life science firms develop the R&D and financial resources to compete in a highly dynamic industry. From a scholarly perspective, it extends the dynamic capabilities framework and offers empirical support to several categories of dynamic capabilities. It also offers support to R&D and financial capabilities as categories of complementary assets. This thesis identifies details of the aforementioned aspects, discusses the importance of the findings in relation to the literature, and offers future research directions.

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Acknowledgements

There are many people that I must thank for their help on my PhD journey. This journey would not have been possible without them.

First and foremost, I am especially thankful to my supervisor Marian Jones. It has been a real honour and privilege to work with her. Her invaluable input and patience has kept me motivated and guided me to the end. I would especially like to thank her for not getting too frustrated with me every time that I wanted to change direction. There were many times in the process that I veered off, but she always brought me back to the centre. I also thank my secondary supervisors Stephen Young and Anna Morgan-Thomas who also helped to guide me.

Many thanks to all the professors and administrators who helped me during my time at the university. A special thanks to Anne McCusker who always went out of her way to accommodate me.

Another group I really need to thank is my fellow PhD students. You are a wonderful group and I hope to remain life-long friends with all of you. Special thanks to my dear friend Karl Warner who went out of his way to house, guide and support me.

Thanks to the people from outside the university that helped me. I am indebted to the executives who gave their time for my research. I am also indebted to my friend Carl Miller for his editing and academic guidance.

I must also give my appreciation to my family and closest friends. Mem Wongsa provided valuable design help and was a tremendous support to me, and I am deeply grateful for this. My cousin Elisa provided me invaluable editing help that I must acknowledge. My friends David Smith and Jeff Kennedy also supplied valuable knowledge and support that helped me throughout this process. Lastly, I am grateful to my mom, dad, brother, sister-in-law, niece Anna, my newest niece (born May 28, 2011) Amelia, Aunt Roxana and Uncle Bill for their unwavering support.

Author's Declaration

The attached material is submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Management Research in the University of Glasgow, and accords with the University Regulations on plagiarism as detailed in the Programme Handbook and University Calendar.

I declare that this document embodies the results of my own work and that it has been composed by me. Following normal academic conventions, I have made due acknowledgement of the work of others. The thesis is less than 100,000 words in length, exclusive of tables, figures, bibliographies and appendices, and complies with the stipulations set out for the degree of Doctor of Philosophy by the University of Glasgow and the Faculty of Law, Business and Social Science.

Signed: *Jon Carrick*

Date: *July 2011*

Definitions and acronyms

CAs	Complementary assets. Auxiliary assets and capabilities needed in the commercialisation of an innovation.
Endowments	For the purposes of this study endowments are the cumulative resources, assets and capabilities that a firm possesses.
GCAs	Generic complementary assets. CAs that are easily developed or bought on the free market.
IO	Industrial Organisational economics
NTBFs	New Technology Based Firms
Particalise	This refers to a process of breaking up matter into very fine particles.
Paths	Opportunities that are available to firms or past decisions that affect a firm's strategy.
Positions	Resources, assets or capabilities that a firm possesses.
RBV	Resource-Based View
ROI	Return On Investment
SCAs	Specialised Complementary Assets. Auxiliary assets and capabilities that are not easily obtained or contracted.
SEC	Securities Exchange Commission. US regulatory body that all firms traded on a US stock exchange must report to.
SBIR Grant	Small Business Innovation Research grant; US government grant given to small innovative firms that have a technology that can help fill a government need.
TMT	Top Management Team. These are executive-level managers that are in charge of the firm.
VC	Venture Capital. High risk capital invested in promising ventures.
VCs	Venture Capitalists. The study refers to this as the firm(s) that invests in high-risk ventures.

Chapter 1 – Introduction

Chapter Objectives

- To provide an overview of the life science industry in the USA and globally in the contextual setting for the research.
- To discuss the fundamental issues in the resource-based view of the firm and how this interacts with the dynamic capabilities framework that this study draws on.
- To delineate the broad aims and objectives relating to the development of financial assets and capabilities in life science ventures.
- To provide an overview of the structure of the research and a brief description of each chapter.

1.1 Background of the research

This thesis examines the resource and capability development of small life science firms. Its focus is on R&D and financial resources and capabilities, what they are, how they are determined and deployed by small life science firms towards competitive advantage. This study is specifically interested in small life science firms that are less than 250 employees and in the early stages of development; which the study refers to as life science ventures. A growing number of these ventures are springing up around the world, and these small ventures are having a profound effect on the industry (Van Beuzekom & Arundel, 2009). Evidence suggests that these ventures require a unique set of R&D and financial resources and capabilities to grow (Baum & Silverman, 2004; Murray & Wolfson, 2010; Zheng, Liu, & George, 2009).

Although there is a growing recognition of the importance of R&D and financial resources and capabilities on the growth of young life science ventures, research on the development of these resources is still scarce. Studies on these topics tend to focus on larger firms (Mittra, 2007; Rothaermel & Hess, 2007). This is largely attributed to the public nature of large life science firms and the fact that data is more readily available. Moreover, Murray and Wolfson (2010) suggest that the nature of life science start-ups has changed drastically in the last five years. This has made studying these firms difficult, and this coupled with the fact that these firms often fail, make studying small life science firms difficult. However, it is estimated that over forty per cent of biotech innovations stem from firms of under 250 employees, and there are over 300 life science start-ups formulated in the United States (US) each year (Van Beuzekom & Arundel, 2009). Thus investigating how these firms develop R&D and financial resources and capabilities is an important topic that needs to be addressed. This thesis aims to help fill this gap by examining the paths, positions and processes that lead to the development of life science ventures' R&D and financial resources and capabilities.

The literature on life science firms reveals that they are highly innovative and that innovation is often the motivation for their start-up (Audretsch, 2001). Furthermore, innovation drives the strategic path of these firms. Often life science ventures are focused on the development of innovation at the onset and do not have revenues to support the firm's operations (Baum & Silverman, 2004; Powell, Koput, Bowie, & Smith-Doerr, 2002). In consequence, life science ventures face large resource constraints. Despite this,

few studies examine how life science firms overcome these restraints to develop R&D and financial resources and capabilities.

Resources and capabilities are germane to the development of life science firms, and for this reason, both the resource based view (RBV) and dynamic capabilities models are particularly good lenses for looking at life science firms (Coombs & Deeds, 2000; Madhok & Osegowitsch, 2000; Rothaermel & Hess, 2007). The RBV concentrates on the valuable, rare, imperfectly imitable and non-substitutable resources that lead to long-term competitive advantages (Barney, 1991).

Dynamic capabilities is fundamentally concerned with how firms reconfigure their resources and capabilities in response to rapidly changing environments (Teece, 1986; Teece, Pisano, & Shuen, 1997). Accordingly, firms use dynamic capabilities, such as higher level learning abilities, to create competitive advantages (Winter, 2000). Firms develop dynamic capabilities from their paths, positions and processes (Teece et al., 1997). Past paths represent the events that shaped the firm's present state, such as large scale investments in technology. Future paths are the strategic options available to the firm (Winter, 2003). The past decisions (past paths) and opportunities (future paths) are often the main motivators in a firm's strategic decisions; i.e. firms strategize according to the opportunities available and restraints caused by previous decisions (Eisenhardt, 2000). Positions represent the resources and capabilities of the firm (Madhok & Osegowitsch, 2000). Processes represent a firm's systems and routines of utilising resources and capabilities (Teece et al., 1997). Two important by-products that stems from a firm's paths, positions and processes are key resources and capabilities. Firms with high-level dynamic capabilities are capable of developing complementary assets (Rothaermel and Hess, 2007; Teece, 2007).

Complementary assets (CAs) are the auxiliary assets that are needed in the growth of technology firms (Rothaermel, 2001a; Tripsas, 1997); e.g. R&D, manufacturing, logistics, distribution and service assets. For instance, many firms have a core technology that they are aiming to pursue, but in order to bring the technology to market; the firms need auxiliary R&D assets to refine the technology. In this instance R&D assets could be viewed through a CAs lens (Teece, 1986).

Research is especially interested in the specialised complementary assets (SCAs) that are needed in firm growth. These are the CAs that are not easily developed or contracted for and are a major source of competitive advantage. An example of an SCA is service capabilities of a medical device firm. In many cases medical devices require specialised service capabilities to maintain the product, and if a firm is unable to service the device, then the device cannot be commercialised. These capabilities are such that they require sophisticated and often tacit knowledge that cannot easily be replicated. Whilst generic complementary assets (GCAs) are needed, they are not a source of competitive advantage (Teece, 1986; Teece, 2007; Trispas, 1997). For this reason, most studies focus on SCAs.

The present research takes an integrative approach to looking at the R&D and financial resources and capabilities needed in life science firm growth by integrating a framework based on the resource-based view (RBV) and dynamic capabilities. At the heart of this thesis is dynamic capabilities, and according to this theory, firms continually respond to changing environmental conditions by reconfiguring assets and capabilities (Teece et al., 1997; Winter, 2003). This study also integrates the RBV by incorporating the importance of resource picking abilities with dynamic capabilities. Accordingly, a firm's resource picking abilities and dynamic capabilities is what leads the development of competitive advantages (Eckhardt & Shane, 2010; Makadok, 2001; Teece, 1986; Tripsas, 1997); i.e. the firm chooses the best resources available to it and then dynamically works with these resources to maximise their resources' value.

A review of the literature reveals that a number of resources and capabilities are required for the commercialisation of a life science innovation: R&D (Deeds, DeCarolis, & Coombs, 2000; Lowe & Taylor, 1998), finance (Powell et al., 2002), specialised production (Motohashi, 2008; Rothaermel, 2001b), distribution (Arora & Gambardella, 1990; Rothaermel, 2001b) and service (Tripsas, 1997). Teece (1986) suggests that the resources needed for growth depends on the unique strategic circumstances of the firm. Most studies assume that key resources and capabilities come entirely from internal sources or partners. This is contrary to the R&D literature which clearly indicates that innovation is often the result of the combined effort of many entities, such as universities, industry consortiums and governments (Miotti & Sachwald, 2003). Another shortcoming of studies investigating resources and capabilities is that they ignore the element of time. To date, few studies have looked at the development of key resources and capabilities throughout the growth of a firm; nor have studies properly examined the effect of R&D

and financial resources and capabilities throughout the early growth of life science ventures.

Teece (1986) suggests that the resources and capabilities needed for a firm to grow depend on the strategic circumstances of the firms – which are largely influenced by industrial forces. The present research is fundamentally concerned with the life science industry, which has rapidly-changing technological and regulatory environments, making a firm's ability to reconfigure its resources and capabilities to respond to these changes paramount (Rothaermel & Hess, 2007). Furthermore, previous research indicates that life science firms have specific resources and capabilities that are essential to the commercialisation of innovations – including R&D and financial resources and capabilities (Arora & Gambardella, 1990; Rothaermel, 2001b). Moreover, life science firms in the US are heavily reliant on equity investors (Gompers & Lerner, 2004; Lerner & Merges, 1998) and the ability to attract capital and manage the finances of a firm – which is critical to growth. Because of this, it is important for this thesis to integrate the influence of VC on the development of R&D and financial resources and capabilities.

This thesis examines the resource and capability development of life science ventures. Its focus is on strategic R&D and financial resources and capabilities, what they are and how they are determined and deployed by firms towards competitive advantage. Life science firms have been examined extensively in management studies. However, little work examines how new life science ventures develop key R&D and financial resources and capabilities. The extant research does not offer sound insight specific to life science ventures, nor does it address how these firms develop R&D and financial resources and capabilities. Moreover, the existing theory does not provide strong constructs on this topic. The objective of this study is to help close these gaps. Thus the research objectives and questions are as follows:

Objective 1

To explore and examine how key R&D and financial resources and capabilities are developed.

Q1) How does an innovation affect the development of firms?

1a) Does the source of an innovation affect the development of R&D and financial resources and capabilities?

2a) Does the type of innovation affect the development of R&D and financial resources and capabilities?

Q2) Do partnerships have a major bearing on the development of R&D and financial resources and capabilities?

2a) How do life science ventures know what inputs they have to offer potential partners?

2b) How do life science ventures identify what partners have to offer?

Q3) How does the pursuit of financing impact the development of life science ventures?

3a) How do different financial strategies impact the financial trajectories of firms?

Q4) Are highly trained, skilled and experienced individuals driving the development of R&D and financial resources and capabilities?

4a) Are star scientists playing an important role in the development of a firm's R&D?

Q5) What processes are important to the development of life science ventures' R&D and financial resources and capabilities?

Objective 2

To explore and examine the effect of R&D and financial resources and capabilities on the growth of life science ventures.

Q6) How are R&D and financial resources integral to life science ventures?

6a) How closely linked are R&D and financial resources and capabilities?

6b) Do R&D and financial resources co-evolve?

Q7) Can R&D and financial resources and capabilities serve as a CA?

Q8) Can R&D and financial resources and capabilities act as an SCA?

The first objective stems from the fact that little research investigates the development of R&D and financial resources and capabilities in life science ventures. Despite the importance of R&D and financial resources and capabilities, research has not paid much attention to these in the context of life science ventures. The literature underscores the importance of R&D (Kenney, 1986) and financial (Baum & Silverman, 2004; Powell et al., 2002) resources and capabilities of larger life science firms – but little work examines

these from a small life science firm's perspective. There is a real gap in understanding how life science ventures develop R&D and financial resources and capabilities.

The second object stems from the fact that little research examines the effect of R&D and financial resources and capabilities on the early growth of life science ventures. It is clear from the entrepreneurship literature that new firms are often at a disadvantage because of resource constraints and liability of newness (Singh, Tucker, & House, 1986). Life science new ventures face particularly large constraints, as the industry requires substantial allotments of financial and human capital (Baum & Silverman, 2004). Despite this fact, scores of life science ventures have successfully sprung up all around the globe. However, scholarly research fails to properly examine how new life science ventures' R&D and financial resources and capabilities help them overcome large resource restraints to successfully grow and prosper.

This research aims to – at least partially – fill the gaps identified above. In order to do so, this research uses a RBV influenced dynamic capabilities framework to examine the paths, positions and processes that lead to the development of R&D and financial resources and capabilities. This framework provides an ideal lens to isolate the underpinnings of the development of R&D and financial resources and capabilities in life science ventures. The paths aspect allows questions to be developed that focus on the motivation for developing R&D and financial resources; i.e. what opportunities and past decisions influenced these? The positions aspect allows for questions to focus on the resources that are leveraged to create these resources and capabilities. The processes aspect allows for questions to isolate the important routines firms use to develop R&D and financial resources and capabilities.

1.2 Research approach

This research adopts a qualitative approach in looking at the research objectives. The lack of defined constructs on the development of life science firms' R&D and financial resources and capabilities makes a qualitative approach appropriate. Moreover, this was also influenced by the fact that the main theory – dynamic capabilities – pertinent to this study is not well- developed. The consequence is a need to uncover meaning in the original context and to allow for a theory-building rather than theory-testing approach. The best way to accomplish this is through qualitative methods (Edmondson & McManus, 2007; Eisenhardt & Graebner, 2007).

One method that is often used in a qualitative manner is the case study. This is a particularly good method for providing deep insights and for building theory (Eisenhardt, 1989). Therefore, the case study method was chosen as the research vehicle for this study. An abductive process that recognised that research does not have to be purely inductive or deductive was used to both extend and build new theory. This study takes a longitudinal approach to investigating the development of resources and capabilities over time.

Life science firms were chosen for this research because the researcher has practical management experience in a firm in the industry, and this study was spurred by the researcher's quest to unearth insights on how life science ventures can more effectively develop key resources and capabilities. Thus, six small life science firms served as the sample for the study. Moreover, the industry and the characteristics of life science firms are ideal for the examination of R&D and financial resources. This thesis is also part of wider, on-going research at the University of Glasgow's Centre for Internationalisation and Enterprise Research (CIER), which is looking at the growth of life science firms. Following Eisenhardt (1991), this research adopts a funnelling process that consists of multiple rounds of interviews where each round builds on the previous round; the first round of interviews was conducted, and, subsequently, a more-concentrated interview schedule was created with the intent of honing down the results from the first round of interviews. A third round of interviews was then conducted with the firms. The interview schedule for this round of interviews was created based on the analysis of the first two rounds of interviews and triangulated the key findings from the study.

Each round of interviews' schedules contained both open and closed-ended questions. The open-ended questions allowed the respondents to offer undirected insights, whilst the closed-ended questions captured specific points (Kvale & Brinkmann, 2008). These questions aimed to unearth insights on the important assets and capabilities needed in growth. The second round of interviews probed the paths, positions and processes leading to the development of R&D and financial resources and capabilities inherent to the early growth of life science firms.

Over 3000 pages of secondary data supplemented the twenty plus hours of interview data. The data was analysed using Miles and Huberman's (1994) three-level abstraction process. The analysis uses several of Russell and Bernard's (2003) qualitative data analysis

techniques for each level of abstraction; i.e. 1) identifying repetitions, 2) looking for transitions, 3) identifying similarities and differences and 4) cutting and sorting notable quotes. A case log and a qualitative software program were used to track and query the data. A within-case, within-group and cross-case analysis then further refines the data. Tables, graphs and charts are used as the basis for the analysis and presentation of the findings.

1.3 Structure of the thesis

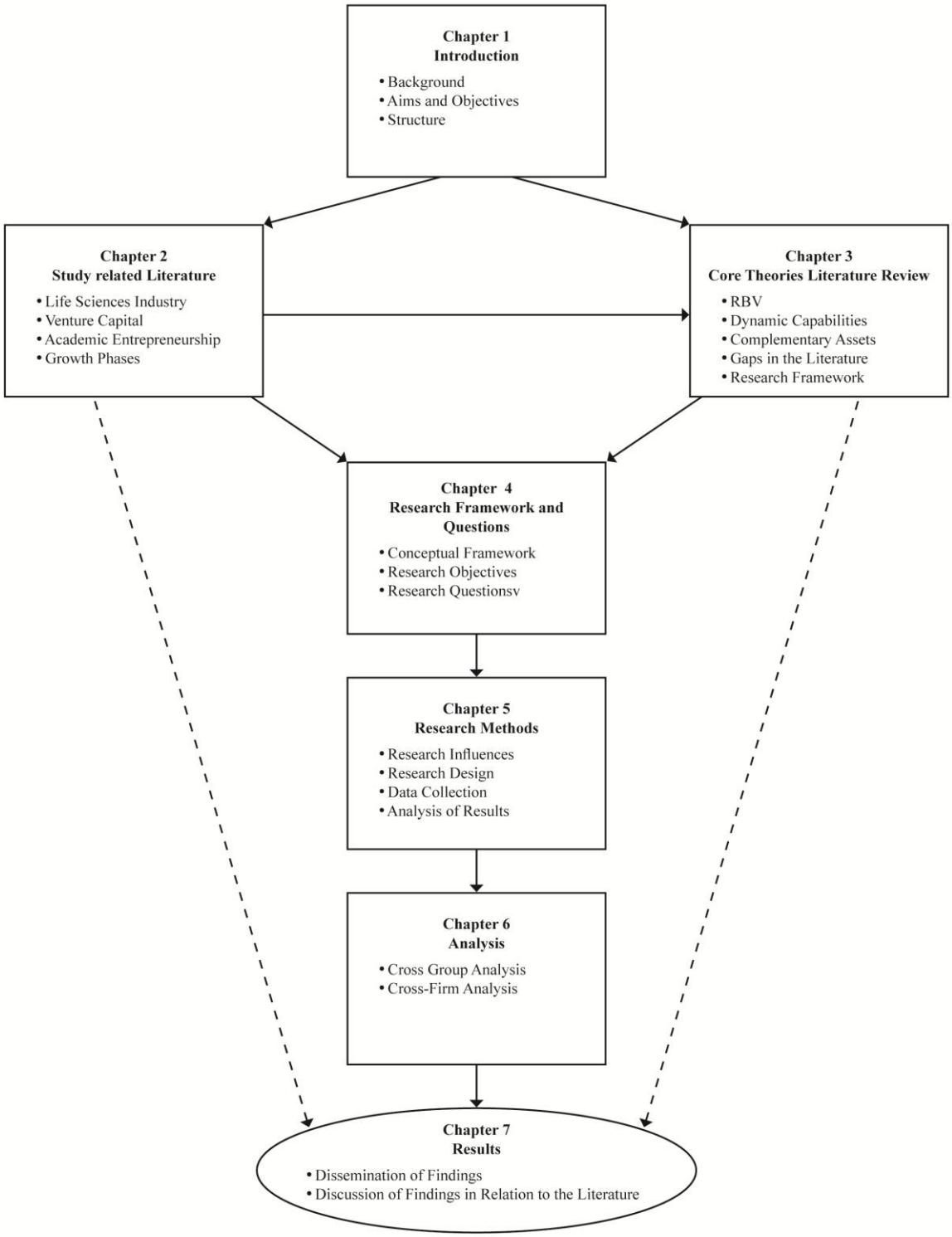
This research focuses on the R&D and financial resources and capabilities needed in the early growth of life science firms. The fact that this is an industry-based study made it important to begin the research with an overview of the life science industry. This review reveals that this is a highly innovative industry with rapidly changing environments (Cooke, 2002; Madhok & Osegowitsch, 2000). A firm's resources and capabilities are vital to its competitive position in the industry. Because of the importance of resources and capabilities to this study, the resource-based view and dynamic capabilities are appropriate models to examine this research through; therefore, the second part of the literature review overviews the resource-based literatures. This reveals that the resource based paradigm has evolved from Penrose's seminal ideas on productive inputs into the RBV, and recently it has evolved into the modern-day theory of dynamic capabilities, which is concerned with how firms reconfigure their resources and capabilities in response to rapidly changing environments (Teece et al., 1997). For this reason it is an ideal lens to look at the development of resources and capabilities in life science ventures (Madhok & Osegowitsch, 2000) and consequently is the main theory that the present study draws on.

The third part of the thesis presents the qualitative methods chosen to examine the research questions. It starts with an overview of the philosophical influences that affected the research methods chosen, and it then goes on to detail the data collection process. Subsequently the chapter details the rigorous abstraction techniques that were formulated on the basis of Miles and Huberman (1994), Bernard and Ryan (2003) and Eisenhardt (1989). This abstraction involves a systematic process of identifying themes, trends, missing information and patterns in the data. A within-case, cross-group and cross-case analysis serves to further refine the data and present the findings in a parsimonious manner. The chapter then discusses the measures taken to ensure validity and reliability. A

number of techniques – including multiple means of triangulation – assure reliability and validity, or trustworthiness, as it is often referred to in the qualitative literature.

The results are presented in a within-group, cross-group and cross-case analysis. Subsequently the findings in relation to the literature are put forth. The structure and relation of each part of this thesis is depicted in Figure 1-1, and it is then sequentially detailed chapter-by-chapter below.

Figure 1-1: Thesis structure



Source: Author

Chapter One introduces the background of the study, the main bodies of literature that the study draws on, the research methods, the research framework, objectives and structure of the study. The aim of this chapter is to overview and lay out the thesis.

Chapter Two presents a review of the literature related to the characteristics of life science firms. It begins with a brief taxonomy of the industry and a discussion of the main characteristics of life science firms. A section on growth is included because this research is concerned with how R&D and financial resources and capabilities affect growth. This section establishes the appropriate ways to measure and view the growth of life science ventures.

Chapter Three presents the second part of the literature review on the core theories upon which this thesis draws. The chapter starts with a discussion of Penrose's growth of the firm, and then moves on to overview the development of the RBV, dynamic capabilities and CAs. A section on CAs is included because CAs are auxiliary assets and capabilities needed in the commercialisation of innovations, and are especially important to life science innovations (Rothaermel, 2001a). Moreover, R&D has been viewed through a CAs perspective, which also makes it important to this research.

Chapter Four presents the research's framework, objectives and questions. It first lays out the dynamic capabilities framework that the study draws on. Subsequently it lays out the objectives of the study, and then it details the research questions.

Chapter Five discusses the research methods selected for this study. A qualitative approach is taken based on the philosophical influences of the study. The chapter justifies the rationale for this approach and further discusses the exact case method used. It then justifies the rationale for the choice of case firms.

Chapter Six presents the findings from the analysis. Following Senker and Sharp (1997), the six case firms are divided into three groups based on industry subsector. For each group a within-case analysis is presented followed by an in depth cross-group analysis. Then the triangulation questionnaire that was completed by each firm is presented. This provides a framework for a cross-case analysis and serves to validate the findings. The analysis uses the following framework to present the findings:

1. Introduction of the firms.
2. A comparison of the paths, positions and processes that led to the development of R&D and financial resources and capabilities.
3. A comparison on the effect of the R&D and financial resources and capabilities on early growth.
4. Conclusion.

Chapter Seven discusses the findings of the study. It first uses the framework developed in chapter six to delineate the findings in relation to the objectives of the research and the literature. Next the chapter underscores the significance of the findings to practitioners and policy makers. The chapter then moves on to discuss the shortcomings of the study. Finally comes an overview of the impact of the research and suggestions for future research.

Chapter 2 – Life Science Industry Context

Chapter Objectives

- To give a background of the life science industry.
- To discuss the general characteristics of life science firms.
- To discuss the importance of specialised financing to life science firms.

2.1 Introduction

Life science ventures compete in a high velocity industry where innovation takes substantial capital and time to develop. Despite this, the number of small life science ventures is growing at an astonishing rate (Giovannetti, 2010). These firms have unique characteristics that influence their ability to compete. Therefore, it is important for this study to establish the context of the industry. In order to accomplish this, the chapter overviews the life science industry and the important factors that influence the industry. The second section presents an overview of the life science industry. This section provides important statistics and taxonomy of the firms that constitute the industry. The third section discusses the literature on firm growth. This section is included because this thesis is concerned with how resources and capabilities are developed in the early stages of life science firms' growth, and technology firms' growth patterns are markedly different than non-technology firms (Kazanjian & Drazin, 1990). Therefore, it is imperative to identify the appropriate lens to view the early growth of life science firms. The fourth section overviews the financing sources and capabilities that young life science firms draw on. This section is important because life science ventures usually engage in costly research and do not have revenues in their first few years (Murray and Wolfson, 2010).

This chapter establishes the context of the firms and the industry and gives an overview of the challenges these firms face and gives a broad understanding of what influences life science ventures and what resources they use to compete.

2.2 Life science firms

Life science firms are broadly defined as all firms involved in the commercialisation of products related to the scientific application of living organisms (Owen-Smith, Riccaboni, Pammolli, & Powell, 2002b; Powell & Owen-Smith, 1998). This includes the fields presented in Table 2-1 below. Although there are thirty fields in this table, there is one predominant one – biotechnology. Most of the literature and statistics on life science focus on biotechnology. In many cases in the US, the term biotechnology is synonymous with the term life science; it could be argued that biotechnology encompasses all of the fields of life science in some way, and some scholars accept the use of the two terms interchangeably (Powell & Owen-Smith, 1998). The United Nations Convention on Biological Diversity (2009, p. 216) defines biotechnology as *'Any technological*

application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use'. Van Beuzekom and Arundel (2006, p. 14) define biotechnology as *'the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services'*. It is evident that biotechnology and life science are closely related, and the distinction, if any, is not important for the purposes of the present research. It is important to note that the firms this study is interested in are ones that could be classified as either life science or biotechnology.

Table 2-1: Life science fields

Agrotechnology	Biomedical Engineering	Food Science
Animal Science	Biomedical Imaging	Genetics and Genomics
Biochemistry	Biomedical Systems	Medical Imaging Techniques
Biocontrol	Biomolecular Engineering	Molecular Biology
Biodynamics	Biomonitoring	Nanotechnology
Bio-engineering	Biophysics	Neuroscience
Bioinformatics and Biocomputing	Biotechnology	Plant Science
Biology	Cell Biology	Proteome and Proteomics
Biomaterials	Ecology	Smart Biopolymers
Biotechnology	Environmental Science	Tissue Engineering

Source: Van Beuzekom and Arundel (2006, p. 65)

2.2.1 Life science firms' characteristics

Life science firms have unique characteristics that allow them to compete in the high velocity environments that they face. In order to better understand the forces that influence the resources and capabilities needed in early growth, it is important to understand the main characteristics of firms in the industry. The four most relevant to this study are: 1) their highly innovative nature, 2) their tendency to form alliances, 3) their capitally intensive nature and 4) their reliance on scientific human capital.

The defining trait of life science firms is innovativeness. From 1980 to 2008 the industry had more patents than any other; from 2004-2008 almost eight percent of the total patents filed in the US were life science patents – over 11,000 (Van Beuzekom & Arundel, 2009). A survey of life science executives found the number one goal of R&D is to discover breakthrough products (Deloitte & Touche, 2009). Decarolis and Deeds (1999) suggest

that innovation in the life sciences is measured and stored in the forms of academic citations and patents. They also note that greater stocks of patents and citations are correlated with superior performance. The high patenting and publishing propensity demonstrates the creative destruction, which is so widespread in the industry, with new and better innovations constantly replacing the old (Kenney, 1986; Powell, Koput, & Smith-Doerr, 1996; Roijakkers & Hagedoorn, 2006).

A body of literature is developing on the influence of innovation on internationalisation (Burgel et al., 1998; Chetty & Stangl, 2010; Knight & Cavusgil, 2004). However, few researchers have looked at the influence of innovation on the internationalisation of biotechnology firms. Madhok and Osegowitsch (2000) is one of the few papers that has examined this when they analysed the influence of innovation through a dynamic capabilities lens. They found that being able to realign capabilities with other firms is important to growth in international markets. Although an interesting paper, especially in the dynamic capabilities perspective they take, but there is a lack of development in the process of changing capabilities. Moreover, it is based on static and out-dated secondary data on US and European biotech alliances. Nevertheless, this paper provides much-needed insights on the influence of international activity on the industry and on how life science firms' resources and capabilities allow them to compete in global markets. More research needs to follow Madhok and Osegowitsch (2000) in looking at biotechnology through a dynamic capabilities lens; the rapidly changing nature of the industry makes dynamic capabilities an ideal lens through which to view it (Deeds et al., 2000).

The second defining trait of life science firms is their reliance on alliances (Carayannopoulos & Auster, 2010; Powell et al., 1996) Often life science firms are lacking the scientific or commercialisation knowledge to develop their product(s), and for this reason they turn to other firms to fill in their knowledge gaps. The Calabrese and Silverman (2000) study found that establishing strong alliances is especially important to start-up life science firms. They suggest small biotech firms align themselves with partners that have complementing capabilities. One important source of these alliances is universities. Zucker et. al (1998) looked at the importance that top university researchers play in new biotechnology companies. They found that standout university researchers are often the driving force behind new biotechnology firm formation. Furthermore, Rahm (1994) study of over 1000 academic researchers found that over seventy-five percent engage regularly in consulting, and over eighy percent have former students in industry

that they are in regular contact with. This is further evidenced by the fact that biotechnology firms tend to cluster spatially near top research universities (Owen-Smith, Riccaboni, Pammolli, & Powell, 2002; Zeller, 2001). In many cases innovation is birthed in university labs; Rothaermel (2007) suggests that innovation birthed at universities disseminate to industry in three main ways: (1) to work with the university scientists and VCs on forming a new company; (2) find established firms to partner with in an equity sharing agreement; and (3) license the rights to the technology to established firms. Even if a firm's innovation was not birthed at a university, universities are still often important partners. They often provide testing and research services, and university professors regularly consult with firms in the industry (Perkmann & Walsh, 2008; Powell & Owen-Smith, 1998).

Alliances are central to a cooperative strategy. Gans et al. (2002) examine the alliance (cooperative strategy) versus competition strategy for commercialising innovations. Based on a study of 118 new innovative firms, this study suggests that firms with strong intellectual protection (i.e. patents) have a higher propensity to enter into a cooperative strategy; whereas firms with weaker intellectual property protection tend to enter into a competitive strategy. In some cases firms earn higher rents from innovations from controlling the commercialisation process, which is a competitive strategy. They also find that certain industries with a high degree of technology appropriability, such as biotechnology, tend to have a higher percentage of firms entering a cooperative strategy because of the intensity of CAs needed for commercialisation. This is supportive of Rothaermel (2001a) finding that incumbents in certain industries (e.g. biotechnology) have an advantage because of their established base of CAs.

The literature on alliances is well developed and provides interesting insights on the influence of partnerships within the industry. However, research fails to properly examine the importance of alliances in formulating key assets, such as R&D and financial resources and capabilities. Rothaermel (2001a, 2001b and 2005) are a few of the only papers to investigate this. These studies confirm that alliances provide key inputs, and that the partnerships between small and large firms are particularly important to the commercialisation of innovations. Future work needs to build on these studies and offer more depth on the process of forming alliances amongst life science ventures that lead to important assets. Specifically, work is needed to examine how alliances impact the development of R&D and financial resources and capabilities.

The third defining trait of the life science industry is its capitally intensive nature. It can take years from the start of innovation until the time it is commercialised (Hall, 2002; Murray & Wolfson, 2010). This lag time from innovation to commercialisation requires great upfront investment with no revenue, especially challenging for new firms. To finance this incubation and growth many firms turn to VC (Gompers & Lerner, 2004; Lerner & Merges, 1998). VC is a form of financing that takes an equity stake in risky projects that offer the potential for great returns. In 2008 VCs provided over $4.4 billion in funding to biotechnology firms; with the average investment in each firm of $10.24 million dollars (Van Beuzekom & Arundel, 2009). Sorenson and Staurt (2001) examined the location of biotechnology firms and found that there is a correlation between the location of them and VCs; i.e. they are spatially located in the same areas. Furthermore, a statistically significant number of biotechnology patents comes from a small number of areas (Zucker et al., 1998). Powell et al. (2002) find that new biotechnology firms tend to locate in areas near sources of VC and of scientific innovation – mainly top tier research universities.

The importance of human capital is the fourth defining trait of the industry. Zucker et al. (1998) note the importance of star researchers to the growth and development of biotechnology firms. This notion is further supported by Boxeman et al.'s (2001) findings that human and social capital are two of the most important building blocks of new technology-based companies. The clustering of biotechnology companies near top universities also supports this idea (Blumenthal, Causino, Campbell, & Louis, 1996; Zucker et al., 1998). Furthermore, an industry survey of biotechnology executives placed attracting scientific talent as one of the biggest challenges in the industry (Deloitte & Touche, 2009). One way this challenge is addressed is through the recruitment of foreign scientists (Stephan & Levin, 2001); the National Science Foundation estimates that 15% of US biotechnology workers are foreign-born (Tsapogas J, 2007). Foreign-trained scientists are not only significant as an input to innovation, but also as a possible driver to internationalisation. Burgel and Murray (1998) present evidence that foreign-educated managers have a higher propensity to globalise their firms than domestically-educated managers. Often new life science firms are founded by scientists, so it logically follows that foreign-educated scientists could be a driver to internationalisation in the industry. Given the international flows of scientific staff, it is perhaps no surprise that they then look to make international links when a new life science firm is founded.

2.2.2 History and state of the industry during this research

The application of scientific principles to biological agents started hundreds of years ago. However, this was not called biotechnology until the 1970s, when recombinant DNA was discovered (Yoxen, 1983). Another major milestone of the modern biotechnology industry is when the US Supreme Court ruled in Diamond vs. Chakrabarty (1980) that modified organisms could be patented (Argyres & Liebeskind, 1998). This sparked massive investment in the industry and launched hundreds of new biotechnology ventures. These initial firms were primarily either large pharmaceutical companies or small firms started by science professors who kept their full-time faculty positions and started firms on the side (Zucker et al., 1998).

The present study focuses on US life science firms, so it is important to understand the size and scope of the US life science industry. This paragraph summarizes Van Beuzekom and Arundel's (2009) OECD statistics of the US life science industry. In 2009 the United States had the most life science firms of any country in the world with 3,301. Of these firms over seventy-five per cent employed fewer than fifty employees. The industry has seen substantial growth in the past few years. Spending in the industry was over $25 billion in 2009, which is up from an estimated $15 billion in 2000. One clear issue is that whilst seventy-five percent of firms in the industry are less than fifty employees, over seventy per cent of the industries R&D spending is by firms over 250 employees. The total revenue for the industry was $554 billion in 2009, which is up from $318 billion in 2004. The average life science firm generated $168 million in revenue. From 2004-2008 11,474 life science patents were filed in the US, which constituted forty-two per cent of the world's life science patents. These statistics help put the industry in perspective and clearly show that it is an important industry.

The global recession that started in the fall of 2008 greatly slowed the growth of the industry. Revenues fell by ten per cent in 2008. Funds raised from initial public offerings fell sixty percent from the 2007 levels. Venture capital funding dropped from $5.5 billion in 2007 to $4.4 billion in 2008 (Giovannetti, 2010). Only ten per cent of the 370 publicly-traded US life science firms had positive cash flow in 2008. Furthermore, in 2008 US biotech stocks were down by a mean average of forty-nine per cent, and 87% of the publicly-traded firms lost value. There were over eighty companies that laid off 5,000 or more employees (BIO, 2009). By the end of the present study (winter 2010), the industry

was on the way up. By 2010 early informal indicators were that the industry was recovering, but the recession has led to some major changes. Academic research has yet to analyse the long-term effect of the recession. The overall consensus of the major consulting firms in the industry is that the industry will recover, but this recession will fundamentally change the industry. Ernst and Young (2010) and Aon Analytics (2009) suggest that firms will become leaner and develop proofs of concepts in a more cost-effective manner. Several consultant reports also indicate that firms will need to make better use of their resources, increase organisational efficiencies and develop strategic partnerships in order to stay competitive. Interestingly, many of these reports emphasise the challenges to small firms, but do not offer depth into what these challenges are. It would be interesting to see how small life science ventures develop the R&D and financial resources to compete in such a dynamic and capitally intensive industry.

The global recession is significant to this research because it was conducted in the midst of it. This may have impacted the data collected for this project. Lack of VC funding could particularly impact the results because VC was extremely difficult to obtain during the time of this study, which is significant because VC is germane to the growth of firms in industry (Baum & Silverman, 2004).

2.2.3 Government policy

A number of variables influence the development of scientific knowledge (Gibbons, Limoges, & Nowotny, 1994). For life science firms these variables are both internal and external. One of the main external variables is government. There are several ways that governments influence life science ventures.

One of the biggest influences that government has on life science ventures is through government approvals. In the US the FDA is the most influential approval process that firms must contend with. Any life science innovation that is used on humans must gain FDA approval (Giovannetti, 2010; Olson, 1997). The FDA approval process is long and arduous and typically it takes three to twelve years to get a product through this process. Furthermore, it usually costs between $250,000 to $5 million to obtain FDA approval (Giovannetti, 2010). These are the direct and indirect costs of testing products and getting them ready for the FDA process. Vernon et al. (2009) found that the FDA is one of the biggest factors in a life science firm's strategy. Firms plan around costs and resources for

gaining FDA approval for their innovations. Surprisingly few studies examine the FDA's impact in regards to small firms. It would seem that the great costs involved with the FDA would make planning for their approval even more important for small firms. However, there is not a lot of depth in the literature offered on this topic. Furthermore, the FDA is more influential on some life science firms than others. For example, drug development firms have the most arduous FDA standards to contend with. It typically takes over eight rounds of FDA tests and over ten years to get a new drug application approved. In comparison, many medical devices that focus on topical applications reach FDA approval with two tests and in less than four years (O'Connor, 2010).

Another policy area that influences the formation of firms are the regulations involved with their start-up. Countries with easier rules and procedures for starting new firms have more than countries that have more cumbersome procedures for starting a new business (Audretsch, 2001; Gnyawali & Fogel, 1994; Wagner & Sternberg, 2004). Along the same lines, a country's legal system, which is important to patent protection, is critical to a thriving life science industry. Without this protection many firms would not have the incentive to innovate (Jaffe, 2000; Jaffe, Trajtenberg, & Romer, 2005; Trajtenberg, 1990). Furthermore, regulations that prohibit certain research or testing influence firms to look overseas to get around those in their home countries (Greis, Dibner, & Bean, 1995).

Many governments have used policy to try to develop and grow life science-related industries; most often through tax breaks, government grants, and access to government property (Chen & McDermott, 1998; Cooke, 2002). Recently governments have become increasingly competitive with their incentives, so incentives are not as effective as they once were (Blomstrom & Kokko, 2003; Nov, 2009). Another way governments can influence life science firms is through assisting them in internationalisation. Many countries create agencies dedicated to helping firms sell their goods abroad. America's main entity is the Export Agency which provides low cost or free assistance to firms wishing to enter international markets. The effectiveness of this entity has is not well documented, and the few studies examining this topic are conflicting and inconclusive.

Another important government influence on life science firms is educational policy, and in particular the government's support for research institutions. These institutions help create the places where many life science innovations are born (Blumenthal, Gluck, Louis, Stoto, & Wise, 1986; Shane, 2004; Zucker, Darby, & Armstrong, 2002). The US has excelled at

transferring academic knowledge to industry. This is largely credited to the fact that government supported academic institutions do not take full control of the innovations that are created there (Giesecke, 2000). Instead the universities and the researchers that created them share the ownership rights, which incentivise researchers to create innovations that are marketable. Many universities have streamlined collaborating with industry through technology offices (Cardozo, Ardichvili, & Strauss, 2011; Friedman & Silberman, 2003). These offices market and license university created innovations and make the transfer of innovation more efficient.

2.3 Firm growth

This study is interested in the development of resources and capabilities in the early growth of life science firms. Consequently, it is important to review the different growth lenses. Growth is the end goal in entrepreneurship, and at some point every firm has to grow or it will go out of business (Churchill & Lewis, 2000). Although easy to grasp in theory, in practice it is an elusive concept to define clearly and measure. There are numerous ways to look at growth, and there is no commonly agreed upon growth definition within the literature (Renko, Carsrud, & Brännback, 2009) .

Some of the most common measures of growth are based on financial indicators. Revenue growth is one measure that is particularly prevalent (Delmar, Davidsson, & Gartner, 2003; Evans, 1987; Reuber & Fischer, 2002). Some other measures include employee growth (Del Monte & Papagni, 2003; Hart & Oulton, 1996), asset growth (Ijiri & Simon, 1964; Lang, Ofek, & Stulz, 1996) and profits (Chittenden, Hall, & Hutchinson, 1996; Jordan, Lowe, & Taylor, 1998). Whilst all of these measures provide an indication of growth, Davidson et al. (2010) suggest that in a significant number of cases these numbers are contradicting. For example, a firm could have substantial revenue growth; whilst at the same time have substantial profit decline. Thus objective financial measures often provide insight on growth, but they do not always accurately portray the whole growth picture. Financial indicators are particularly deceptive for start-up firms, which often do not have revenues or many employees. This is especially true of life science firms, which often go years before they generate revenues or profits (Morecroft, Lane, & Viita, 1991; Tapon, Thong, & Bartell, 2001).

For start-up technology firms a better lens to gauge growth is through how firms develop from a start-up into an established firm. The literature offers a number of stages models to describe this type of growth. Most suggest firms start-up, develop, grow and then mature (Davidsson et al.; Kazanjian & Drazin, 1990; Scott & Bruce, 1987). Stages models are fundamentally concerned with change, how firms change from one type of operation into another. For example, at the inception, firms are usually informal and do not have an advanced infrastructure, and then at some point a firm develops a more advanced infrastructure and larger scale distribution; this is a point of growth according to stage models. Davidson, Achtenhagen and Naldi (2009) suggest that analysing firm growth through stages is often preferred because it captures growth over time. They also contend that studies on growth that do not capture this aspect of growth are invalid because they are prone to selection bias; i.e. studies select samples and measures of growth conducive to their studies.

Whilst stages' lens of growth has some positive attributes, these models have also been widely criticised – the largest criticism being the lack of clear inflection points between stages (Dobbs & Hamilton, 2007; Garnsey, Stam, & Heffernan, 2006; Macpherson & Holt, 2007). These critics contend that there is no clear and objective way to determine when one phase ends and another begins. Certainly this criticism should not be dismissed, but several of the proposed models have established inflection points that show where a firm goes from one phase and to another (Bleaney & Nishiyama, 2002; Kazanjian & Drazin, 1989). Another common criticism of stages models is that different business environments have different influences on growth; therefore, it is difficult for *ceteris paribus* comparisons (Kazanjian, 1988; Kazanjian & Drazin, 1990). For instance, a life science start-up is going have a much different growth path than a start-up bank has; mainly because there are drastically different environmental factors that influence the respective industries. For this reason, Kazanjiaan (1988) suggests that growth stages models should be industry specific.

Kazanjiaan and Drazin (1990) then go on to offer a stages model of growth for technology firms. Based on this model several other researchers developed similar ones. For example, Autio et al. (2007) offers a four stage model that emphasises the importance of resource acquisition and use at each stage. The four stages that most of these models encompass are (1) conception and development, (2) commercialisation, (3) growth and (4) stability. All of the models emphasise transformation; i.e. firms transforming their organisational structure;

and these models recognise that each stage brings a new set of variables and challenges and that organisations must react to these challenges to maintain growth.

One challenge in industry studies is to find a suitable metric by which success can be measured. As above, growth as a concept is often used, but this can be expressed in various ways. Different industries and circumstances dictate which measures of growth are proper to use (Kazanjian, 1988). This thesis is concerned with the development of resources and capabilities in life science ventures. The life science firm overview has established that often these firms do not have revenues for many years. This makes traditional financial measures of growth invalid. A better way to look at growth for life science firms is through the phases of development. There are a number of models offered, each of which has different points of emphasis, but all of them indicate that there are trigger points that determine when a firm moves into another stage of growth. Furthermore, each of the models encompasses a conceptualisation, commercialisation, growth and maturity phases. Kazanjian and Drazin (1990) has emerged as one of the more accepted growth stages models of technology-based firms. Based on the review of the growth literature, the present study takes the stance that this is the most relevant and accurate model for looking at the growth of life science ventures for this thesis. This study is specifically interested in the development of R&D and financial resources and capabilities of life science firms during the conceptualisation and early part of the commercialisation phase of development. It is more important for this study to examine how firms develop an infrastructure, rather than to focus solely on financial measures.

2.4 The financing of life science ventures

The discussion above indicates that capital is paramount to the development of life science ventures. Often new ventures will plan on sustaining many years without revenues (Gruber, 2009). This, coupled with the capitally intensive nature of developing life science innovations, makes investment capital paramount. Financing is one of the biggest challenges that a life science venture faces in its early growth (Freear & Wetzel, 1990; Wright & Robbie, 1998). Financing is particularly challenging during the conceptualisation and early commercialisation stage of development for life science ventures, as firms often do not have revenues to support their operations and firms are investing heavily in R&D at these stages (Murray and Wolfson, 2010). This section

overviews the sources of funds and capabilities that life science ventures draw on to finance their development.

Sources of funds

In the early stages of growth, life science ventures demand a substantial sum of capital – even more so than other new technology-based firms (Deeds et al., 2000). At the seed stage, capital is especially difficult to attract as the firms often have not proven the research concept. The capital at this point is allocated to research and initial product development. During the conceptualisation phase, firms often finance their incubation through insider funding, VC, public sector grants and business angels (Gruber, 2009). However, a true taxonomy of where capital comes from has yet to emerge in the literature, though it has noted that the initial capital often comes from the founders and angel investors (Freear & Wetzel, 1990; Soleimani & Kharabi, 2010). Nevertheless, there is a lack of evidence to substantiate what percentage of life science ventures initially capitalise through these means.

Business angels are usually informal investors made up of wealthy individuals who are willing to invest in high risk ventures for the potential of hyper returns (Chesbrough, 2000). Often angels have substantial background in the fields they invest, and they offer management inputs along with their capital. They typically invest amounts less than $1 million, and seldom invest in subsequent rounds (Chesbrough, 2000; Wong, 2009).

In some cases the government offers capital to early stage life science firms (Toole & Czarnitzki, 2009). One of the main ways the government invests in firms is through the Small Business Innovation Research (SBIR) grant program. Through this program the government offers grants from the range of $40,000 to $1.3 million to firms of under 500 employees that have innovations that have the potential to help society (Bauer & Arthanat, 2010). In 2010 approximately 6,000 SBIR grants were awarded of which approximately 2,100 were to life science firms (Lemond, 2011). In a study of grant versus VC backed firms Lerner (1996) found that SBIR grant firms display superior performance as compared to VC backed firms. He conjectured that this is because the SBIR grants are so competitive that only the best firms receive the grants, but he did not offer sufficient evidence to substantiate this. Other studies have also supported Lerner's (1996) findings that grant backed firms display superior performance and that SBIR grants are helpful to

firms (Cooper, 2003; Wallsten, 2000). However, like Lerner (1996), these studies also do not provide breadth on what is driving the superior performance of SBIR backed firms.

One source of financing that is usually not available to new technology-based firms is bank loans because these companies usually do not have the credit history and are high risk (Donnelly & Betts, 2006). However, entrepreneurs often secure loans on their personal property (e.g., their homes) to finance new ventures (Han, Fraser, & Storey, 2009). This, however, should be viewed through insider financing rather than commercial loans.

A fourth source of capital for life science ventures is VC, which is especially important to because of the risky nature and the potential for abnormal returns of life science ventures (Chakma & Sammut, 2011; Cooke, 2002). The importance of VC has captured the attention of a number of researchers (Gompers & Lerner, 2001). The literature identifies three main sources of VC: independent venture capital (IVC), corporate venture capital (CVC), and angel investors. It is clear that angel investors are markedly different than IVC or CVC. Angel investors are the most hands off investors. Angel investors tend to invest on the ground level versus investing after a venture has already been established for a period of time (Wright & Robbie, 1998). In contrast, IVC and CVC tend to be hands on and invest only after the company is established. Many IVCs and CVCs invest in early stage firms, but rarely will they invest in a firm that has not been formulated or is only a few months old because they like to have some established criteria to base their investment decisions on (Gompers, 1995). The difference between IVC and CVC is not as great as that of angel investors and IVC/CVC. The literature is well defined on this topic and overviewed in Table 2-2.

Table 2-2: IVC and CVC differences

Attribute	Difference
Incentive	VCs have larger incentives tied to the performance of the portfolio firms than CVCs do.
Financial risk	CVCs are more risk adverse.
Monitoring of portfolio firms	IVCs more closely monitor their portfolio firms.
Discovering alternative business models	IVCs are more likely to help their portfolio firms discover alternative business models.
Time horizon	CVCs have a longer term outlook on their investments. IVCs strive to get their investment returns within the established life of the portfolio.
Investment size	CVCs can invest larger sums of money.

Source: Author based on Chesbourgh (2000; p. 41)

A fifth source of funding for life science ventures is industry partners. Smaller firms sometimes sign agreements with a larger firm where the larger firm finances part of the smaller firms R&D. In return the larger firm is offered ownership and or access to the smaller firm's innovation(s) (Higgins, 2007; Higgins & Rodriguez, 2006; Rothaermel, 2001a). In general, life science ventures are not able to sign such agreements until they have developed their proof of concept and can show that their technology has market potential, and often small firms shy away from these agreements until they can protect their intellectual property (Dickson & Weaver, 2011; Luukkonen, 2005) .

A sixth source of capital for life science ventures is public stock markets. Generally, firms usually do not offer an initial public stock offering (IPO) until they are in the growth stage of development (Pástor, Taylor, & Veronesi, 2009). Stock markets tend to embrace firms that have a proven revenue model (Lévesque, Joglekar, & Davies, 2010). However, recently a number of life science firms in the conceptualisation phase of development have launched an IPO (Williams, 2007).

Financial capabilities

Although there is some understanding on the sources of financing for life science ventures, there is still a large gap in understanding how new ventures obtain capital from the sources discussed above. The NBTF literature has touched on the process of raising capital, but it has not gone into great depth on what resources and capabilities firms use to develop financial resources. Hsu (2007) examined the investment behaviour of VCs and found that

the founder's background is a key element that factored in the investment decision process; i.e. VCs are more apt to invest in firms whose founders show a successful track record of starting firms. This has been substantiated by several other notable studies (Colombo, Delmastro, & Grilli, 2004; Colombo & Grilli, 2005; Stuart & Abetti, 1990). It has also been noted that the potential of a firm's technology is an important criteria in the investment decision (Cockburn & MacGarvie, 2009; Freear & Wetzel, 1990). This is particularly important to NTBFs, but as of yet a way to gauge the potential of an innovation and how financiers value an infant technology has not emerged.

There are also studies that have examined the importance of alliances to attracting investment capital. These studies have shown that firms that are well networked have more access to capital (Hite & Hesterly, 2001; Shane & Cable, 2002). For example, Shane and Cable (2002) suggest that firms with deeper industry ties are able to raise more than firms that are not well connected in the industry. However, this study did not shed light on how these alliances are formed. There is little work that looks at how the networking capabilities lead to financial resources.

Studies have also shown that capabilities in conserving capital are important to new ventures. There is an emerging body of literature on 'bootstrapping'; which Winborg and Landstrom (2001, p. 236) refers to as '*the use of methods for meeting the need for resources without relying on long-term external finance from debt holders and/or new owners'*. Accordingly, firms operate as lean as possible and cut all non-essential costs to preserve capital. Several studies have indicated that bootstrapping capabilities are essential to start-up ventures because resources are almost always in short supply (Auken, 2005; Jones & Jayawarna, 2010; Winborg & Landstrom, 2001a). However, there is little work that has looked at how bootstrapping capabilities affect the development of life science ventures. It would seem that cost containment capabilities would be critical in an industry where R&D expenses are high and difficult to project for.

Investor relations is another capability that becomes important as firms develop and take on larger amounts of investment. Gorman and Sahlman (1989) found that executives' in VC backed firms spend over 100 hours a year meeting with their VCFs. Similarly, Bushee and Miller (2009) findings indicate that after an IPO firm's CEO's devote up to twenty per cent of their time to functions related to investor relations. Moreover, research indicates that capabilities related to dealing with investors are critical because one of the largest

sources of future investment capital is previous investors; it is therefore crucial to maintain strong relations with investors. Laurent-Ottomane and Weimer (2010) suggest investor relations capabilities mainly revolve around communicating with investors on the status of the firm and 'selling' the investors on investing more capital.

2.5 Industry context conclusions

The discussions in this chapter have highlighted the dynamic nature of life science firms. Innovation is paramount in this industry, and rapidly changing environments underscore the importance of effectively choosing and developing resources and capabilities. Furthermore, new life science innovation takes millions of dollars and specialised scientific resources and capabilities. Despite this, there are over 2,500 life science firms in the US that are under 250 employees and over 300 new life science ventures are launched every year (Van Beukezekom & Arundel, 2009). Even with the importance of small firms to the industry, there is a major gap in the understanding of how small resource-constrained firms develop the R&D and financial resources and capabilities needed to incubate innovation.

This review has highlighted that human capital, university inputs, industry partners and government inputs underpin the development life science ventures' R&D. However, there is still not a deep understanding of how these combine to help a firm develop its R&D resources and capabilities. There is also a lack of understanding of how firms obtain inputs from these sources. Furthermore, few studies look at how the nature of a life science innovation affects its development; i.e. do different life science innovations have different effects on the development of a firm?

It is also apparent that life science ventures are costly to incubate and that investment capital is paramount to the incubation of life science ventures. The review suggests that this investment comes from several sources; insider finance, angel investors, VC, government grants, industry partners and IPOs. However, there is a real gap in understanding how firms obtain capital from these sources. More specifically, there is little understanding of the capabilities needed to attract investment and mange financial activities. Moreover, research does not properly identify which combinations of sources of capital are used early in the development of life science firms.

It is clear from this review that R&D and financial resources and capabilities are germane to the early development of life science ventures. The review also shows there are deficiencies in the knowledge base of how life science ventures formulate these resources and capabilities. Because of the importance of resources and the dynamic nature of the industry, the resource- based view (RBV) and dynamic capabilities offer good lenses through which to examine the development of resources and capabilities of life science ventures. The next chapter is devoted to tracing the evolution of the resource-based literature and establishing a theoretical lens through which to view this research.

Chapter 3 – The Resource-Based Paradigm

Chapter Objectives:

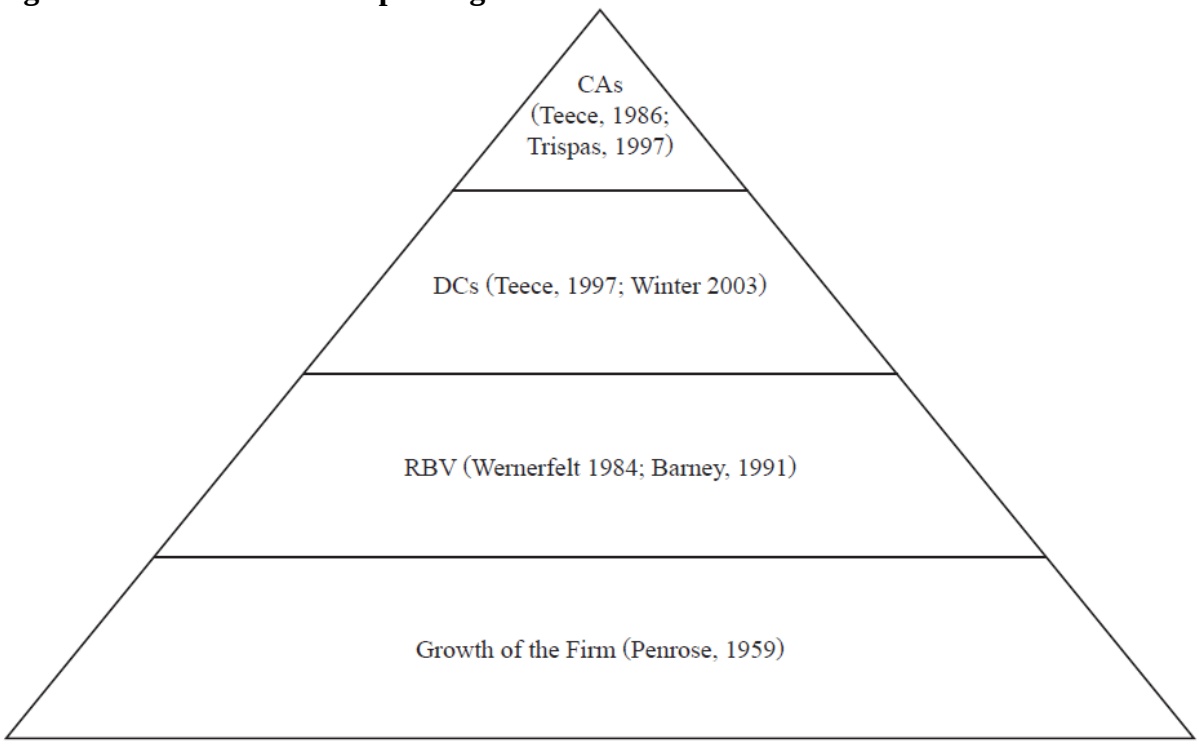
- To discuss the evolution of the resource-based literature.
- To review the major conceptual and empirical studies on the Resource-Based View, dynamic capabilities and CAs.
- To evaluate the shortcomings and identify research gaps in the resource-based literature.
- To discuss the potential applications of dynamic capabilities in the examination of life science firms.

3.1 Introduction

Chapter two emphasised the importance of resources and capabilities to the development of life science firms. Central to the strategic management of life science firms is how to acquire, build, use and reconfigure resources. A number of prominent theories have sprung up based on this. The RBV and dynamic capabilities is clearly rooted to this theoretical approach (Barney, 1991; Teece et. al., 1997), but resources are still paramount to other theories as well. For example, Porter's five forces model recognises resources are important, but it emphasises this in regards to how environments shape the development of firms' resources (Porter, 1985). Upwards of ten strategic management theories touch on resource development and use (Aimé, 1997). Most of these are specific to one sub-discipline within management. Following Aime (1997), the present study takes the stance that a strategic management issue should be isolated within one main theoretical paradigm. This is not to contend that one theory is necessarily better than another; rather it is better in a single study to isolate a phenomenon under the umbrella of one rather than many strategic management theories (Eisenhardt, 1989a). Furthermore, this is not to suggest that other theories should not be incorporated in a study, as multiple theoretical perspectives are good for comparative purposes and looking at the problem from different angles (Yin, 2008). Rather, this is to suggest that it is important to have one overarching research paradigm guiding a study. Because of the importance of resources and capabilities to life science ventures, this thesis uses a resource-based paradigm to examine life science ventures.

The RBV has gained significant scholarly attention in the last twenty years. It has become one of the most prominent strategic management theories, as thousands of articles draw on it. Out of the RBV, dynamic capabilities has developed. This theory looks at how firms reconfigure their resources to respond to rapidly changing environments (Teece et al., 1997). The present study is interested in the growth of life science firms, and because of the rapidly changing environments life science firms face, dynamic capabilities makes an excellent lens through which to examine life science firms. A firm displaying high-level capabilities is able to create complementary assets (CAs), which are the auxiliary assets needed in the commercialisation of an innovation (Teece, 2007). Figure 3-1 below traces the evolution of the resource-based literature. Starting with Penrose's (1959) Growth of the Firm, this review systematically works through this evolution.

Figure 3-1: Resource-based paradigm evolution



Source: Author

3.2 Penrose

Penrose's (1959) growth of the firm is one of the earliest theories to address why some firms grow at a faster pace than others. Not only is this an important piece because it is one of the first significant pieces to look at firm growth from a strategic management perspective, but it is also the basis for the RBV and several other modern strategic management theories. Because this thesis is directly seeded in the aforementioned theories, Penrose's early theory is where this discussion begins.

According to Penrose (1959), a firm is an administrative structure with productive resources. These productive resources are both physical and human. The physical are the tangible assets, such as plants and materials. Human resources are the labour that the firm has available. The function of the firm is to engage these resources to create outputs. In order to maximise outputs, the firm must recognise productive opportunities, which are the opportunities of output that are available to the firm (Penrose, 1959).

Arguably, Penrose's largest contribution is her managerial view of the firm (Kor & Mahoney, 2004). Prior to her work in *The Growth of the Firm*, scholars mostly ignored the influence of management. She, on the other hand, saw management as one of the most important resources of the firm. Resources themselves are not enough to make a firm

grow. Management is needed to convert resources to valuable outputs (Teece, 1986; Winter, 2003). These valuable outputs she calls 'productive services,' which she differentiates from resources that have no value until they are converted to something productive (Kor & Mahoney, 2004). A manager's firm-specific knowledge can adjust and expand, which allows a firm to grow over time; managers can be hired and trained in the long run. However, in the short run management expansion is limited because of the time it takes to hire them. This causes a bottleneck to growth, which is known as the 'Penrose Effect' (Uzawa, 1969). Penrose also makes significant contributions to the process of innovation within the firm. Specifically she attributes unused resources as the source of firm innovation. This excess capacity is one of the key variables to firm growth (Penrose, 1959).

The variables described above are the building blocks of the RBV. One of the main architects of the RBV, Barney (1991, p.103), credits Penrose's contributions:

> *'Her work portrayed how resources may provide long-term rent streams'.*

Many of the prominent theories in management trace back to Penrose's *The Theory of the Growth of a Firm*. Most notably are the RBV, transactions' costs and dynamic capabilities models. Penrose's ideas on physical and human resources provided the foundation for the RBV (Rugman & Verbeke, 2005). *The Theory of the Growth of the Firm* also lays the groundwork for other growth theories, as it describes firm growth happening over a series of steps (Rugman & Verbeke, 2005).

3.3 RBV

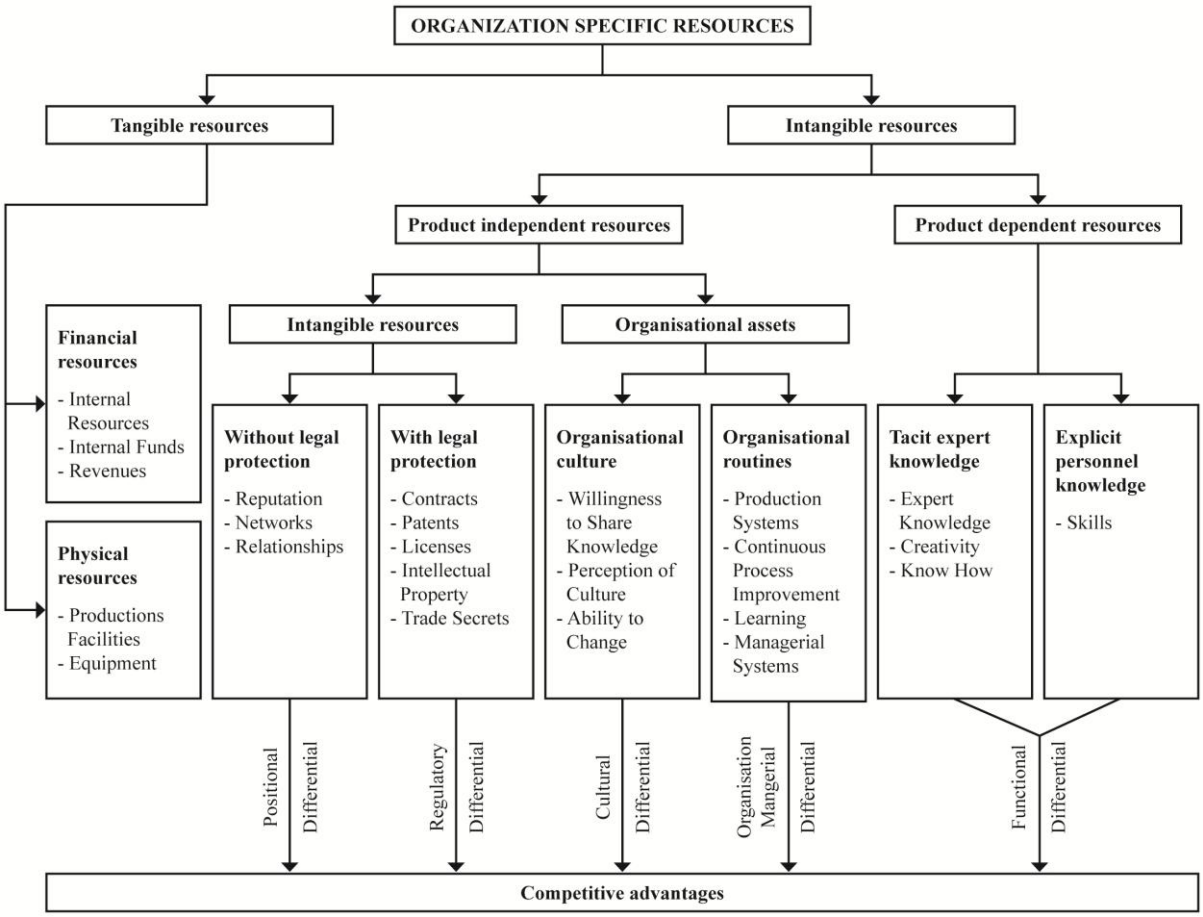
Penrose's main ideas are disseminated in her 1959 piece, but it was not until years later that her ideas were fully realized. Throughout the 1960's, 1970's and into the early 1980's, Industrial Organisational (IO) economics became popular in the strategic management literature (Conner, 1991). This literature is concerned with the influence of the outside forces on the market. By far the most influential work to come out of this school is Porter's Forces Model. According to the theory, the firm holds some degree of control in its strategic direction, but its ability to compete is limited within the confounds of its industrial environments (Miller & Dess, 1993). Whilst there is a sound basis for looking at environmental forces, critics contend that IO-related theories are overly concerned with

outside forces and neglect firm resources and abilities. Although Hendry (1990) finds fault in assuming that markets work in equilibrium, many economic and political barriers show otherwise. Furthermore, studies have found that even firms that operate within sub-optimal environmental conditions are able to achieve above average economic rents (Schoemaker, 1990).

These shortcomings brought scholars back to Penrose's growth ideas. Wernerfelt (1984) and Barney (1986) extended her ideas into the RBV of the firm. These pieces, concerned with integral resources, examined firm competitiveness from the resource side, instead of the product or industrial standpoint. Accordingly, the basis of competitive advantage in lies in a firm's bundle of resources (Wernerfelt, 1984); thus firms with superior bundles of resources enjoy superior performance. Conceptually, this is an easy theory to grasp, but in practice it is difficult to understand clearly. For starters, what constitutes a resource? Penrose defines a resource in terms of either physical or human capital. Physical capital consists of the tangible property of the firm (e.g. land, equipment, etc.), and human capital is the knowledge and abilities of a firm are contained within it workers. Werenerfelt (1984, p.171) offers a similar definition: '*Those attributes of a firm's physical, human, and organisational capital that do enable a firm to conceive of and implement strategies that improve its effectiveness'*.

Figure 3-2 presents Maier's (2004) comprehensive categorisation of resources. He divides resources into tangible and intangible assets. He then further breaks each of these categories down. Tangible assets are divided into two groups: financial and physical. Intangible assets are divided into person independent and person dependent resources. This is a comprehensive categorisation that is similar to several others offered in the literature (Black & Boal, 1994; R. Hall, 1992; Ray, Barney, & Muhanna, 2004).

Figure 3-2: Organisational resources



Source: Maier (2004, p. 221)

In theory, the categories and definitions of resources are straightforward. In practice though, they are not as clear cut. For example, when is access to a network considered a resource? If a life science firm can simply join a large network, such as the US Bio Organisation, is this still a resource? This grey area is a large source of criticism for the RBV (Priem and Butler, 2001). Measuring resources has proven even more problematic, especially for intangible ones. For example, how can the reputation of a firm be convincingly measured? To overcome these shortcomings, a number of RBV scholars have created ways to measure intangibles. Bontis, et al. (1999) suggest that there a host of correlations that can be looked at between intangible assets and objective measures, such as return on investment (ROI); these suggestions are further supported by several other studies (Barth & Clinch, 1998; Bowman & Ambrosini, 2003; Rodov & Leliaert, 2002). However, even these studies acknowledge that there is no perfect way to measure resources. It is especially difficult to measure all of a firm's resources. In an in-depth analysis of studies using the RBV, Newbert (2007, p. 141) found that 76% of RBV studies only examine one resource. Furthermore, he finds that less than 5% of studies looked at

more than two resources, perhaps because it is so difficult to isolate resources; most modern firms are a web of interconnected resources, and often resources share functions (R. Hall, 1993). This is the central argument of Priem and Butler (2001) who contend that how resources create value cannot possibly be discerned. For example, how does a life science firm discern between the value of the scientific staff and their equipment? Life science firms usually have advanced scientific equipment, but it is rendered useless without the skilled scientists who use it; so in this instance which is more valuable, the equipment or the scientists? As this example illustrates, it is extremely difficult to gauge the value of a resource.

Barney (1991) and others contend that the valuable, rare, imperfectly in-imitable and non-substitutable (VRIN) framework discerns how a resource creates value. Accordingly, a resource must meet the VRIN criteria for it to help the competitive position of a firm; i.e. the resource is valuable, rare, imperfectly imitable and non-substitutable. A number of scholars feel that it is too difficult to discern whether or not a resource meets these criteria, and for this reason have rejected, at least parts, of the theory (Priem & Butler, 2001). However, many management scholars, at least to an extent, have accepted the VRIN framework, which explains why it is such a prevalent theory in management. However, not all resources are a source of permanent competitive advantage, as changing environmental factors influence the relative value of a resource (Eisenhardt & Martin, 2000; Fiol, 2001); i.e. changing environments and organisational factors degrade the value of certain resources whilst increasing the value of other resources. However, some scholars contend that firms consistently find and better allocate resources; therefore, some types of resources are a source of sustained competitive advantage (Barner, 2001; Mikado, 200).

Although the VRIN framework provides a basis for how a resource gives rise to competitive advantages, it does not explicitly state how resources are obtained or developed (Hoopes, Madsen, & Walker, 2003). Some contend that firms develop resources from superior resource picking abilities (Barney, 2001; Lounsbury & Glynn, 2001); whilst others contend that firms develop resources from other resources (Makadok, 2001; Teece et al., 1997; Winter, 2003). The lack of clarity in how resources are developed and used has even led to the contention that the RBV has no management implications (Priem & Butler, 2001). Accordingly, the RBV tells managers to obtain VRIN resources, but it offers no prescriptions or insights on how to obtain these resources. Furthermore, it gives little input on how to use the resources once they are obtained (Miller, 2003). Barney (2005)

suggests that these are not problematic because the theory was never intended to be prescriptive. However, Starkey and Madan (2001) clearly show that there is a major disconnect between scholars and practitioners, and that if management research does not provide relevance to practitioners, then it will become irrelevant. Furthermore, Vila and Canales (2008) suggest that managers must have a clear picture of the issues they wish to address in the planning process. In its current state, the RBV makes it difficult for practitioners to define resource based issues, and for this reason the RBV needs to make strides to make a clearer connection to the practice of management.

There is also little work that used the RBV in the examination of small firms (Trott, Maddocks and Wheeler, 2009; Sapienza et al., 2006). Trott, Maddock and Wheeler (2009) call for more work to apply a RBV to the examination of small to medium size enterprises (SMEs). They assert that the RBV makes an ideal lens for SMEs, but work is needed to refine the RBV framework for these firms. This connection especially needs to be made within the life science industry, and chapter two surfaced some resources vital to the growth and development of life science ventures. For example, the chapter underscored the importance of R&D, scientific human capital, alliances and specialised financing. However, the literature does not clearly specify how these resources give rise to competitive advantage. Ambiguity in the understanding of how these resources are formulated or obtained also exists, and these are vital issues to the present study, which is specifically interested in how life science ventures formulate R&D and financial resources.

3.4 Dynamic capabilities

The previous discussion indicates that the RBV has become one of the most widely used theories in management. It also suggests that it is a useful theory, but there are several flaws that limit its application. The most common criticism of it is its static nature (Priem & Butler, 2001). This makes applying a RBV lens to a fluid industry, such as the life sciences, difficult. Life science resource demands rapidly change, which changes the values of a firm's resources (Carayannopoulos & Auster, 2010). To get beyond the criticisms, researchers started applying a dynamic view of how resources are integrated, built, and reconfigured to respond to changing environments to create sources of sustained competitive advantage (Teece & Pisano, 1994). This view evolved into what is now called dynamic capabilities, which is one of the only frameworks to offer plausible insights on the growth of technology based firms, such as life science firms.

3.4.1 Evolution of dynamic capabilities

Dynamic capabilities stems from the RBV (Helfat & Peteraf, 2003; Mikado, 2001; Teece et al., 1997). However, several other fields have also influenced its evolution; including organisational learning (Argyris & Schon, 1978; March, 1991), evolutionary economics (Schumpeter & Opie, 1934), transactions cost analysis (Coase 1937; Monteverde and Teece 1982) and competencies (Patel & Pavitt, 1997; Prahalad & Hamel, 1994). Dynamic capabilities draws heavily on how the firm absorbs and applies knowledge. In doing so it makes extensive use of Nelson and Winter's (1982) emphasis of routines, and the importance of the individual on organisational routines (Cyert & March, 1992). Whilst dynamic capabilities evolved from the RBV, it is important to note that the idea of resources does not simply go away because of the introduction of dynamic capabilities. Resources are central to how dynamic capabilities are formed and what they reconfigure. Several scholars (Bowman & Ambrosini, 2003; Eisenhardt & Martin, 2000; Helfat & Peteraf, 2003; Makadok, 2001) suggest that the traditional resource picking view is still important as well as complementary to dynamic capabilities; i.e. firms can have a competitive advantage in picking resources, but they can also use these resources more effectively by reconfiguring them in the most optimal manner.

Collis (1994) is one of the first to explicitly identify dynamic capabilities in his categorisation of *static*, *dynamic* and *creative*. A static capability is the ability of a firm to perform basic functions, including marketing and simple manufacturing; functions that almost any firm could easily become proficient at. He refers to dynamic capabilities as those that help the firm learn or grow. These are capabilities such as improving operational efficiency through trial and error. Creative capabilities he describes as 'metaphysical' (p.146), and are used for higher-level innovation. Whilst the ideas introduced by Collis are not markedly different than those in the modern-day theory of dynamic capabilities, he is rarely mentioned as a pioneer on the topic. Most notably, he is not cited in the most influential papers on dynamic capabilities, Teece, Pisano and Sheen (1997). This piece also emphasises the ability of a firm to reconfigure its resources, but it focuses on paths, positions and processes. Paths refer to the firm's history and future opportunities available to the firm. Past paths represent how it evolved, what it has learned and the major events that have influenced its decision-making. Future paths represent the strategic alternatives available to the firm. Positions refer to the resource stocks of the firm. These resource

stocks have a large bearing on dynamic capabilities because resources are what dynamic capabilities reconfigure. Processes refer to the internal routines of the firm, especially those that have a significant impact on changing the firm. Another distinction of Teece et al.'s (1997) ideas on dynamic capabilities is the emphasis of rapidly changing environments, especially technical environments. The next section further compares notable dynamic capabilities' definitions offered in the literature.

3.4.2 Definitions and frameworks of dynamic capabilities

Most research follows Teece et al.'s (1997, p. 516) definition: *'the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments'*. In a different vein, Eisenhardt et al. (2000, p. 1106) emphasise the importance of resources in their definition of dynamic capabilities: *'strategic and organizational processes like product development , alliancing, and strategic decision making that create value for firms within dynamic markets by manipulating resources into new value creating strategies'*. Solo and Winter (2002, p. 340) offer another definition emphasising the importance of the customer and the competition: *'A dynamic capability is a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness'*. The problem with these, along with the other definitions scattered throughout the literature, is that they are vague. Conceptually, most of the definitions make sense, but operationally it is almost impossible to pin down what a dynamic capability is from these definitions. Zahra et al. (2006) suggest that three common elements are confounded in the literature: 1) substantive capability, 2) environmental characteristics and 3) higher order capabilities. This problem is largely because of the lack of clear and specific definitions (Salvato, 2003). There has been a movement to clarify the definition, but this has gone in many uncoordinated directions, highlighted in Table 2-1. From this table, it is evident there are several inconsistencies. A central problem is that these definitions assume that a capability is only dynamic if it provides a competitive advantage. Tautologically this assumption is flawed. For example, the definition offered by Rind ova and Taylor (2002, p. 16): *'A newer source of competitive advantage in conceptualising how firms are able to cope with environmental changes'.* This definition does not delineate where competitive advantages stem from. It also fails to consider that a dynamic capability is often only a building block or one part of a competitive advantage.

In short, the definitions presented in the literature give a good sense of what dynamic capabilities are, but they are still not specific enough. A better direction for defining dynamic capabilities is to trace it back to its ontological roots and hierarchically break it down. Put differently, the concept is too complicated to define in one sentence, and it would be better for the literature to break the definition into interrelated pieces.

Table 3-1: Definitions of dynamic capabilities

Author	*Definition*
Helfat (Kaplan, Murray, & Henderson, p. 342)	The subset of the competences/capabilities that allow the firm to create new products and processes and respond to changing market circumstances.
Teece et al. (1997, p. 516)	The firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments.
Eisenhardt and Martin (2000, p. 1107)	The firm's processes that use resources – specifically the processes to integrate, reconfigure, gain and release resources – to match or even create market change. Dynamic capabilities thus are the organizational and strategic routines by which firms achieve new resources configurations as market emerge, collide, split, evolve and die.
Griffith and Harvey (2001, p. 598)	A global dynamic capability is the creation of difficult-to-imitate combinations of resources, including effective coordination of inter-organizational relationships, on a global basis that can provide a firm a competitive advantage.
Lee et al. (2002, p. 729)	A newer source of competitive advantage in conceptualizing how firms are able to cope with environmental changes.
Rind ova and Taylor (2002, p. 16)	Dynamic capabilities evolve at two levels: a micro-evolution through 'upgrading the management capabilities of the firm' and a macro-evolution associated with 'reconfiguring market competencies'.
Zahra and George (2002, p. 186)	Dynamic capabilities are essentially change-oriented and help firms redeploy and reconfigure their resource base to meet evolving customer demands and competitor strategies.
Solo and Winter (2002, p. 340)	A dynamic capability is a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness.
Winter (2003, p. 991)	Those that operate to extend, modify or create ordinary (substantive) capabilities.
Zahra et al. (2006, p. 920)	The abilities to reconfigure a firm's resources and routines in the manner envisioned and deemed appropriate by the firm's principal decision-maker(s).
Helfat (2007, p.1) Helfat and Peteraf (2009, p. 91)	The capacity of an organization to purposefully create, extend, and modify its resource base.

Source: Author based on Zahra et al. 2006.

Dynamic capabilities frameworks

The unbounded definitions of dynamic capabilities are complemented by the lack of a coherent framework. Many different authors (most notably, Eisenhardt & Martin, 2000; Makadok, 2001; Zahra et al., 2006) have proposed theoretical frameworks. However, as of yet not one of these has become commonly accepted. These models share several commonalities. Almost all of the models view dynamic capabilities as a standalone theory that stems from the RBV. One notable exception to this is Mikado (2001), whose model does not substitute dynamic capabilities for resources. Instead his model views them as complementary; i.e. managers help firms grow by both strategically picking resources and using dynamic capabilities to optimise their resources.

Winter (2000) develops a hierarchical conceptualisation of dynamic capabilities based on Collis' categorisation. Winter's conceptualisation includes an ordered level categorisation of zero-level, first-order and second-order dynamic capability. A zero-level capability is the most basic and is the operational capabilities needed to run a firm in the short term. A first-order capability is dynamic, the ability of a firm to reconfigure resources and respond to market conditions. An example is the ability of a pharmaceutical firm to recognise an opportunity for a new drug development opportunity. A second-order is the capability of learning. This capability facilitates identifying, creating and modifying dynamic capabilities that are most useful in the firm's operations. According to this hierarchical model, all three are linked together and build off of one another to create the total capabilities of a firm. Another premise of the model is that higher-level capabilities are not always beneficial to a firm, and in some cases, the cost of developing them is a poor use of resources. Whilst this is an interesting model, there are still many holes in it. Most notably, this model does not clearly define each level. Furthermore, it could also be argued that learning is a key element to the broader concept of dynamic capabilities. For these reasons few studies have used this model. Nevertheless, this hierarchical conceptualisation of capabilities has the potential to unearth insights on the values of their different types of dynamics. It would be beneficial for future research to synthesise and further the ideas presented by Collis (1994) and Winter (2003) into a more specific model(s).

The dynamic capabilities literature tends to emphasise three elements: (1) learning, (2) routines and (3) the environment. Each of these is detailed below.

Learning

The importance of learning is scattered throughout the dynamic capabilities literature. In their conceptualisation of dynamic capabilities, Eisenhardt et al. (2000) suggests that learning mechanisms underlie the development of dynamic capabilities. They suggest that firms with more experience in responding to change are more apt to develop dynamic capabilities. However, anecdotal and empirical evidence (Boccardelli & Magnusson, 2006; Macpherson, Jones, Zhang, & Street, 2004; Newbert, 2005) suggests the opposite. Take for example the rise of Google, Microsoft and Dell. These firms were all inexperienced and were in competition with well-established firms, yet all of them significantly outgrew their competitors because they learned quicker and responded better to changing business environments, even though they had little previous learning experience. Furthermore,

Autio et al. (2000) found that new ventures have an advantage in the internationalisation process because of their learning advantage of newness; i.e. new firms do not have the bad habits of established firms and respond to market conditions more swiftly. Solo and Winter (2002, p. 348) propose a better view on the development of dynamic capabilities through three learning-related mechanisms: 1) past experience, 2) knowledge articulation and 3) knowledge codification processes; accordingly, these three mechanisms underpin learning capabilities.

Winter (2000) goes against the grain of these studies to explore when learning adversely effects a firm's dynamic capabilities. In this paper she suggests that firms can focus too much on learning and not make the most effective use of their resources. This piece is unique because it challenges the rhetoric so often seen in the literatures of dynamic capabilities, absorptive capacity and organizational learning that say learning always has a positive effect. Though learning is one of the most popular themes in dynamic capabilities, relatively little empirical support backs it up. Most of the learning studies cited in dynamic capabilities are studies from other fields that are synthesised into the analysis of dynamic capabilities. One notable empirical study is the Engelhard et al. (2002) analysis of the dynamic learning of a major pharmaceutical company. Their analysis indicates that it is critical for biopharmaceutical firms early on to enable learning capabilities and to create actionable knowledge based on what they have learned. Engelhard et al. (2002) also support the idea that knowledge is only important if it is actionable. In a similar study Swift and Hwang (2008) suggest that organisational learning requires organisation-wide commitment, including top managers, mid-level managers and line workers in order to articulate, codify, and disseminate knowledge derived. This piece is also significant in that it takes a holistic look at the learning approach, instead of just looking at the importance of top management in the learning process. In a similar vein Davies and Brady (2000) found in their study of telecommunication manufacturing firms that it is vital to develop organisational-wide learning capabilities from previous experiences.

Routines

The second reoccurring theme in the dynamic capabilities literature is routines. Teece et al. (1997) referred to these as processes in their conceptualisation of dynamic capabilities and defined this as the way things are done within the firm. This emphasis on routines is a central source of criticism. The critics note that this is tautological, vague and immeasurable (Blomqvist, Kyläheiko, & Virolainen, 2002; Priem & Butler, 2001).

Eisenhardt and Martin (2000) argue that these are criticisms of the RBV and that dynamic capabilities is differentiated because such routines are identifiable and empirically measurable. They point to product development and strategic decision making as examples of identifiable and measurable routines. However, strategic decision making is an abstract topic to measure, and there is little empirical support of how routines influence dynamic capabilities; so Eisenhardt and Martin's (2000) arguments do not completely dispel the critic's points of contention.

Zahra et al. (2006a) propose that organisational routines are an antecedent to organisational learning and change. This notion is supported by Inanity and Clark's (1994) study on the integration of dynamic capabilities in automobile and computer industries. Although an interesting and insightful study, its findings are far from conclusive because of the weak measures they drew from secondary data. Another study by Abuja and Lambert (2001) concludes that the routine of continual experimentation is critical to reconfiguring capabilities to respond to environmental conditions in the global chemical industry. According to this study, experimental routines are the basis of how new knowledge on which these firms compete is created. Whilst the aforementioned studies offer insights on the importance of routines, they do not empirically support the emphasis placed on routines as suggested in marquee works on dynamic capabilities (Eisenhardt & Martin, 2000; Teece et al., 1997; Winter, 2003; Zollo & Winter, 2002). This is not to suggest that routines are not important; rather more empirical work needs to isolate the importance of routines in dynamic capabilities.

Research is especially needed in the context of life science ventures. This research needs to examine what routines underpin the development of life science ventures' key assets and capabilities. The previous chapter in this thesis underscored the importance of R&D and specialised financing to the development of life science firms. The importance of these resources is well-documented, but there are gaps in understanding the routines that firms practice to develop R&D and financial resources and capabilities. This is one area that the present research specifically addresses.

Environment

A third emphasis of dynamic capabilities models is the importance of the environment. Dynamic capabilities is an especially useful lens to examine firms in rapidly changing business environments (Blyler & Coff, 2003; Davies & Brady, 2000; Eisenhardt & Martin,

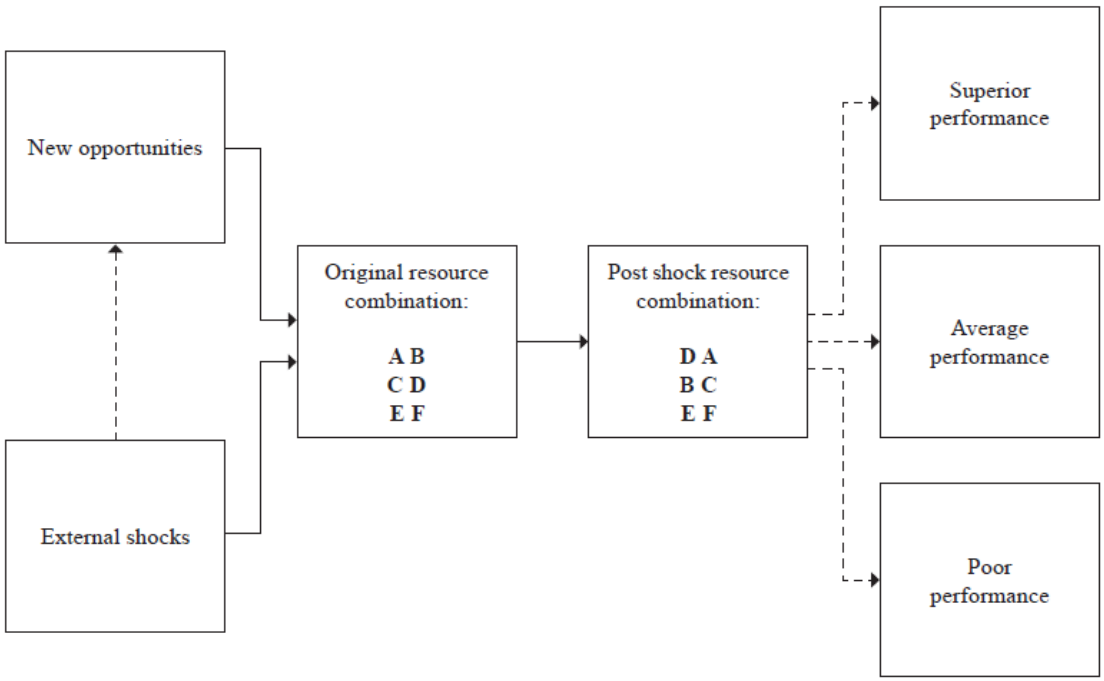
2000; D. Teece & Pisano, 1994; Teece et al., 1997). The importance of responding to a rapidly changing environment is a plausible explanation as to how young resource constrained firms can enter markets and outperform large and rich competitors (March, 1991). A prime example of this is the rise of Microsoft: A young firm started by two college dropouts who out-performed multibillion dollar firms, Microsoft credits much of their success, especially their early success, to their ability to out manoeuvre and respond to the tremendous technical changes taking place in the software industry (Stross, 1997). Researchers emphasise the importance of dynamic capabilities in technology-based industries such as software, biotechnology and semiconductors because the changing technology in these industries requires firms to quickly change their operations and product offerings in order to stay competitive. Conventional wisdom and anecdotal evidence support the effect rapidly changing environments have on firms; however; there is little empirical work to fully substantiate it. Most of the studies on the influence of environments cited in dynamic capabilities are from studies not specific to dynamic capabilities.

The previous chapter highlighted the rapidly changing environments that life science ventures face, but research has not thoroughly investigated how these environments influence these firms. One aim of the present study is to investigate how these environments impact life science ventures.

Figure 3-3 conceptualises the effect that the environment has on the firm. The figure starts with an original resource combination that is then shocked by an outside event. Outside events are either new market opportunities or external shocks. Examples of external shocks are changing economic conditions, technological shifts or political events. The dashed line from external shocks to new opportunities in the figure represent the new paths that arise as the result of external shocks (Deeds et al., 2000; Zahra & George, 2002); thus external shocks either directly or indirectly impact the firm. A shock or combination of shocks causes a firm to respond and reconfigure its assets and capabilities. This is represented by the original resource recombination being reconfigured to the post-shock resource combination. Figure 3-3 below offers a simple example, but in actuality there can be hundreds, if not more, reconfigurations that a firm can go through. In this example only two of the three sets of resources are reconfigured post shock: AB and CD reconfigured to DA and BC, whilst EF stayed the same. This illustration shows that in many cases firms will reconfigure many operations, but some units or divisions will stay the same even after

a shock. The reconfigured resources then either lead to superior performance, average returns or poor performance. This is an important part of the conceptualisation because it illustrates Winter's (2000) notion that reconfiguration does not always lead to superior performance; if resources are not optimally reconfigured to respond to the external events, it can also lead to average or poor performance.

Figure 3-3: Conceptualisation of dynamic capabilities



Source: Author

3.4.3 Empirical studies on dynamic capabilities

Although the quantity and depth of empirical work is lacking, there are several notable empirical studies that help to substantiate the theory. Table 3-2 highlights these studies and shows that a broad consensus is emerging. One industry that has recently gained popularity for use in the empirical testing of dynamic capabilities is the life science industry (Anand, Oriani, & Vassolo, 2010; Ingelgard et al., 2002; Rothaermel & Hess, 2007). A recent study by Rothaermel and Hess (2007) looked into the antecedents of dynamic capabilities. Unlike previous studies on the topic, their research factored in the interaction of the three antecedents (individual, firm and network) of dynamic capabilities; instead of isolating them individually as previous studies have done (Christensen, 1997; Henderson & Cockburn, 1994; Zucker & Darby, 1997). Rothaermel and Hess (2007) suggest that there is important interaction between the individual, firm and networks levels in creating dynamic

capabilities. In some cases they work as complements, but in others they can work as substitutes. Their study indicates that firms can substitute superior human capital for firm-level factors such as R&D capacity. Thus this study established that managers must weigh individual, firm and network resources when developing an overall firm strategy constitutes the most important contribution of this study. Although a noteworthy study, it is based on weak secondary data and ill-defined constructs and measurements. Therefore it needs further refinement and testing.

Another dynamic capabilities study that uses life science firms as the sample is Zucker and Darby's (1997) study on the influence of star scientists on the transformation of an organisation. Their findings suggest that star scientists greatly influence the growth and direction of a firm through their innovative abilities. The scientists' innovations set the direction of the organisation and force it to reorganise to commercialise the star scientists' discoveries. Zucker and Darby (1998) followed this study up with an investigation clearly showing that knowledge spills over from universities to biotech firms located near universities. This tacit knowledge is a large source of dynamic capabilities for the recipient firms of the knowledge. Deeds et al. (2000) is another empirical study on dynamic capabilities that uses life science firms as the sample; it also highlights the importance of human capital and supports the notion that knowledge spilled over from universities provides important antecedents to dynamic capabilities. Another important finding from this paper is that it is better to keep top scientists in R&D than to have them as top executives. The management duties take away from their tacit scientific knowledge, which serves as a driving force to creating innovations that change a firm. This study suggests that it is important to have a top management team with business experience and scientific knowledge.

In a different vein, Madhok and Osegowitsch (2000) use dynamic capabilities at the macro-level to look at the diffusion of biotechnology around the world. They studied alliance and innovation flows of the US and Europe; their findings show that initially the technology flows were one way from the US to Europe, but over time the innovative capabilities built up in Europe and the flow of innovation became two way. Although an interesting study that gives a good overview of the evolution of the cross continental flow of biotech knowledge, it would have been even more interesting had they included some firm-level examples.

These studies clearly demonstrate that dynamic capabilities is starting to gain the empirical support that it needs to become a strong theory. Also apparent from the discussion above is that the life science industry offers an ideal setting in which to apply a dynamic capabilities framework. The industry fits the key prerequisites as it is rapidly changing and has constructs that lend themselves to empirical testing. For instance, the industry is heavily dependent on patents, which are a good proxy to measuring innovation (Acs & Audretsch, 1989). There are also critical technological inflections in the industry, which lead to interesting research opportunities on how firms reorganise themselves to respond to these opportunities. However, empirical work as a whole on dynamic capabilities needs further development. Table 3-2 presents the key empirical studies done on dynamic capabilities from 1992-2010. From this table it is evident that Arend and Bromiley (2009) were justified in their assertion that dynamic capabilities does not have enough empirical support. Specifically there is little longitudinal work, and many of the studies examine dynamic capabilities post hoc. There are also few studies that have used mass surveys, and scant work on small firms exists.

Table 3-2: Empirical studies on dynamic capabilities

Study	Measurement	Research focus	Findings
*1. Van de Ven and Polley (1992)	Single biomedical innovation over a five year period; in-depth case study with multiple sources and on-going observation	Examined the process of trial and error learning in technological innovations by a joint venture created to commercialize products.	– Observed greater escalation of commitment and other types of non-rational behaviour than implied in the learning literature – Suggested the following to increase adaptation ability: • separate planning from resource funding • limit 'impression management' opportunities • foster frank communication across departments and levels.
2. Eisenhardt and Tabrizi (1995)	36 Computer-related firms, (72 projects); case studies – multi-respondents per project	Examined effects of planning, CAD tools, teams, supplier involvement, reward, and time schedules on product development time.	– Found planning and CAD tools *increase* the time to develop new products – Cross-functional teams, frequent iterations, leader power, and trial-and-error learning decrease development time.
3. McGrath (McGrath, 1995)	23 Financial services firms; over 200 interviews	Exploratory research to see how firms process and learn from poor outcomes in internal corporate venturing.	– Noted three processes needed to learn from disappointments: • recognition of failure (*measurement, involvement, communication* of results) • interpretation of results into a business model that can be tested • action taken to change routines.
4. Helfat (1997)	The 26 largest energy firms over extended period of time; historical and secondary data	Examined if success of responses to changes in external conditions depends on existing stocks of complementary know-how and assets.	– Firms with larger stocks of complementary technological knowledge and physical assets experienced greater increase in capabilities. – Yet, such increased capabilities could not compensate for the large drop in real oil prices.
5. Brown and Eisenhardt (1997)	6 firms in computer industry (41 projects); case studies	Examined the ability of firms to change their competences continuously in response to high velocity environments.	– Reject notion of punctuated equilibrium and event-based approaches in favour of time-paced responses. Learning and dynamic capability creation based on: • well-defined managerial responsibilities and project priorities • extensive communication • frequent low-cost experiments and iterations.
6. Moorman and Miner (1998)	One electronics instruments firm; one food products firm (107 action events over nine months); survey data on selected events	Examined the effects environmental turbulence, improvisation, and organization memory on product and process efficiency/effectiveness.	– Turbulence has a weak positive effect on use of improvisation. – When turbulence is low, improvisation has negative effect on effectiveness; when turbulence is high, the effect is positive. – Organization memory has a negative effect on improvisation. – However, organization memory significantly improves positive effects of improvisation on all process and product outcomes.
7. Kazanjian and Rao (1999)	225 Computer-related companies; survey data in two waves Hypothesis tests on survey data	Examined factors influencing engineering capability institutionalization in firms highly dependent on this expertise.	– Found managerial advocacy key positive factor. – Found mixed results with regard to CEO background. – Found institutionalization more likely with smaller TMTs. – Found no effects of formalization or centralization..
8. Bosch et al. (1999)	Publishing firms; illustration of two cases	Focused on how organization form and combinative capabilities mediate effects of prior related knowledge on absorptive capacity.	– Definitive conclusions hard to draw, but arguments regarding organization forms are • Functional form is + for efficiency, - for flexibility, - for speed. • Divisional form is - for efficiency, + for flexibility, + for speed. • Matrix form is - for efficiency + for flexibility, + for speed
9. Majumdar (2000)	39 telecommunication firms over 16 yrs; secondary data	Examined effects of structural changes in the environment on resource accumulation, configuration, and utilization capabilities of firms.	-Concludes that contrary to popular beliefs, larger more stable firms can indeed transform their capabilities in the face of overwhelming structural changes to the industry.
10. Autio et al. (2000)	59 electronics firms; panel survey data over four-year period, some validation from repeat surveys and secondary sources Hypothesis testing based on survey responses	Examined the effects of early inter-nationalization on the prospects of smaller firms' growth. Argued that such firms may possess learning advantages over older firms.	– Found that internationalization at an early age was associated with greater growth both domestically and internationally. – Found product imitability to be positively rather than negatively associated with growth. – Found knowledge intensity positively related to growth.
*11. Madhok and Osegowitsch (2000)	Data on international alliances, joint ventures, licensing, acquisitions and new Greenfield subsidiaries of European and US biotechnology firms	Examined the cross national flow of biotechnology innovations between the US and Europe.	-Found that initially biotechnology innovation was a one way flow from the US to Europe. -Found that as Europe developed capabilities, innovation became a two-way flow

Study	Measurement	Research focus	Findings
	Hypothesis testing based on secondary data		
*12. Deeds et al. (2000)	94 publicly held biotechnology firms Hypothesis testing based on secondary data	Examined the effects of technological and management skills on new product development.	-Found that location near research based universities is key to developing scientific dynamic capabilities. -Found that top scientists are more effective in a research role than in a top management role.
13. Zahra et al. (2000)	321 high technolog y firms (from 12 different sectors); survey data with validation from second respondents and secondary data Hypothesis testing based on survey responses	Examined the effects of international diversity and mode of market entry on technological learning and performance of high technology firms.	– Found that international diversity had positive effects on the breadth, depth and speed of technological learning in new internationalizing high technology ventures. – Found that knowledge integration significantly enhanced the positive effects of diversity on the breadth, depth and speed of technological learning. - Found that modes of entry also significantly affected breadth, depth and speed of learning. – Found a positive relationship between international diversity and performance.
14. Abuja and Lambert (2001)	97 global chemical; secondary data, especially patent citations	Examined how large corporations create breakthrough inventions and how exploration of novel, emerging, and pioneering technology helps them overcome competency traps.	– Found inverted-U shaped relationship of exploration of novel and emerging technologies with creation of breakthrough invention. – Found positive relationship of exploration of pioneering technologies with creation of breakthrough invention. – Concluded that continual activity and experimentation are needed for firms to renew and reconfigure capabilities.
*15. Engelhard et al. (2002)	Action research: interviews with 26 different individuals involved with R&D at three different pharmacy firms.	Examined organizational learning techniques in the creation of actionable knowledge.	-Suggests that the learning capability of a firm has to be dynamic in order to create complex knowledge. -Suggests knowledge assessment is an important capability.
16. Katila and Abuja (2002)	124 Robotics firms; secondary data, especially patent citations Hypothesis testing based on secondary data	Examined the effects of search depth and search breadth on a firm's ability to create change in product introduction.	– Found a positive relationship between search breadth and depth on new product introduction; but beyond a certain level, additional depth begins to reduce new product introduction. – Concluded that exploitation is a broader concept and more beneficial than previously believed.
*17. Rothaermel Hess (2007)	A cross national sample of 35 pharmaceutical firms' alliances and innovation output; data collected from secondary sources of information covering 24 years Hypothesis testing based on secondary data	Examined the antecedents of dynamic capabilities looking at the interaction of individual, firm and network antecedents.	-Found that the 3 levels of antecedents are not always complementary. -Often human capital (individual level) can substitute for the other two levels (firm and network)
18. Harreld and O'Reilly (2007)	A case study on IBM. Data collected from secondary data.	Examined the success of IBM from a dynamic capabilities perspective.	-Found IBM has been able to thrive largely based on the ability to reorganize itself in the face of rapidly changing technology and competition environments .
19. Kale and Singh (2007)	175 computer, telecommunications, pharmaceutical, chemical and electronics firms that have been involved in alliances Hypothesis testing based on survey responses	Examined the process of learning in alliances.	-Found that learning that involves articulation, codification, sharing, and internalization of alliance management know-how leads to superior performance.
20. Macher and Mowery (2009)	93 manufacturing processes in 36 different manufacturing facilities from 32 different semiconductor firms from 1995 to 2001.The sample consisted of firms from the US, the EU, Japan, Korea and Taiwan Hypothesis testing based on secondary data	Examined the role of R&D and learning on capabilities .	-Found support for the arguments of Teece et al. (1997), Eisenhardt and Martin (2000), Solo and Winter (2002) and Winter (2003) that managing and reconfiguring capabilities is crucial in high-technology industries. -Found that deliberate learning is important to creating capabilities. -Found 'learning before doing' is the most effective approach.

Study	Measurement	Research focus	Findings
*21. Chiaroni et al. (2009)	Two step (1) an interview panel of 20 industry experts (2) An analysis of the open innovation modes used by 20 large pharmaceutical companies	Examined the organizational modes of open innovation and how these effect drug development.	-Found that the characteristics of the biotech industry are mitigating variables in the implementation of open innovation.
22. Newey and Zahra (Newey & Zahra, 2009)	40 interviews with multi informants from two firm case analysis and comparison	Examined how dynamic capabilities react to changes within the individual firm.	-Found that firms build absorptive capacity in value networks whilst they are developing new products. -Found that learning captured at the product planning level is the most beneficial.
23. McKelvie and Davidsson (2009)	Sample of 108 Swedish new (<10years) SMEs from various industries Hypothesis testing based on survey responses	Examined the effect the founder human capital, access to employee human capital, access to technological expertise, access to other specific expertise and access to two types of tangible resources had on the development of dynamic capabilities.	-Found that resources and changes to resources are important to forming dynamic capabilities. -Found changes in resources have more influence on the development of dynamic capabilities then the stock of resources does. -Suggested that the firm is a dynamic stock of resources rather than a static stock.
*24. Narayanan et al. (2009)	Multiple interviews with several layers of management at one pharmaceutical firm	Examined the cognitive orientations of key personnel, managerial action within the firm and the firm's internal and external contexts and how these effected the development of capabilities.	-Suggests that key personnel have a significant impact on the development of capabilities; not because their actions were inimitable but because of their persistence in developing the capabilities led the dynamic capabilities. -Found that external contingencies have a major impact on the development of dynamic capabilities.
25. Romme, Zollo and Berends (2010)	Experiment simulation of how executives develop knowledge routines in the face of different environmental variables Hypothesis testing based on experiment results	Examined how firms respond to various factors to develop knowledge.	-Suggests that the impact of deliberate learning on dynamic capability is non-linear, complex, and in some instances counter-intuitive.

Source: Adaptation and expansion of Zahra et al. (2006) *Life science studies

The table above shows that some studies are starting to surface that use hypothesis testing, and certain areas are justified to do so. In certain areas the theory has grown to a point where it can be tested. However, there are many areas related to dynamic capabilities, such as the development of capabilities in small firms that cannot be properly tested because of the lack of defined measures and constructs. The largest problem restraining empirical testing in dynamic capabilities is the lack of a consistent framework. Teece et al.'s (1997) paths, positions and processes framework offers a way to address this. Essentially, this framework contends that competitive advantage lies in a firm's processes, which are determined from a firm's paths and positions. Previous paths are the past decisions and future opportunities that shape where a firm can go. Past decisions commit resources and often create rigidities because the firm is deeply tied to its earlier commitments. For example, Deeds and DeCarolis' (2000) study on new life science firms shows that a firm's future development opportunities is limited by investments made in earlier research. They suggest that often firms invest so heavily in a technology that they drain resources that could be used for future projects. Future paths represent opportunities available to the firm

and how the firm strategizes and organises its resources to pursue these opportunities. Positions are the resources the firm uses to leverage in their pursuit of future paths. For example, life science firms often leverage their patents in the pursuit of developing a technology (Deeds et al., 2000; Madhok & Osegowitsch, 2000; Ziedonis, 2004).

Although Teece et al.'s (1997) paper lays out a viable framework for examining dynamic capabilities; i.e. probe the paths, positions and processes that lead to competitive advantage – little work examines all of these in a single study. As discussed above in the section on key empirical studies relating to dynamic capabilities, studies have examined competitive advantage and firm growth using parts of the framework, but surprisingly little work holistically examines the paths, positions and processes in a single study. Furthermore, it is hard to take a study that examines the paths leading to competitive advantage and then compare it to a study that examines the positions that lead to competitive advantage. Dynamic capabilities is fundamentally process-based, and processes are hard to dissect and compare in multiple studies (Pettigrew, 1992). Therefore, a sharp need for research to examine the paths, positions and processes leading to growth in a single study exists. In-depth qualitative work is especially needed to unearth insights on:

- What past decisions create path rigidities?
- What future opportunities motivate reconfiguring resources and capabilities?
- What positions do firms leverage to create key resources and capabilities?
- What are the processes the firms use to create key resources and capabilities?

Qualitative work has the potential to show how a firm develops dynamic capabilities and what the outputs of dynamic capabilities are. In turn, this will give quantitative scholars more measureable and valid constructs to work with.

3.4.4 Dynamic capabilities' shortcomings and conclusions

Intermixed in the discussion above are several shortcomings of dynamic capabilities: lack of a coherent definition, weak empirical support and difficult to measure constructs. Arend and Bromiley (2009) note these shortcomings along with several others; they even go as far as to use these shortcomings as a basis to abandon dynamic capabilities. One of their main assertions is that the theory does nothing more than restate previous work of absorptive capacity, strategic fit, first-mover advantage, organisational learning and change

management. Accordingly, dynamic capabilities must add value beyond these theories and have a basis for prediction to be considered a credible theory. Their second criticism of dynamic capabilities is the inconsistent definitions in the literature. This is a view that is shared by many scholars, including those who publish on dynamic capabilities (Collis, 1994; Williamson, 1999; Winter, 2003). Arend and Bromiley's (2009) third grievance is that dynamic capabilities lacks rigorous empirical support. They clearly show that the little empirical support for dynamic capabilities mainly comes from weak quantitative studies that do not include a longitudinal component. They also illuminate the fact that most of the empirical support comes from post hoc studies; i.e. research that finds successful firms that have dynamic capabilities. A fourth grievance of Arend and Bromiley is the lack of coherent and logical proxies for measuring dynamic capabilities; there are too many measures of dynamic capabilities, which indicate that there are incoherent constructs. The fifth grievance of Arend and Bromiley (2009) is the lack of practical implications for dynamic capabilities.

Whilst Arend and Bromiley's (2009) criticisms have some merit, they do not take into account the entire body of work on dynamic capabilities and fail to consider that the theory is a young theory. Helfat and Peteraf (2009) offer a well thought out rebuttal to Arend and Bromiley (2009) that clearly acknowledges and addresses their concerns. They show that dynamic capabilities is a young theory that is just emerging from its conceptual stage; therefore, it will have some foundational issues to iron out. Helfat and Peteraf (2009) also refute the suggestion that there is weak empirical support. They point to several strong empirical studies (Helfat, 1997; Ingelgard et al., 2002; Zahara, Ireland, & Hitt, 2000), and also reiterate that because of its youth, dynamic capabilities should not be expected to have an established body of empirical work.

In short, dynamic capabilities has the underpinnings of a strong theory. First, it can show causality. For example, several of the studies discussed above show how dynamic capabilities can cause a firm to have more creative capacities (Eisenhardt & Tabrizi, 1995; Harreld et al., 2007; Majumdar, 2000). Second, it is measurable. For example, it can be measured through new product development (Drnevich & Kriauciunas, 2011), patents (Katila & Ahuja, 2002) and learning outcomes (Zollo & Winter, 2002). Third, dynamic capabilities has shown predictive powers. For example, studies have predicted that firms with learning capabilities can better contend with rapidly changing environments (Romme et al., 2010; Zollo & Winter, 2002). Furthermore, the importance of learning capabilities in

certain settings has been disconfirmed (Kale & Singh, 2007), which shows that dynamic capabilities has the theoretical quality of being able to be falsified. Although dynamic capabilities has shown the underpinnings of a theory, it is still far from robust. It is still in its nascent stage and lacks defined measures and constructs for small firms, especially for small life science ventures.

Conclusions

There is no perfect theory in management – whether the RBV, the five forces model, or transactions cost analysis. Dynamic capabilities is no exception. It has ill-defined constructs and measures and little empirical support to back it up. Although many of the criticisms are valid, there is potential for future research to address these. Moreover, it is one of the few theories that can properly account for rapidly changing environments. It also has a sound theoretical basis because it draws heavily on the RBV (Eisenhardt & Martin, 2000; Teece et al., 1997; Winter, 2003). Furthermore, Teece et. al. (1997) paths, positions and processes framework offers a way to tie the theory together. At the highest level firms are able to use their paths, positions and processes to create CAs (Teece, 1997; Trispas, 1997, Rothaermel, 2001). These are auxiliary assets needed in the commercialisation of a technology. CAs are often a large source of competitive advantage as they create unique competitive positions (Teece, 1986; Tripsas, 1997). The next section of this review delineates the literature on CAs.

3.5 Complementary Assets

This section is dedicated to further discussing one of the highest levels' outputs of dynamic capabilities – CAs. These are high level auxiliary assets and capabilities needed in the commercialisation of innovations (Teece, 2007). CAs are especially relevant to life science firms as these are needed to commercialise innovations in the field (Rothaermel, 2001a). This topic is also relevant to the present study because R&D has been viewed through a CAs lens (Gans et al., 2002; Teece, 1986). This section provides a description of CAs, overviews the empirical work on CAs and discusses the shortcoming of the CAs framework.

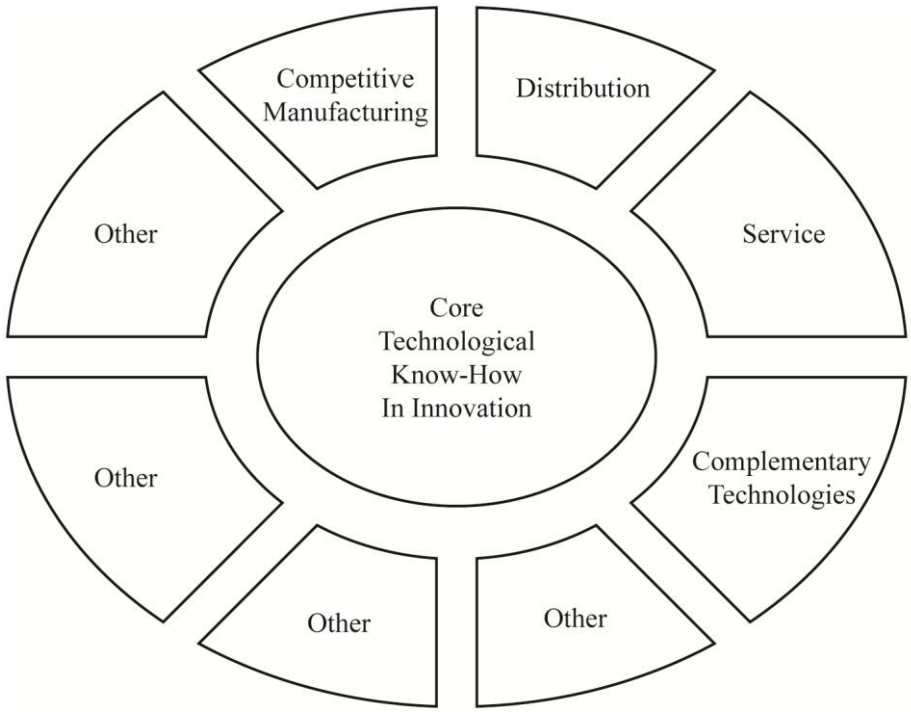
3.5.1 Description of CAs

Teece (1986) formally introduced CAs as the auxiliary assets and capabilities needed to commercialise an innovation. Edvinsson and Sullivan (1996, p. 360) offer a slightly different definition specific to knowledge-based firms: '*the string of assets through which the technology must be processed in order to reach the customer'*. Teece (1986) further proposes three broad categories of CAs: 1) general CAs (GCAs) 2) specialised (SCAs) and 3) co-specialised complementary assets (CCAs). GCAs are generic assets needed in commercialisation that are easily purchased on the open market, for example, general shipping. If a firm can ship its goods through a company like UPS or Federal Express, then this is a GCA; the shipping is needed for commercialisation, but it is easily obtained on the free market. SCAs are similar to GCAs, but they cannot be obtained on the free market. They are assets with a unilateral dependence that are needed for commercialisation. An example of an SCA is service capabilities of a medical device firm. In many cases medical devices require specialised service capabilities to maintain the product, and if a firm is unable to service the device, then the device cannot be commercialised. In many cases medical device firms partner with specialised service firms to provide the specialised service for their medical device(s), which could be a unilateral dependence because the medical device has to have the specialised service capabilities to be commercially viable, but the service provider does not need the medical device firm to stay in business; they have other clients that could sustain their business. CCAs are assets that are mutually dependent on each other. An example of this is Microsoft and IBM in the early 1980's. In the beginning of Microsoft they needed IBM for the hardware platform to run their software, and IBM needed the Microsoft software platform for programs to make their hardware usable and desirable.

Figure 3-4 presents Teece's (1986) illustration of the CAs needed to commercialise an innovation. He identifies four areas that are usually involved with the commercialisation of an innovation: 1) competitive manufacturing, 2) distribution, 3) service and 4) complementary technologies. The illustration also includes 'other' boxes to represent CAs not encompassed in the four other areas, an example being compliance capabilities for a pharmaceutical company. In many cases biopharmaceutical companies have to have specialised capabilities in meeting government regulation before their products can be sold (Hopkins & Nightingale, 2006). This illustration gives a good conceptualisation of the CAs needed in commercialisation.

The present research is specifically interested in R&D and financial resources, and as discussed earlier, R&D has been viewed through a CAs lens. It would be interesting for empirical work to explicitly see where R&D fits in within a CAs framework, as there is little research that has looked at this. Furthermore, finance has not been viewed through a CAs lens, but it would be interesting to see if it could be. Capital should not be viewed through such a lens, but the capabilities in raising capital could be. Conceptually they meet the definition of CA, auxiliary assets or capabilities needed in the commercialisation of an innovation (Teece, 1986); i.e. the capabilities to raise capital are auxiliary capabilities needed to fund the development of other assets.

Figure 3-4: CAs needed in commercialisation



Source: Teece (1986, p. 289)

The ideas discussed above indicate that CAs is rooted in the RBV. Many researchers contend that capabilities are resources that can be used to build competitive advantages from (Barney & Hansen, 1994; Helfat & Peteraf, 2003; Mahoney & Pandian, 1992; Peteraf, 1993). It follows that SCAs/CCAs are resources that can be used to build competitive advantages; they meet the criteria of the RBV; valuable, rare, imperfectly imitable and non-substitutable (Barney, 1991). SCAs and CCAs are valuable because commercialisation cannot happen without them. By definition, they are rare because they are not easily purchased on the free market. They are inimitable because they are not easily

reproduced. Lastly, they are non-substitutable, as little else can fill the void needed for the SCAs/CCAs. If a CA does not meet all of these requirements, then it is a GCA. Moreover, SCAs and CCAs are the product of the highest level of dynamic capabilities (Teece, 2007). Firms must be able to either create the CCAs and SCAs needed for the commercialisation of innovations or cooperate with other firms to obtain these assets (A. M. Arora & Ceccagnoli, 2006; Rothaermel, 2001a). This requires firms, both internally and externally, to constantly manage their asset combinations and rearrange them to create the appropriate CCAs and SCAs needed to commercialise their innovations. Moreover, abnormally high profits are obtained when a firm creates a platform that other firms need as CCAs (Meyer, 1997; Yang & Jiang, 2006). For example, Microsoft created an operating system that other software firms needed to commercialise their software. This platform provided a source of competitive advantage that yielded massive profits for Microsoft.

The discussion above shows why CCAs and SCAs are at the pinnacle of the resource pyramid presented at the beginning of the chapter in Figure 3-1. They are the most refined resources needed in the commercialisation of innovations. Even though CCAs and SCAs offer possible insights into how firms obtain hyper-returns, there is little research that looks at the topic. The next subsection looks into the reasons for this.

3.5.2 Empirical work on CAs

Although Teece's (1986) seminal work on CAs is well-noted, there is relatively little empirical work to support it. Numerous studies touch on CAs, but few directly examine it. This section highlights the noted empirical studies to date.

Moorman and Slotegraaf (1999) looked at the CAs needed for product commercialisation. Their study identifies and tests a model of complementary capabilities. The model emphasises the interaction between information and capabilities (namely marketing, technical, R&D and distribution) of the firm. It suggests that flexibility is imperative to responding to new information; i.e. firms' capabilities must be flexible and work in conjunction in developing the assets needed for product commercialisation. In a similar study, Mitchell (1992) looked at the role of CAs in the medical diagnostic imaging industry. His research indicates that the SCAs of sales and service buffer, to a point, incumbents from new, more innovative competitors. Similarly, Trispas (1997) analysed the typesetter industry between 1886 and 1990 and found that SCAs played a critical role

in buffering incumbents from new competition. The new and often more innovative firms lacked specialised sales and service capabilities that kept them from overtaking the incumbents that possessed these SCAs. The buffering property of SCAs is also backed up by Rosenbloom and Christensen (1994), who suggest firms have a whole value network that has to change in order for a new firm with a new innovation to enter the market.

Much of the recent work on CAs focuses on alliances and networks (e.g, Eckhardt & Shane, 2010; Motohashi, 2008; Rothaermel, 2001a; Rothaermel, 2001b). Rothaermel (2001b) examines the role of inter-firm alliances and CAs in the biopharmaceutical industry, suggesting that incumbent firms enhance their industry position by using their established CAs to commercialise the innovations of new entrants. The study also indicates that often incumbents have well-established positions and SCAs, but often are not as innovative as the new entrants. In addition, the study finds new entrants lack the SCAs that established firms have, such as specialised manufacturing. Thus it is often better for the incumbent and the new entrant to form alliances to fully exploit innovations and SCAs. Rothaermel (2001a) came to similar conclusions from another 2001 study of CAs in the biotechnology industry. This study differed from his other 2001 study in that it focused on the alliances of large biotechnology companies, finding that firms focusing on exploiting CAs outperform firms focusing on creating new innovations. The study also indicates that the biotechnology industry focuses on establishing mutually beneficial CAs. Interestingly, he did not follow Teece (1986) in calling these CCAs because, in his view, it was too difficult to discern between SCAs and CCAs and that the difference was irrelevant for the study. Similarly, Rothaermel (2001b) felt the real importance is whether an asset was generic or specialised. In a similar vein, Rothaermel and Hill (2005) justifies using SCAs and CCAs interchangeably because it was not critical to the study. In this study they also conjecture that it is very difficult to a draw a distinction between CCAs and SCAs. Several other studies follow the same protocol in not distinguishing between SCAs and CCAs (Arora & Ceccagnoli, 2006; Christmann, 2000; Tripsas, 1997); instead calling any specialised assets, whether and SCA or CCA, an SCA. Although the distinction between CCAs and SCAs was not critical to these studies, distinguishing them would have improved the studies by magnifying the importance of bilateral alliances.

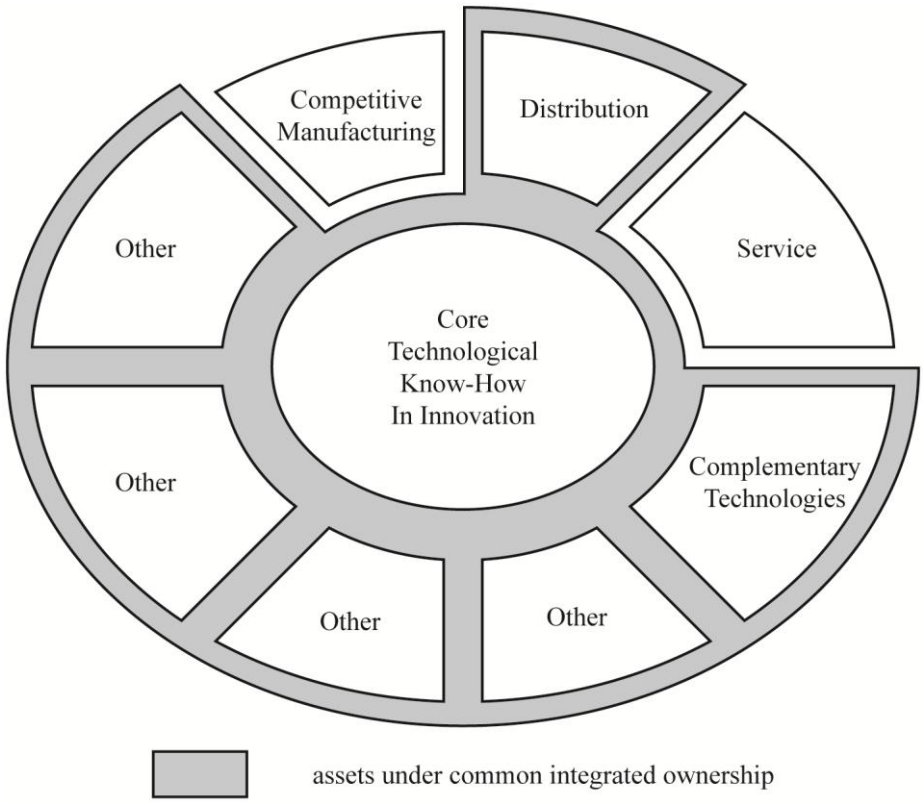
Many others have taken a similar approach as Rothaermel (2001, 2001a, 2005) and looked at the role of alliances in the creation of CAs. Harrison et al. (2001) notes the importance of resource complementarities in the formation of alliances. According to this study,

synergies are created between two firms that mutually create assets that are needed for commercialisation. In a similar vein, Teece (2003) notes the importance of CAs that are created through alliances in the commercialisation of knowledge-based innovations. Several others look at the importance that alliances play in establishing CAs for start-up firms. Most notably, Baum et al. (2000) suggest that start-ups benefit themselves by early along in the venture aligning themselves with alliances, integrating themselves in efficient alliances and aligning themselves with rivals when the opportunity for learning outweighs the risks of working with a competitor. Hopkins and Nightingale (2006) put forward that alliances offer a CA in the form of risk reduction. Their study looks at the risk-spreading of biotechnology firms and concludes that firms can reduce risk by creating alliances with firms that have specialised risk management capabilities.

It is interesting that these studies note the importance of alliances to life science firms in creating CAs. However, studies on CAs and alliances do not examine how alliances interact to create the CA of R&D. The life science literature discussed in chapter two emphasised the importance of alliances to R&D, and the present chapter put forth R&D as a possible category of CA (Lowe & Taylor, 1998), yet studies have not thoroughly probed whether or not alliances lead to the CA of R&D. This thesis is specifically interested in R&D and probes whether partnerships lead to the development of CAs.

The discussion in the two paragraphs above indicates that cooperation is important. Even firms pursuing competitive strategies will most likely have to have some degree of cooperation with other firms; i.e. suppliers, competitors or customers. Teece (1986) highlighted this in his conceptualisation in figure 3-5 below. This illustration shows that many areas (shaded) are jointly controlled through alliances (cooperative strategies), whilst other areas are completely controlled by the innovating firm (competitive strategy). Although this figure gives a good conceptualisation of the fact that often cooperative and competitive strategies are pursued at the same time, it fails to consider that individual CAs can have elements of cooperation and competition. For example, R&D can mostly be undertaken by an individual firm, but the individual firm may have partners for select R&D functions.

Figure 3-5: CAs under joint control



Teece (1986, p. 291)

The largest problem plaguing the empirical work on CAs is the lack of defined measures. The studies on CAs use many different measures. Whilst it is good to have different measures to look at the theory from different perspectives, consistent measures are needed for comparative purposes (Johnson & Onwuegbuzie, 2004). Furthermore, the lack of consistent measures also raises reliability and validity concerns for the framework. Gans and Hsu (2002) developed five-point Likert scales to measure the importance and degree of specialisation of CAs. Their scales are the most accurate measures offered to date and are adapted by several others (Parmigiani & Mitchell, 2009; Pries & Guild, 2007, 2010). Other than the measurements offered by Gans and Hsu (2002), there have been few other reliable and valid independent variable measures offered to date. The dependent measures are not as problematic in CAs because these measures are adapted from studies in related areas, such as firm growth, the RBV, and transactions costs.

CAs and patents

Patents are an important resource that influences CAs. Arora and Ceccagnoli (2006) looked at the effect that patents have on CAs and found that firms with weaker patent protection rely more on stronger CAs to commercialise their products. They also find that firms with stronger patents rely more on licensing to commercialise their goods; because their value added activities are in the patent and not the SCAs/CCAs. This work has been supported by several others (Colombo, Grilli, & Piva, 2006; Deeds et al., 2000; J. S. Gans & S. Stern, 2003). Grauff et al. (2003) examines the effect of intellectual property in the mergers and acquisitions of agricultural biotechnology firms. The results from their study indicate that firms merge with each other to align their complementary intellectual property portfolios. In a similar vein, Edvinsson and Sullivan (1996) suggest that patents themselves do not fully protect technology. Instead they contend that SCAs/CCAs are needed to protect novel innovation. Though patents protect innovations as a whole, some important processes or ideas cannot always be patented. Furthermore, processes and ideas can be exposed in the licensing process when information is shared; the exposed information could be used to create competing innovations (Lanjouw & Schankerman, 2001). Difficult to obtain, SCAs/CCAs offer protection that patents cannot because they protect knowledge and make it so other firms cannot commercialise a similar innovation. Edvinsson and Sullivan (1996) emphasise this in their model of innovation, which is based off of four major elements: human capital, structural capital, complementary assets and intellectual property.

Size is another mitigating factor in the development of CAs needed to commercialise patents. Arora and Fosfuri (2003) offer a model of rent vs. revenue for patents. This model looks at what factors drive a firm to either license their innovations or to commercialise their innovations themselves. One mitigating factor is the size of the firm. Small firms often do not have the resources and capabilities to commercialise an innovation; instead they often focus on one particular process such as R&D. Because of the lack of assets and capabilities to commercialise an innovation, small firms often license their ideas; even though the rents they earn are less than if they commercialised the products themselves (Pries and Guild, 2010). Conversely, large firms that develop innovations often control the upstream and downstream activities. Not only does this allow them to earn higher rents from their innovations, but it also shields them from competition. Furthermore, controlling the downstream activities also allows firms to reduce transactions costs (Heller & Eisenberg, 1998). Each company that is involved in commercialisation adds layers of

transactions; especially in the case of patent licenses where contracts consume substantial time and resources in developing (Hennart, 1988; Oxley, 1997).

From the discussion above it seems natural that large firms should control the upstream and downstream activities in developing an innovation. However, an increasing percentage of downstream research comes from small firms (Jones, 1999; Nicholas, Ledwith, & Perks, 2011; Van Beuzekom & Arundel, 2009). For this reason large firms are working with small firms to create CCAs/SCAs to commercialise the innovations conceived by small firms. The competition for the most novel ideas is intense and has led to large firms investing in smaller R&D firms that have ideas with grand potential (Arora & Gambardella, 1990). This investment helps secure the innovation rights for the larger company.

It is surprising that small firms are often the source of knowledge and innovation needed for the development of CCAs and SCAs, especially in capitally intensive industries such as the life science industry. This phenomenon is credited to two things: the spill-over effect from universities and the fact that small firms are more flexible and can more quickly respond to changing technological environments. There is a clear correlation between the spill-over of innovations from universities to industry, especially to small firms. Studies indicate that in areas with top-tier research universities, there are an inordinately high number of innovative start-ups (Anselin, Varga, & Acs, 1997; Jaffe, Trajtenberg, & Fogarty, 2000; Jaffe et al., 1993). The ideas for innovations are often birthed in universities and then either sold to firms located near the university or a spin off firm is created near the university. This is especially prevalent in life science innovations where scientists like to stay on the university's faculty whilst still pursuing the opportunity to commercialise innovations (Audretsch & Stephan, 1999; Zucker et al., 2002). The second reason attributed to the innovativeness of small firms is flexibility. Small firms have the advantage of newness and are not entrenched in bureaucratic routines the way large, established firms are (Autio et al., 2000). Acs and Audretsch (1987) suggest that small firms have an advantage in innovating in industries, such as life science, that are technologically intensive. Furthermore, the literature on absorptive capacity suggests that new firms often have an advantage in recognising opportunities (Cockburn & Henderson, 1998a; Stock, Greis, & Fischer, 2001). In short, small firms are often innovative because of their university ties and the fact that they are flexible and dynamic.

3.5.3 An unexplored framework

Perhaps the reason so many researchers avoid the explicit use of the term CAs is that it is so elusive to define and measure. Teece (1986) describes CAs as support assets or capabilities needed for the commercialisation of an innovation. Whilst in theory this seems clear, in practice it is much more difficult to pin down, especially for SCAs and CCAs. Take the example of manufacturing capabilities in the pharmaceutical industry: if a firm has truly unique manufacturing capabilities, then this would be considered an SCA or CCA. However, if a firm could contract the manufacturing of a drug out, would this be an SCA or CCA? If the contract manufacturer has truly unique capabilities and formed a partnership with a pharmaceutical firm, and both were reliant on each other, then this would be a CCA. But if the R&D firm in this example could set this alliance up with a few different manufacturing firms that had unique and specialised production capabilities, would this be an SCA or CCA? As this example shows, there is clearly a grey area in defining CAs, especially in discerning amongst GCAs, SCAs and CCAs. Moreover, measuring CAs has proven even more difficult. For example, Rothaermel (2001a) attempted to measure complementary alliances based on secondary data of biopharmaceutical alliances and new product development. The results indicate that incumbents prefer alliances to leverage CAs over those to create new innovations. However, the analysis fails to show how a coded variable based on secondary data can differentiate between an alliance for the purposes of obtaining a CA and an alliance for creating new innovations. This is not to criticise this research, as it was an excellent study that provided much needed insight on CAs; rather this illustrates how difficult it is to measure CAs. One way to overcome these difficulties is to capture the essence of CAs in survey and interview studies. Qualitative work is especially needed to unearth insights on the connections between CAs and firm growth. These insights are needed to create valid and reliable measures.

Table 3-3 below outlines the major empirical work done on CAs. This table is much leaner than the table presented earlier in the chapter on the empirical work on dynamic capabilities. CAs lacks the conceptual and empirical robustness of a major framework. However, there are several strong studies that have conceptually laid the ground work for the framework (e.g., Eckhardt & Shane, 2010; Edvinsson & Sullivan, 1996; Teece, 1986), and several other studies that provide an empirical base for it (e.g, Rothaermel & Hill, 2005; Tripsas, 1997). More studies in the fields of strategic management,

internationalisation, entrepreneurship and marketing need to study the role of CAs in firm growth.

Year over year a higher percentage of firms in developed countries are technology-based firms (Conway, Janod, & Nicoletti, 2005). Technology firms require ancillary assets to commercialise their innovations (D. J. Teece, 1986), yet the management literature has failed to properly investigate the topic. Stieglitz and Heine (2007) make a strong argument on the merits of using CAs in the study of strategic management. Specifically they conjecture that CAs are an important part of the strategic direction of firms and need to be factored in. They also suggest that CAs should be centrally coordinated by management, and that controlling CAs on an ad hoc basis to the firm does not work because the whole firm must be integrated with the CAs, a key point that other studies on the topic have missed. Another area that is specifically lacking, especially with regard to new ventures, is how firms create CAs. Many of the studies discussed above note the importance of alliances in ascertaining key CAs, but not all CAs are accessed through partners. Little work investigates how firms internally develop CAs. Moreover, there are few studies that examine the interface between creating CAs and finance; i.e. how CAs are capitalised, which is especially relevant for new ventures that are resource constrained. Thus the question remains: how do young firms overcome financial restraints to create or acquire CAs?

Table 3-3: Key CAs studies

Author	Area of CA Looked At	Type Of Study	Results
Teece (1986)	Introduction and conceptualization of complementary assets	Conceptual Paper	-Introduces GCAs, SCAs, and CCAs
Edvinsson and Sullivan (1996)	Conceptual model of intellectual capital	Conceptual Paper	-Introduces a model of intellectual capital based on human capital, structural capital, complementary business assets, and intellectual property
Tripsas (1997)	CAs as a buffer to competition	Hypothesis testing based on historical data of the typesetter industry	-Firms can buffer themselves from new more innovative firms if they have well established specialised CAs
Shane (2001)	Developed and tested a model of firm formation based on four variables: the age of the technical field, effectiveness of patents, the tendency of market segmentation, and the importance of CAs	Took 1,397 patents from MIT and looked at how many of these led to firm foundation.	-Found that firm foundation off of university patents is more likely when technical fields are young, markets are segmented, patents are more effective, and marketing CAs are less important
*Rothaermel (2001a)	Alliance formation for the purposes of developing CAs	Testing based on secondary data of Alliances of large	-Incumbents that focus on developing networks to exploit CA outperform firms which focus on networks to

Author	Area of CA Looked At	Type Of Study	Results
		international biopharmaceutical firms	develop innovation
*Rothaermel (2001b)	Alliances formation for the purposes of developing CAs	Testing of secondary data of alliances of large international biopharmaceutical firms. Focuses on incumbents alliances with new firms to access new technologies.	It is better for firms to focus on developing SCAs and CCAs than on further developing technology.
*Rothaermel (2002)	Alliance formation. How firms go about forming alliances	Testing secondary data of 325 new biotechnology firm alliances	New biotech attractiveness is related to its new product development.
Funk (2003)	Looked at how firms can exploit information advantages to gain preferential access to CAs	Examining five major Japanese cell phone producers. Collected data through 17 interviews.	Found that firms that had an information advantage over the competition were able to gain preferential treatment to valuable CAs.
*Graff et al. (2003)	Tests an overarching hypothesis that the biotech agriculture seed industry has changed because of advanced CAs	Taking two sets of mergers and alliance data on agriculture biotech firms: one set of 60 and one set of 46.	Found that the agriculture biotech industry has reorganized itself through mergers and acquisitions to exploit CAs.
West (2003)	Looks into the optimal combination of open and closed source code in software platforms	Uingd four major software companies as case studies: Apple, IBM, SUN, and Microsoft.	Suggested that hybrid strategies of open and closed source will provide the highest returns. This strategy will enable other firms to use the platforms as CCAs.
*Hopkins and Nightingale (2006)	Risk management as a complementary asset	Examining four biotechnology case studies.	Found that risk management is a useful SCA/CCA. Firms should align themselves with partners that have complementing risk management capabilities.
Swink and Nair (2007)	Tested the theory of complementarities on manufacturing design and advanced technologies	A survey of 224 technical manufacturing firms	Found that manufacturing design is important complementarily to advanced manufacturing.
Stieglitz and Heine (2007)	The role of CAs in strategy	Conceptual	Suggested that CAs are an important factor in strategy. Suggested that top managers must properly account for CAs and also create or secure CAs needed to be competitive. Suggested that CAs are important resources that fit into the RBV framework.
Motohashi (2008)	Strategic use of patents by Japanese firms	Secondary data testing of Japanese patents	Indicated that smaller firms with undeveloped CAs have a higher propensity to license than firms with developed CAs. Indicated that large firms tend to be the licensor to obtain innovations so that they can exploit their developed CAs.
Parmigiani and Mitchell (2009)	Source of complementary manufacturing assets	A survey of 193 US manufacturing firm.	Found that firms often concurrently source manufacturing assets from several sources. Noted that knowledge is a key factor on the source of manufacturing assets. Indicated that experience firms are more apt to concurrently source than inexperienced firms.

Author	Area of CA Looked At	Type Of Study	Results
Eckhardt and Shane (2010)	Technological innovation and entrepreneurial activity	Secondary data on 201 industries over a 15 year period	Found that technical innovation is an important driver to entrepreneurship. Discovered that CAs are not a big restraint to the dissemination of innovation.
*Ceccagnoli et al. (2010)	The role of CAs in technology outsourcing	Secondary data from the pharmaceutical industry	Found that firms with more CCAs outsource less of their technology. Indicated that increased transactions costs can stimulate the demand for technology from external sources.

Source: Author ***Life science studies**

CAs is an offshoot of dynamic capabilities, and as the name suggests, it has potential to complement research on dynamic capabilities. CAs offers unique insights into the auxiliary assets and capabilities needed in the commercialisation of innovations, especially in high tech innovations. It has sound theoretical backing, but unfortunately lost momentum shortly after it was introduced. However, as of late it has started to regain momentum and is being led by Frank Roethermel who has produced several influential pieces (2001a, 2001b, 2005) in the last ten years. Several others have also joined him (Arora & Ceccagnoli, 2006; Ceccagnoli, Graham, Higgins, & Lee, 2010; Colombo et al., 2006; Helfat & Peteraf, 2003; Hopkins & Nightingale, 2006; Stieglitz & Heine, 2007; Swink & Nair, 2007), and the topic should see great progress in the next ten years. CAs has great research potential in many different fields, especially those interested in high tech firms.

This section discussed several shortcomings of CAs with two notable ones being (1) it is difficult to empirically define and measure and (2) it lacks a clear framework. This makes it difficult to generate and test hypotheses and is why there is not a more robust body of empirical studies that have tested CAs. However, CAs is an off shoot of dynamic capabilities, which allows it to be examined from a dynamic capabilities framework; i.e. probe the paths, positions and processes that lead the development of CAs. In the context of new life science ventures, work is especially needed to examine how R&D CAs are financed and developed. The importance of R&D resources to the development of new life science firms is well documented, but little work looks at how these resources are financed and developed.

3.6 Resource based paradigm conclusions

It is clear from this chapter that Penrose's (1959) ideas on the importance of resources and management to firm growth are alive and well. Her ideas evolved into the RBV and are now transforming into the theory of dynamic capabilities. Findings from the review suggest that dynamic capabilities is a unique theory rooted in the RBV that has particular potential for use in the study of high technology firms. This chapter also suggests that CAs is a complementary framework rooted in dynamic capabilities. CAs offers unique insights on the auxiliary assets and capabilities that are needed to commercialise innovations. It is an especially useful framework on firm growth because it allows research to look at growth from several different angles. In short, dynamic capabilities and CAs offer frameworks that could help unravel the growth process of high tech firms.

The literature on dynamic capabilities is fragmented and difficult to bring together, largely because of a lack of coherent direction in the literature. There are many incongruent ideas and weak frameworks manifested in an undeveloped body of empirical studies; a group of work marked by vastly different and unsubstantiated studies. However, in the past ten years it has made large conceptual and empirical strides towards becoming a strong theory. This review clearly shows that there is potential for dynamic capabilities to become a powerful framework for explaining life science firm growth. Furthermore, work needs to use a dynamic capabilities framework to look at how key resources and capabilities are formed; i.e. what paths, positions and processes lead to the development of key resources and capabilities.

3.7 Literature review summary

The literature on life science firms suggests that they are highly innovative in high velocity environments. Resources and capabilities are paramount to the development of firms in the industry. Despite this, the prominence of smaller firms is increasing (Giovannetti, 2010). These small firms are contributing significantly to innovation in the industry. Surprisingly little research has examined how firms develop their R&D resources and capabilities. Furthermore, the research is limited on how life science ventures develop financial resources. Some work exists that looks at the role of alliances, universities and venture capital in supplying R&D and financial inputs. However, most of this examines the topic

from the supplier side. Little work has been done on the motivations and assets that lead to the development of R&D and financial resources and capabilities in life science ventures.

The discussion on the evolution of the resource-based paradigm suggests that resources are paramount to growth. In highly dynamic environments it is critical for firms to reconfigure their resources and capabilities in response to industry changes. The dynamic capabilities framework examines the paths, positions and processes that lead to the configuration and reconfiguration of resources and capabilities that lead to long-term competitive advantages. This framework is still in a juvenile state, but it has proved to be a good lens to examine life science firms through. It provides a particularly good lens for investigating the paths, positions and processes that lead to key resources and capabilities. The next section introduces the study's framework that is based on this.

Chapter 4 – Problem Statement and Research Questions

Chapter Objectives

- To outline the theoretical background of this study.
- To develop the framework of this study.
- To establish the research questions of this study.

4.1 Introduction

It is estimated that over forty per cent of life science innovations stem from firms that have fewer than 250 employees and that there are over 300 new life science ventures formulated in the US each year (Van Beuzekom & Arundel, 2009). The innovations that life science ventures develop require unique R&D resources and capabilities. These typically cost millions of dollars to develop and often new ventures sustain years without revenues whilst their innovations are being developed (Murray and Wolfson, 2010). Despite this, research has not thoroughly investigated how firms develop the R&D and financial resources and capabilities to develop novel life science innovations.

Although there is a growing recognition of the importance of R&D and financial resources and capabilities to the growth of young life science ventures, research on the development of these resources and capabilities is still scarce. Studies on these topics tend to focus on larger firms (Mittra, 2007; Rothaermel & Hess, 2007). This is largely attributed to the public nature of large life science firms and the fact that data is more readily available for large firms. Moreover, Murray and Wolfson (2010) suggest that the nature of life science ventures has changed drastically in the last five years. This has made studying these firms difficult, and this, coupled with the fact that these firms often fail, makes studying small life science ventures difficult. Thus investigating how these firms develop R&D and financial resources and capabilities remains an important topic. This thesis examines it.

This chapter is devoted to identifying the conceptual framework and research questions of the study. It starts with a discussion of the influences on the research topic. From this, the theoretical framework for the study is then presented. Subsequently, the research questions are then presented in relation to the study's framework.

4.2 Theoretical basis

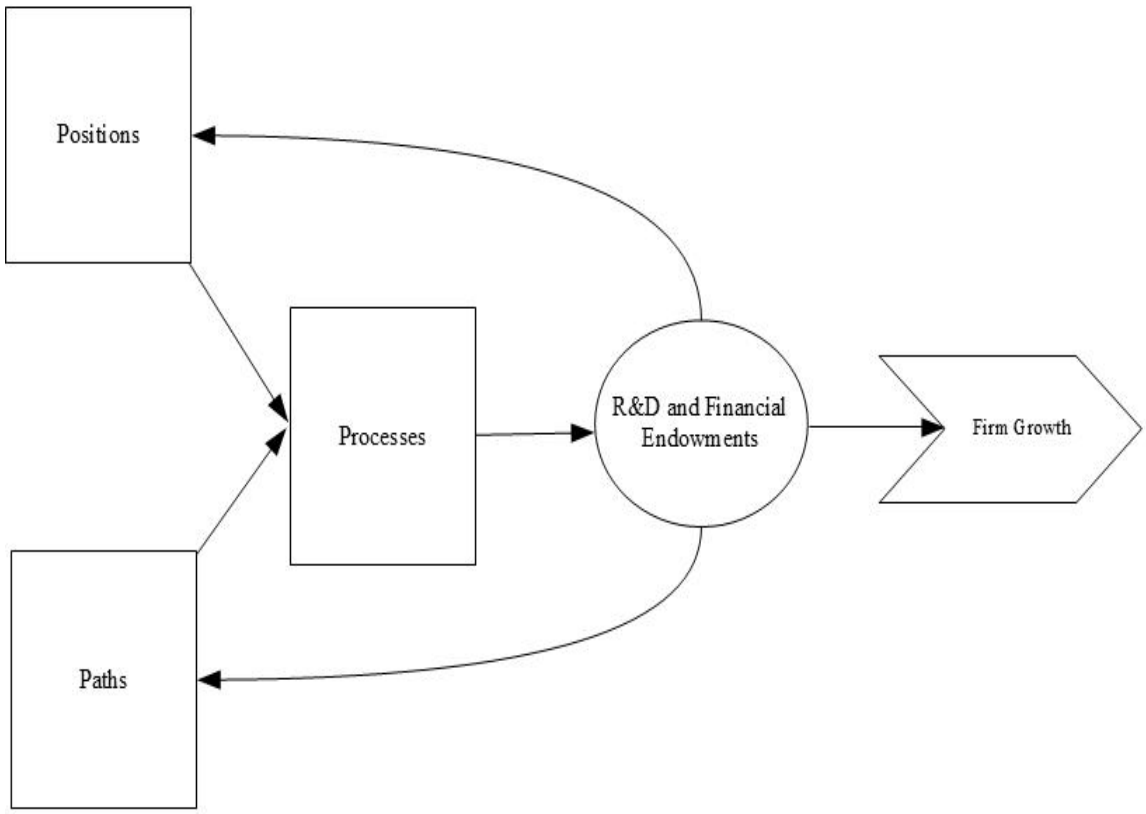
The literature review emphasised that resources and capabilities are germane to the development of life science firms, and for this reason both the resource-based view (RBV) and dynamic capabilities models are particularly good lenses for looking at life science firms (Coombs & Deeds, 2000; Madhok & Osegowitsch, 2000; Rothaermel & Hess, 2007). The literature review also underscored that there are few defined measures and constructs on the topics related to this research. For this reason a framework is called for that allows the study to deeply probe how R&D and financial resources and capabilities are developed. The paths, positions and processes dynamic capabilities framework proposed by Teece et al. (1997) answers this call. This framework allows the study to isolate the paths, positions and processes that lead to the development of R&D and financial resources and capabilities.

Previous paths are the past decisions and future opportunities that shape where a firm can go. Past decisions commit resources and often create rigidities because the firm is deeply tied to its earlier commitments. For example, Deeds and DeCarolis' (2000) study on new life science firms shows that a firm's future development opportunities are limited by investments made in earlier research. They suggest that often firms invest heavily in a technology, and this drains resources that could be used for other projects. Future paths represent opportunities available to the firm, influencing the firm's strategies. Positions are the resources that firms use in their pursuit of future paths. For example, life science firms often leverage their patents in the pursuit of developing an innovation (Deeds et al., 2000; Madhok & Osegowitsch, 2000; Ziedonis, 2004). Processes represent a firm's systems and routines. A firm's processes are determined by its paths and positions; i.e. firms develop processes based on the available opportunities, the restraints caused by past decisions and resources available to them. Examples of processes are learning and sensing. Life science firms require competencies in sensing out technologies and learning from their earlier research (Kaplan, Murray and Henderson, 2003).

The paths, positions and processes framework allows this research to deeply probe how R&D and financial resources and capabilities are formulated. Figure 4-1 presents the framework this study draws on. The paths aspect allows the study to develop questions pertaining to the decisions and opportunities that influenced the development of the firms' R&D and financial resources and capabilities. For example, what investments in

technology influenced the development of a firm's financial resources and capabilities? The positions aspect allows questions to probe the resources that the firms used in the pursuit of developing R&D and financial resources and capabilities, such as whether or not a firm's scientists were an important resource that helped in the development of R&D. The processes aspect of the model allows questions to be developed that probe the routines that proved important to the development of the firm's R&D and financial resources and capabilities. For example, whether or not learning routines were important to the development of the firm's R&D. In turn, the study is then interested in how R&D and financial resources and capabilities help a firm grow. The two loop-backs in the figure represent the resources and capabilities feeding back into the paths and positions of the firm; i.e. the new resources and capabilities will affect the positions and strategic paths available. For example, a firm with initial paths, positions and processes that lead to the development of advanced R&D resources and capabilities will be affected by these resources and capabilities. The newly created resources and capabilities provide the firm additional positions on which to compete and open new research and market paths. In turn, the firm leverages its expanded paths and positions to broaden its R&D and finances, and ultimately this perpetuates the firm's growth.

Figure 4-1: Research framework



Source: Author

4.3 Research objectives and questions

The literature review indicates that existent theory does not offer deep insight into the R&D and financial resource and capability development of life science ventures. Moreover, the existing theory does not provide strong constructs on this topic. Thus the overarching objective of this study is to close the gap in the deficiency of knowledge related to the R&D and financial resources and capabilities of life science ventures. Based on the topic and discussion above, two research objectives are set forth:

Objective 1

To explore and examine how R&D and financial resources and capabilities are developed.

Objective 2

To explore and examine the effect of R&D and financial resources and capabilities on the growth of life science ventures.

Each of these is discussed below along with the research questions for each objective. The questions are defined by the findings from the literature. These questions focus the study; however, they are purposely asked in order to allow for flexibility in the findings. This is important in qualitative research where interviews are used to collect data (Yin, 2008). The next chapter further elaborates on this point.

4.4 Objective 1

The first objective stems from the fact that little research investigates the development of R&D and financial resources and capabilities in life science ventures. Despite its importance, this topic has not properly been examined. The literature underscores the importance of R&D (Kenney, 1986) and financial (Baum & Silverman, 2004; Powell et al., 2002) resources and capabilities of larger life science firms, but little work examines these from a small life science firm's perspective. There is a real gap in understanding how life science ventures develop R&D and financial resources and capabilities. This objective is examined under the guise of the study's paths, positions and processes framework.

4.4.1 Paths and positions

The defining trait of life science firms is innovativeness. From 1980 to 2006 the industry had more patents than any other; in 2008 almost eight percent of the total patents filed in the US were life science patents, over 11,000 (Van Beuzekom & Arundel, 2009). A survey of life science executives found the number one goal of R&D is to discover breakthrough products (Deloitte & Touche, 2009). Decarolis and Deeds (1999) suggested that innovation in the life science industry is measured and stored in the forms of academic citations and patents. They also note that greater stocks of patents and citations are correlated with superior performance. The high patenting and publishing propensity demonstrates the creative destruction that is so widespread in the industry, with new and better innovations constantly replacing old ones (Kenney, 1986; Powell et al., 1996; Roijakkers & Hagedoorn, 2006). Other than noting that life science ventures are often created to pursue a novel innovation, the literature has not provided great depth on the influence that innovation has on the development of life science ventures. Further knowledge is needed as to how innovation affects the development of firms. More specifically, little work has explored how the type and source of knowledge affect the development of a firm's R&D and financial resources and capabilities. The first set of questions aims to address this gap:

Q1) How does an innovation affect the development of life science ventures?

1a) Does the source of an innovation affect the development of R&D and financial resources and capabilities?

2a) Does the type of innovation affect the development of R&D and financial resources and capabilities?

In the context of this research framework these questions are viewed through a paths lens. The decision to pursue a technology is a past decision that influences the development of firms; whilst future technological opportunities influence the future paths that a firm takes.

Another distinctive trait of life science firms is their reliance on alliances (Carayannopoulos & Auster, 2010; Powell et al., 1996). Often life science firms are lacking the scientific or commercialisation resources and capabilities to develop their product(s), and for this reason they turn to other firms to fill these gaps. Calabrese and Silverman's (2000) study found that establishing strong alliances is especially important to start-up life science firms. They suggest that small life science firms align themselves with partners that have complementing capabilities. One important source of these alliances is universities. Zucker et al (1998) looked at the importance that top university researchers play in new life science companies. They found that star university researchers are often the driving force behind new life science firm formation, an idea that is further evidenced by the fact that life science firms tend to cluster spatially near top research universities (Owen-Smith et al., 2002; Zeller, 2001). Although there is little work specific to small life science firms, it follows from the discussion above that partnerships provide important inputs to life science ventures, which leads to the second set of questions:

Q2) Do partnerships have a major bearing on the development of R&D and financial resources and capabilities?

2a) How do life science ventures know what inputs they have to offer potential partners?

2b) How do life science ventures identify what partners have to offer?

In the context of the framework of this study these can be viewed through both a paths and a positions lens. Previous work has shown that partnerships in the life science industry open research opportunities that influence strategy (Haeussler, Patzelt, & Zahra, 2010; Rothaermel, 2001a); thus it follows that alliances can have an influence on paths. Alliances also provide important resource inputs, such as scientific knowledge (Powell et al., 1996; Rothaermel, 2001a), and thus they can supply important resources (positions).

The literature review also underscored the capitally intensive nature of the life science industry. It takes years from the time an innovation is conceived until the time it is commercialised (Hall, 2002; Murray & Wolfson, 2010). This lag time from innovation to commercialisation forces life science ventures to sustain long periods without revenues whilst they are developing their innovations. During the conceptualisation phase, firms often finance their incubation through insider finance, VC, public sector grants and business angels (Fraer, 1990; Murray & Wolfson, 2010).

Furthermore, the amount and type of financing that a firm acquires will have a major bearing on its development. For example, VC has been shown to have a major impact on the development of their portfolio firms (Sapienza, Manigart, & Vermeir, 1996). Raising VC requires substantial effort, and the VCs have a major impact on their portfolio firms' management; furthermore, the capital they supply is a catalyst to firm growth (Gompers & Lerner, 2001; Unger, Greiman, & Leybourne, 2010). In comparison, firms that bootstrap their operations do not exert great effort in attracting outside investors, but it also limits them in the capital that they have to invest in the development of their innovation (Winborg & Landstrom, 2001). It logically follows that financing has a major bearing on the development of a life science firm, which leads to the third set of research questions.

> Q3) How does the pursuit of financing impact the development of life science ventures?
>
> > 3a) How do different financial strategies impact the financial trajectories of the firms?

In the context of this study's framework both these questions can be viewed through a paths lens. The pursuit of financing is a major event that firms devote substantial resources to. It takes time and effort to obtain the investment capital needed to finance a life science

venture. Moreover, once investment capital is obtained, it opens up future opportunities, as it allows firms to invest in new areas (Chakma & Sammut, 2011; Gompers & Lerner, 2004).

Another important finding from the literature review is the importance of human capital to life science ventures. Zucker et al (1998) note the importance of star researchers to the growth and development of life science firms, which is further supported by Boxeman et al's (2001) findings that human and social capital are two of the most important building blocks of new technology-based companies. The clustering of life science companies near top universities also supports this idea (Blumenthal et al., 1996; Zucker et al., 1998). Furthermore, an industry survey of life science executives placed attracting scientific talent as one of the biggest challenges in the industry (Deloitte & Touche, 2009). From a financial standpoint, investment in a new technology-based business is often determined by the key individuals involved in a venture (Murray and Wolfson, 2010). Similarly, Baum and Silverman (2004) found that an important criterion that investors look at in life sciences ventures is the background of the top managers.

The discussion above underscores the importance of key individuals to developing a firm's R&D and financial resources and capabilities. It follows that key individuals are the drivers to the development of R&D and financial resources and capabilities, which leads to the fourth set of research questions:

> Q4) Are highly trained, skilled and experienced individuals driving the development of R&D and financial resources and capabilities?
>
> > 4a) Are star scientist playing an important role in the development of a firms R&D?

In the context of this study's framework this question is viewed through a positions lens. Key individuals are resources that firms draw on to develop their R&D and financial resources and capabilities. From an R&D standpoint, scientists provide vital inputs from their scientific abilities that allow firms to develop their R&D (Zucker et al., 2002). From a financial standpoint the TMTs' backgrounds supply a resource that firms use to attract investment capital. Furthermore, the TMTs in new ventures are the ones who use their skills and abilities to secure investment capital (Colombo & Grilli, 2009).

4.4.2 Processes

The literature review emphasised the importance of a firm's processes to the development of their resources and capabilities. Two processes of particular emphasis are sensing and learning. The importance of learning is scattered throughout the dynamic capabilities literature. In their conceptualisation of dynamic capabilities Eisenhardt et al. (2000) suggest that learning mechanisms underlie the development of dynamic capabilities. They suggest that firms with more experience in responding to change are more apt to develop dynamic capabilities. Autio et al. (2000) found that new ventures have an advantage in the internationalisation process because of their learning advantage of newness; i.e. new firms do not have the bad habits of established firms and learn from changing market conditions more swiftly. Helfat (1997) is one of the few studies that have directly looked at learning in life science firms. This study found that learning from experimentation is vital to the progress of a firm's R&D. Although few studies have directly looked at learning in life science firms from a dynamic capabilities perspective, studies in other areas have also indicated that learning is important to the development of R&D (Cohen & Levinthal, 1989; Powell et al., 1996). Similarly, studies have indicated that learning from earlier financial investment decisions is an important process for NTBFs. That is, firms must learn how to better use their capital and how to attract additional investment (Unger et al., 2010).

Processes relating to sensing opportunities is another area that has been emphasised in the literature (Teece, 2007). In an in-depth study on the IBM Corporation Harreld and Tushman (2007) found that sensing opportunities is a process that IBM has mastered, and this has been one of the firm's main sources of competitive advantage. IBM's sensing processes have allowed them to find unique innovations to develop, and these innovations have been important to the firm's competitive position. Similarly, Trispas and Gavetti (2000) in an in-depth study of the Polaroid corporation find that sensing new technological opportunities was an important process that the firm developed and has been one of the this firm's main competitive advantages. In a similar vein, Kaplan, Murray and Henderson (2003) took an in-depth statistical look at fifteen pharmaceutical firms' TMTs ability to recognise scientific opportunities. Their findings suggest that sensing is a process that gives firms a competitive advantage by allowing them to develop drugs that have unique and desirable characteristics.

A third set of processes that have been found to be important to NTBFs is networking routines. As discussed above, partners provide important inputs to small resource-constrained firms in dynamic environments. In order to develop partnerships, small firms must develop a number of formal and informal processes. They must identify partners, negotiate partnership agreements and develop working relationships with partner organisations. The literature has shown that these processes can lead to alliances that provide access to inputs such as R&D (Rothaermel, 2001a) and capital (Bygrave, 1988; Sengupta, 2011).

Although there is little work that has examined the processes that lead to the development of life science ventures' R&D and financial resources and capabilities, from the discussion above it follows that several processes, including learning, sensing and networking, are important to the development of R&D and financial resources and capabilities, which leads to question five:

> Q5) What processes are important to the development of life science ventures' R&D and financial resources and capabilities?

4.5 Objective 2

The second objective stems from the fact that little research examines the effect of R&D and financial resources on the early development of life science ventures. It is clear from the entrepreneurship literature that new firms are often at a disadvantage because of resource constraints and liability of newness (Singh et al., 1986). Life science ventures face particularly large constraints, as the industry requires substantial financial and human capital (Baum & Silverman, 2004). Despite this fact, scores of life science ventures have successfully sprung up all around the globe (Giovannetti, 2010), and scholarly research fails to properly examine how life science ventures' R&D and financial resources and capabilities help them overcome large resource constraints to successfully grow and prosper. This objective is examined through the second part of the model presented in Figure 1 (above) and it examines what the impact of R&D and financial resources and capabilities are.

The literature review suggests that R&D and financial resources and capabilities are at the heart of a life science ventures development. Often a unique innovation is the motivation

for the start-up of a life science firm (Audretsch, 2001), and innovation sets the strategic path of life science firms. For this reason R&D, coming in the form of scientific capabilities and resources such as advanced laboratories, is paramount to the growth of these firms. .

Often life science ventures are focused on the development of innovation at the onset and do not have revenues to support the firm's operations (Baum & Silverman, 2004). For this reason, investment capital is crucial to the firm's growth, and frequently this capital comes from VCs (Gompers & Lerner, 2001; Powell et al., 2002). A new firm without a track record requires a compelling case to attract the capital that is required to develop a novel innovation. In order to attract this investment, firms must have a business that offers the potential for great return and the firm must have capabilities in attracting investment capital (Gompers & Lerner, 2001). From the arguments above it follows that R&D and financial resources and capabilities are central to the development of life science ventures and are closely linked. This leads to the sixth set of research questions:

Q6) How are R&D and financial resources integral to life science ventures?
6a) How closely linked are R&D and financial resources and capabilities?
6b) Do R&D and financial resources co-evolve?

The literature review emphasised that a number of resources and capabilities are needed in the development of new firms. Research has noted the importance of CAs to the development of life science innovations (Eckhardt & Scott Shane, 2010; Rothaermel, 2001a). CAs are the auxiliary assets and capabilities required for the commercialisation of an innovation (Trispas, 1997). R&D has been put forth as a CA but has not yet been fully substantiated. Teece (1986) suggests that a complementary technology is a category of CAs; i.e. technologies that go along with the core technology that a firm is attempting to commercialise. Similarly, Gans et al. (2002) suggest that the research assets needed to get through government approval is a category of CA. Moorman and Slotegraaf (1999) discuss product development capabilities and allude to R&D as a potential category of CA. Similarly, Lowe and Taylor (1998) allude to R&D as a CA, but do not explicitly call R&D a CA. It follows from these studies that R&D can be a CA.

Although financial resources and capabilities have not been looked at through a CAs lens, it follows that they could be viewed as such. Financial capital is needed for the growth of a

life science firm, but the capital itself is not a CA. In management research capital is generally viewed as a generic proxy or transactional tool. However, financing is much more encompassing than just being a transactional tool or a proxy. The capital is a generic asset, but it follows that capabilities in raising capital could be viewed through a CAs lens, as these are auxiliary capabilities needed to develop an innovation. Although the extant research does not explicitly look at finance through a CAs lens, financing lends itself to being a CA.

From the discussion in the two paragraphs above it follows that both R&D and finance can be viewed through a CAs lens. This leads to the seventh question:

Q7) Can R&D and financial resources and capabilities serve as a CA?

Specialised complementary assets (SCAs) are the auxiliary assets and capabilities that are not easily developed or contracted for that are needed in the commercialisation of an innovation. These can serve as a source of competitive advantage (Teece, 1986; Rothaermel, 2007). An example of an SCA is service capabilities of a medical device firm. In many cases medical devices require specialised service capabilities to maintain the product, and if a firm is unable to service the device, then the device cannot be commercialised. These capabilities are such that they require sophisticated and often tacit knowledge that cannot easily be replicated. Likewise, little work has explored whether financial capabilities are SCAs; as discussed above, it follows that capabilities in raising and managing capital could be an SCA. These are capabilities that are not easily created but can serve as a source of competitive advantage, especially true in the context of new life science ventures where there is hyper-competition for investment capital (Chakma & Sammut, 2011).

From the discussion in the paragraph above it follows that both R&D and financial resources and capabilities in certain circumstances serve as SCAs. This leads to the eighth question:

Q8) Can R&D and financial resources and capabilities serve as a SCA?

4.6 Summary of framework and research questions

There is a gap in the understanding of how small resource constrained life science ventures create advanced R&D and financial resources and capabilities that allow them to develop novel innovations. There are few defined constructs and measures on this topic, which calls for a framework that allows it to deeply probe the matter. The paths, positions and processes framework answers this call. The paths aspect allows questions to be developed that focus on the motivation for developing R&D and financial resources. The positions aspect allows for questions to focus on the positions that are leveraged to create these resources and capabilities, and the processes aspect allows for questions to isolate the important routines firms use.

This section develops a dynamic capabilities research framework. This framework underpins the eight main research questions of this study, which are summarised in Table 4-1 below.

This research is embedded in an era of massive shifts in technology, a new age in innovative life science ventures, and is at the forefront of a very important topic, as young life science firms are having a profound effect on the life science industry. Moreover, it is a critical topic as R&D and finance are central to the development of life science ventures. The two sets of questions set forth in this chapter allow the research to examine how R&D and financial resources and capabilities are formulated and what affect they have on the development of life science ventures. The framework and research questions presented in this chapter dictated the research methods of this study. The next chapter details the specific methods used to address this research.

Table 4-1: Research questions

Q1) How does an innovation affect the development of firms? 1a) Does the source of an innovation affect the development of R&D and financial resources and capabilities? 2a) Does the type of innovation affect the development of R&D and financial resources and capabilities?
Q2) Do partnerships have a major bearing on the development of R&D and financial resources and capabilities? 2a) How do life science ventures know what inputs they have to offer potential partners? 2b) How do life science ventures identify what partners have to offer?
Q3) How does the pursuit of financing impact the development of life science ventures? 3a) How do different financial strategies impact the financial trajectories of firms?
Q4) Are highly trained, skilled and experienced individuals driving the development of R&D and financial resources and capabilities? 4a) Are star scientists playing an important role in the development of a firm's R&D?
Q5) What processes are important to the development of life science ventures, R&D and financial resources and capabilities?
Q6) How are R&D and financial resources integral to life science ventures? 6a) How closely linked are R&D and financial resources and capabilities? 6b) Do R&D and financial resources co-evolve?
Q7) Can R&D and financial resources and capabilities serve as a CA?
Q8) Can R&D and financial resources and capabilities serve as an SCA?

Source: Author

Chapter 5 – Research Methods

Chapter Objectives

- To overview the philosophical assumptions underlying the study.
- To identify the appropriate research paradigm for the study.
- To justify the research methods chosen for the study.
- To discuss the techniques used to ensure the reliability and validity of the study.

5.1 Introduction

Chapters two and three introduced the relevant literature to this study and chapter four presented the research questions based on this review. This chapter introduces the methods used to explore these questions.

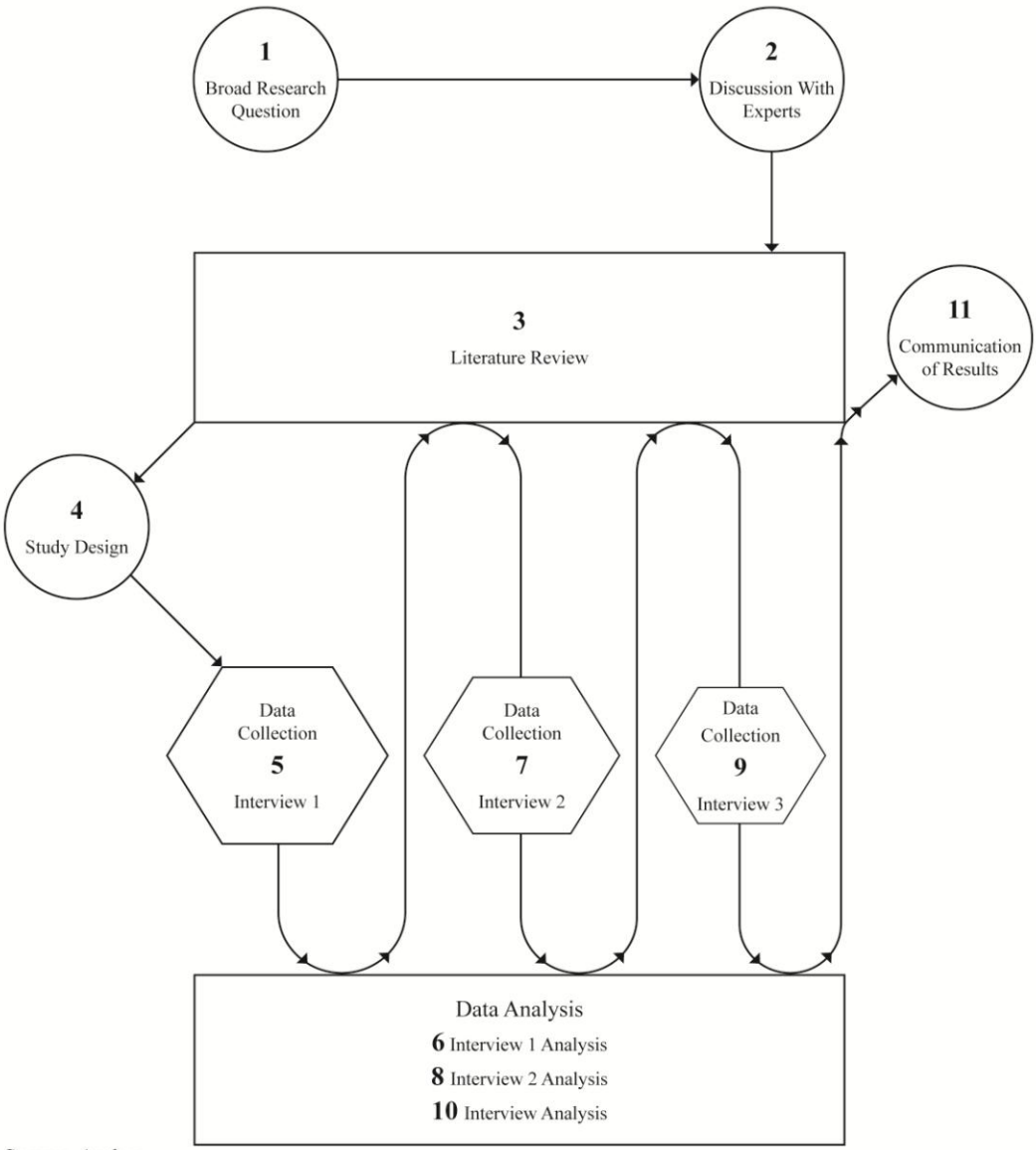
This thesis aims to generate insights on how life science ventures develop R&D and financial resources and capabilities, and how these resources and capabilities affect the early growth of these ventures. Initially the research was intended to explore the research questions through quantitative techniques. However, a look into the literature found few defined constructs and measures with which to properly conduct an empirical, positivist study. The dynamic capabilities framework that this thesis draws on also made a positivist study difficult to conduct, as it is a young theory that does not have many well-defined constructs and measures (Helfat & Peteraf, 2009). Furthermore, in positivist social science research the phenomenon of interest is separated from it social setting (Easterby-Smith, Thorpe, & Lowe, 2002). After further information on the research questions were gathered, the researcher came to the determination that to unearth insights on the research topic, the phenomenon of interest could not be separated from its social setting. Put differently, life science firms should be examined in their setting to find insights on the research questions. For this reason, the research adopts a phenomenological approach that stresses that meaning stems from the interaction with the phenomenon of interest (Bryman and Bell, 2003).

Regardless of the research method used, reliability and validity is a major issue. For this reason the present study kept reliability and validity at the forefront of this research. Reliability and validity in qualitative work refers to the trustworthiness of the study (Lincoln and Guba, 1985). From the onset this study established dependability from proper design, well-crafted questions, appropriately selected cases and reliable data collected from multiple sources. Another challenge of qualitative work is to properly apply the findings from the study. This study adopts Miles and Huberman's (1994) data reduction and packaging to produce themes related to the research topics. Data was collected, compared across cases and funnelled into themes through multiple data reduction steps. To manage the massive amount of data, the researcher used case record and qualitative data analysis software to aid in the reduction of the data. The resulting themes were then compared across existing theory.

There are no perfect research methods in business (Bryman and Bell, 2003). All research is contextually based, and the proper methods depend on the research setting. Furthermore, methodology is restrained by time and budgets (Easterby-Smith & Lowe, 2002). It is not the purpose of this chapter to review all of the literature on research methods. An effort such as this would take years to complete and volumes of manuscript. Rather this chapter focuses on the methods that were considered and used in this study. The research process is generally illustrated in a linear fashion (Bell & Bryman, 2003; Creswell, 2008). However, Edmondson and McManus (2007) suggest that whilst research ultimately follows a sequential process, it often happens in an iterative manner. Figure 5-1 presents the iterative process followed in this study.

To summarise: the research started with a broad interest (1) on the resources and capabilities important to life science ventures and then the researcher discussed the interest with topic experts (2). Followed by this the researcher reviewed the literature and designed the study based on the literature and discussion with topic experts. The study then underwent an iterative process of collecting data (5, 7 and 9), then analysing the data (6, 8 and 10) and then comparing the data to the literature. In the last step (11) the results were written up. Figure 5-1 serves as the framework for this chapter.

Figure 5-1: The study's research process



Source: Author

5.2 Steps 1-3: background

The literature review in chapters two and three examined the major literatures (i.e. RBV, dynamic capabilities, CAs, life science, and VC value added) most relevant to this research. Dynamic capabilities is the overarching theory used here because this work is fundamentally concerned with how life science ventures respond to changing environments to develop key resources. More specifically, this thesis is concerned with the paths, positions and processes that lead to the development of R&D and financial assets and capabilities (D. J. Teece, 1986, 2007).

The literature review clearly showed that the central focus of this thesis was still early on its theoretical development. There is little empirical support for many of the constructs and propositions, and there are several grey areas that need clarification. Furthermore, little work has attempted to tie together the theory of dynamic capabilities with firm growth. The main research questions emerged from the review and discussion with industry and scholarly experts.

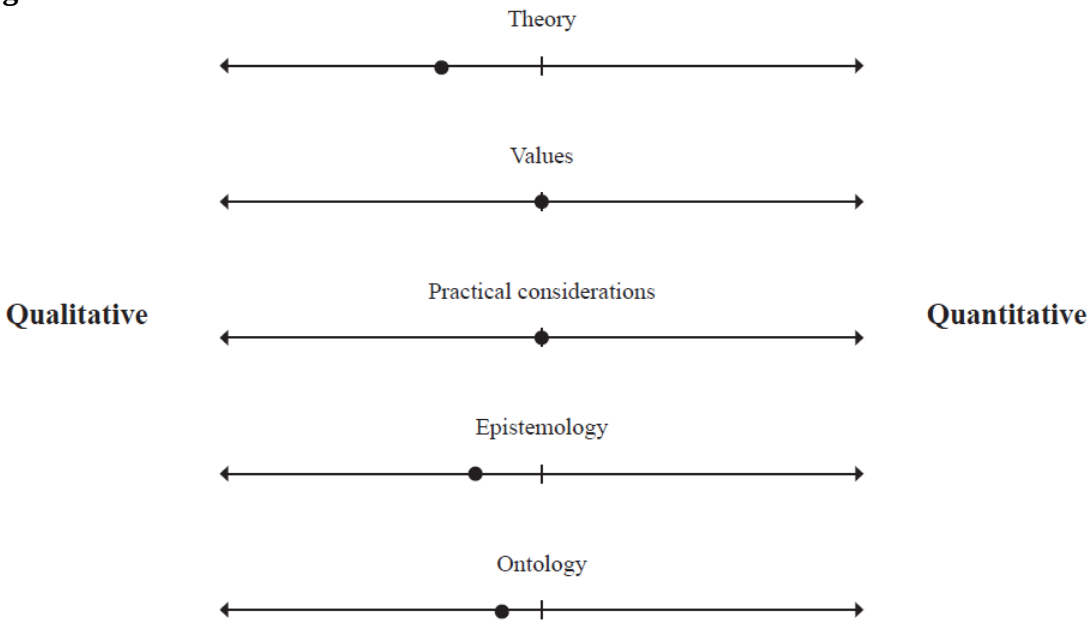
5.3 Step 4: Study Design

Steps 1-3 established the background of the research and positioned where the research questions are in terms of their theoretical development. Prior to establishing a research paradigm it is important to establish the philosophical stance of the research (Edmondson & McManus, 2007). In Step 4 this stance was established and the research framework was created based on this stance.

5.3.1 Method choice for the present study

Bell and Bryman (2003) suggest that there are five forces that influence a study towards a quantitative or qualitative paradigm. Figure 5-2 illustrates the major influences on business research, and how each of these influenced this work towards qualitative or quantitative methods. Each influence from figure 5-2 is analysed below, and then the research paradigm chosen for this study is presented based on this analysis.

Figure 5-2: Research influences



Source: Author

The theories involved in this research favour a qualitative approach. The literature review chapters established that dynamic capabilities is beyond its nascent stage of development, but it is still far from developed and it is in need of further empirical refinement. Further knowledge on the understanding of the underpinnings of how life science ventures develop R&D and financial resources and capabilities is what is most needed at this point. These are best gleaned from qualitative work (K. M. Eisenhardt, 1989b). The second influence from above, values, neither favours a quantitative or qualitative approach. Bell and Bryman (2003 p. 27) define values as '*either the personal beliefs or the feelings of the researcher'*. Values have a large impact on the outcome of research – especially interpretive research. Bias can result at any stage of research. Just because a researcher does not have preconceived biases does not mean that these cannot be formed (Easterby-Smith et al., 2002; Yin, 2008). Bias is prevalent in all types of research, both quantitative and qualitative, and it is the job of the researcher to minimise the effect of bias in the research (K. M. Eisenhardt, 1989b). The validity and reliability section later on in this chapter further elaborates on how biases were minimised for the present study. Overall, bias did not have a major influence on the philosophical stance of this research and therefore is placed in the middle.

The third major influence on business research is practical considerations. Ideally researchers in business should capture both great depth and generalisibility. However, it is usually not practical to capture both of these in a single study (Creswell, 2008). There are

time, cost and feasibility constraints that inhibit a researcher from being able to obtain everything he would like to. For this reason practical considerations are a major influence in designing a research project. The context and philosophical stance of the research, plus the previous research on the topic(s) dictate the practical considerations. (Hurmerinta-Peltomaki & Nummela, 2004). Put differently, practical considerations are what the research is trying to accomplish, its main objectives. On the highest level this is concerned with whether the research is theory building, theory testing or both. The present study is concerned primarily with unearthing new insights on how life science ventures develop R&D and financial resources and capabilities. Therefore an interpretive approach is more appropriate for this and the reason why practical considerations in figure 5-2 are towards the qualitative end of the spectrum.

The fourth influence on business research is epistemological influences. For this study the epistemological influences slightly favour a qualitative approach. Pettigrew (1992) emphasises that organisational processes are embedded in an organisation. This is especially true in the growth process of the firm; it would be extremely difficult to unearth insights on the growth process of life science firms if the researcher did not interact with the firms themselves. Furthermore, it would be difficult for the researcher to take an objective stance on the key R&D and financial resources needed for life science firm growth because there are few defined and tested constructs and measures on the topic. Therefore the epistemological influences on this study favoured a qualitative approach.

The fifth influence on business research is ontology. This refers to what social entities exist and whether their existence is driven by established principles or if the social entities themselves drive the establishment of the principles. The latter is known as constructionism, which sees the social actors as the ones constantly constructing and reconstructing the principles that guide the actors (Bell & Bryman, 2003). In the context of a business organisation the actors (managers, employees, customers, and suppliers) drive the guiding principles of the firm. These principles constantly change depending on the interaction of the actors. The opposite view is objectivism, which sees the principles of the organisation as the guiding force of the actors. In the case of the firm, the established principles of the organisation guide the actors. For example, established work hours determine the actions of employees. The present study takes the stance that the managers in the firms are the ones that construct and guide the growth process. Because the

constructs related to the social entities (i.e. the managers) in this study are not well-developed, a more qualitative approach is favoured.

The analysis of the forces influencing the present study indicates that overall a qualitative approach is more appropriate for this thesis. However, the analysis from Figure 5-2 above shows that mixed approaches could also be appropriate. Table 5-1 summarises the main types of research designs. This table shows that there are three main research paradigms: qualitative, quantitative and mixed methods.

Table 5-1: Methodological approaches

Paradigm	Types of Studies
Quantitative	Survey, hypothesis testing using primary or secondary data, experiment, quasi experiment
Qualitative	Case studies, ethnography, action research, grounded research
Mixed methods: with equal emphasis	Combination of quantitative and qualitative with equal emphasis
Mixed: with quantitative emphasis	Combination of quantitative and qualitative with the quantitative being more dominant
Mixed with qualitative emphasis	Combination of qualitative and quantitative with the qualitative being more dominant

Source: Author

It would seem since the present research is towards the middle of qualitative-quantitative spectrum, that mixed methods would be ideal. Mixed methods give a good alternative to strictly quantitative or qualitative approaches and are often good for research in the middle of the qualitative-quantitative spectrum. They are not without flaws though. One of the main weaknesses of mixed methods is that it is difficult for a single researcher to execute. A second major weakness of mixed methods is that it tends to be expensive (Perry, 1998).

5.3.2 Method Considerations

After sifting through the many possible methods that could be used for this research, two general approaches surfaced as the most appropriate: 1) mixed methods and 2) the case method. This is based on the philosophical influences discussed above and that the topics in the research had some theoretical underpinnings, but still needed further development. Mixed methods and the case method are the most appropriate for topics in this stage of development because they both can serve to further develop constructs into a more

quantifiable state (Bell & Bryman, 2003; Edmondson & McManus, 2007; Eisenhardt, 1989b).

In recent years the use of mixed methods in the social science has become accepted (Creswell, 2008; Jick, 1979; Johnson & Onwuegbuzie, 2004). Mixed methods is especially useful when the phenomenon of interest is neither at the nascent stage of theoretical development nor at the advanced stage of theoretical development (Greene & Caracelli, 1997). In instances such as this, qualitative research adds insights that extend the prior empirical base. Kuhn (1961) suggests that qualitative work is a prerequisite to quality quantitative work. Before jumping into a research paradigm, McManus and Edmonson (2007) emphasise that fit between the methods and the state of theory is the most important element of a research design. Theories fall between a developmental spectrum of nascent to mature. Nascent theories call for a qualitative approach because the constructs and measures needed to quantitatively test the theory are not available; thus a qualitative approach is needed to develop these constructs and measures. Mature theories call for a quantitative approach to reaffirm or disconfirm theory. Because the theories of interest to this study have some defined constructs and measures, a purely qualitative approach is repetitive, unless it is intended to look at the topic from a different angle. Theories in the intermediate stage of development can use a qualitative, quantitative or mixed approach. Qualitative work can further establish constructs and measures, which then can be tested using quantitative techniques. It is critical to pair the right methods for the stage of development that a theory is in; pairing the wrong methods for the development that a theory is in has become endemic to management research (Edmondson & McManus, 2007). Table 5-2 summarises the problems associated with this.

Table 5-2: Methods and theoretical maturity

Prior work on research question	Data collection and analysis	Problems encountered	Outcome
Mature: Extensive literature complete with constructs and previously tested measures	Qualitative only	Reinventing the wheel; Study findings risk being obvious or well known.	Research fails to build effectively on prior work to advance knowledge about the topic
	Hybrid	Under status of evidence; Paper is lengthened but not strengthened by using qualitative evidence.	
Intermediate: One or more streams of literature offering some but not all constructs and measures needed	Quantitative only	Uneven status of empirical measures; New constructs and measures lack reliability and external validity	Results are less convincing, producing potential contribution to the literature.
	Qualitative only	Low opportunity; Insufficient provisional support for a new theory; Lessens papers' contribution	
Nascent: Little or no prior work on the constructs and process under investigation	Qualitative only	Fishing expeditions; Results vulnerable to finding significant associations among novel constructs and measures by chance	Research falls too far outside guidance for statistical inference to convince others of its merits
	Hybrid	Quantitative measures with uncertain relationship to phenomena; Emergent constructs may suggest new measures for subsequent research, but statistical tests using same data that suggested the constructs are problematic	

Source: Edmonson and McManus (2007, p. 1170)

According to Yin (1981, p. 59) the distinguishing characteristics of a case study are *'that it attempts to examine: (a) a contemporary phenomenon in its real world context, especially when (b) the boundaries between phenomenon and context are not clearly evident'*. Unlike many other approaches, especially strictly quantitative methods, case study research has the potential to uncover novel theory (Eisenhardt, 1989); the unique and flexible nature allows fresh insights to emerge. Case studies are also particularly useful for the development of hypotheses. They provide a sound basis for defining constructs and measures (Eisenhardt, 1989). There are no defined rules for case study research. They can use qualitative methods, quantitative methods, or a combination thereof. Although there are no defined rules or set protocols for case research, it is important for a case study to be properly designed based on the study's objectives (Eisenhardt, 1989a; Yin, 2008). Put differently, the objectives should determine the research protocols.

Researchers must first establish what a case study's purpose is. Case studies serve multiple purposes. They can be exploratory, descriptive, explanatory or a combination thereof. An exploratory case study looks at 'what' is happening around the phenomenon of interest; e.g. what motivates life science firms to start up? A descriptive case study is intended to categorise events and paint a portrayal of the phenomenon. An explanatory case study seeks to establish and explain causal relationships. In many instances, including the present study, a combination of these is appropriate.

This study adopted a strictly qualitative research approach for two main reasons: (1) the major theories and other major research influences involved with the research favoured a qualitative approach and (2) there were time and resource constraints that would not have allowed a proper mixed-methods study to be conducted. Case studies make an ideal bridge between qualitative and quantitative research (Eisenhardt, 1989a; Larsson, 1993; Miles & Huberman, 1994). The rich insights from the cases can be used to develop constructs and measures for quantitative studies. Gilmore and Coviello (1999) suggest that in qualitative entrepreneurial research a study design should allow for refinement through multiple stages and multiple techniques; this allows for new themes to emerge. Case studies answer this call and allow for research to unfold over multiple stages, and it also allows for the use of multiple techniques in a single study. Furthermore, Coviello and Jones (2004) call for research to integrate positivist and interpretivist methodologies, whilst at the same time incorporating time as a key dimension. Case studies also answer this call because of their ability to incorporate different data and method techniques over specified time periods. For the reasons outlined above, the present study used a qualitative case method.

It is important before conducting a study to establish the philosophical stance of the research. The case method can use either positivist or phenomenological assumptions. In positivist paradigm the extraneous variables are attempted to be minimised so the observed variables can be isolated (Bell & Bryman, 2003). In a positivist study, results usually come from statistical testing of hypothesis. Generally speaking this type of research does not allow for great flexibility (Easterby-Smith et al., 2002). In contrast, phenomenological research observes the variables of interest within their wider context. Variation and flexibility in the study design are accepted. The basis for moving data to theory stems from comparison. In the context of cases, this is comparison is to both other cases in the study and to the literature (Eisenhardt, 1989a). The present study establishes a phenomenological paradigm that is inductive in nature. This decision was based on the researcher's stance

that the best means to unearth insights on the research questions stemmed from unearthing fresh insights from life science ventures in the context of their operations.

Although the case approach taken in this study is inductive, it is not purely inductive. There are few instances when research is truly inductive or deductive (Miles & Huberman, 1994; Reichertz, 2004). Langley (1999, p. 694) sees '*rigid adherence to purely deductive or inductive strategies as unnecessarily stultifying*'. The present study started with an inquiry based on existing literature; thus from the start it was not truly inductive. If it were truly inductive it would have followed a grounded approach where no information was gathered on the topic prior to the start of the study. On the other hand, and as discussed previously, the study is not purely deductive. A better classification of the approach used in this study is abductive, which Reichertz (2004, p. 305) defines as '*a cerebral process, an intellectual act, a mental leap, that brings together things which one had never associated with one another*'.

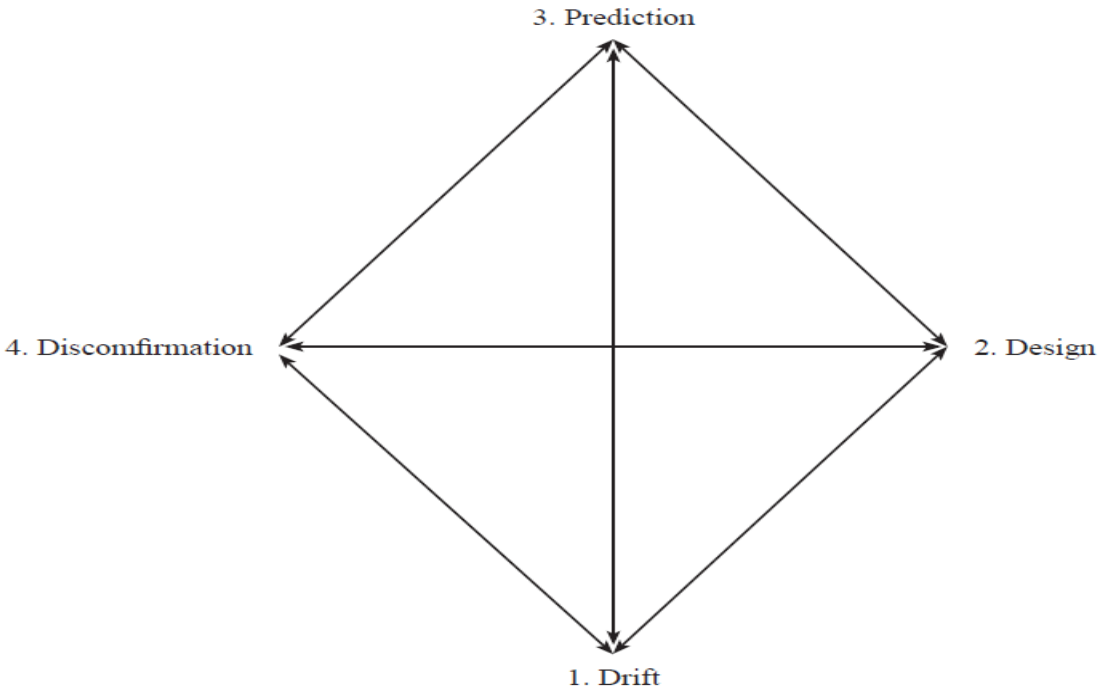
Abduction is in between induction and deduction, but does not necessarily fall exactly in the middle. It can follow ontological assumptions that are more inductive, but it also can follow ontological assumptions that are more deductive (Dubois & Gadde, 2002; Kovács & Spens, 2005). For the present study the ontological drivers were more inductive; therefore the study used an abductive approach more towards the inductive side of the spectrum. Abduction also emphasises an iterative process of refining theoretical prospects and concepts (Dubois & Gadde, 2002).

This thesis follows Bonoma (1985) in using four iterative steps in the research process: 1) drift, 2) design, 3) prediction and 4) disconfirmation. In the first stage the problem is defined; that is, its nature and scope. Essentially this stage is concerned with getting intimately familiar with the topic. The drift stage then becomes the design stage. At this point data collection begins, the major areas of inquiry are further refined, and conceptualisations are fleshed out. The design stage then becomes the prediction stage where ideas are further refined and compared. The prediction stage then becomes the disconfirmation stage where the findings are attempted to be refuted.

Whilst the present study followed the steps outlined above, it also still followed Eisendhardt's (1989b) suggestion not to follow a rigid research structure when using the case method. Instead this thesis uses the four steps in a dynamic manner. This research

continually iterated backwards and forwards between the four steps, redefined concepts and questions and gathered additional data from multiple sources. Figure 5-3 depicts the iterative steps of this research. Each step taken is shown in the diamond and the bi-directional arrows between and across the diamond represents the backward and forward iteration that occurred amongst all of the steps in the process. Each of the steps taken in this research is further discussed below.

Figure 5-3: The dynamic process of the research



Source: Author

In the drift stage research topics are probed. This research started with informal interviews with industry and subject experts, and these were followed by an overview of the literature. This helped to further refine the research questions and focus. At this stage the research established the broad research questions and objectives. This stage established the context of the phenomenon; including the industry terminology, trends and industry concepts.

In the design stage ideas were further fleshed out and the framework for the research was constructed and refined. Following Eisenhardt (1989) and Bonoma (1985), this study constantly referred back to the theory in a theory/data/theory fashion. This led to using dynamic capabilities as the overarching framework. It also led to the further refinement of the concepts of this study. Furthermore, the major concepts that surfaced aided in the selection of the case firms and the development of the first formal interview schedule. The

analysis from the exploratory interviews in this stage led to the further refinement of the studies direction. Most notably, analysis of the first round of interviews also underscored the importance of R&D and financial resources and capabilities in early growth. In summary, in the design stage the research concepts and ideas were refined to narrower but still relatively broad categories.

In the prediction stage, ideas from the design stage were again referenced against the literature and the previous findings of the study. This led to the further refinement of the research concepts and the development of a second interview schedule and then subsequently the second round of interviews. This stage led to the development of general propositions related to the research questions.

In the disconfirmation stage, the data from the interviews was scrutinised. Researchers often fixate on data that supports their notions and ignore data that might disconfirm their notions (Spiggle, 1994). This is especially problematic in interview analysis, and because this research relied heavily on interview data, it was important to include a step in the research process to disconfirm or refute findings. This study relied on three main refutation techniques. The first was in the data analysis where the data was attempted to be refuted. This was accomplished by going back through the data once major themes had been abstracted and looking for data to refute them. This process is further detailed later in this chapter in the data analysis discussion. The second refutation technique involved gathering data from multiple sources. The third refutation technique involved triangulating the findings with the key informants from each firm. This process it detailed later in this chapter.

5.4 Steps 5, 7, and 9: data collection

Steps 1-4 established the background of the research and laid out a paradigm for the study. Steps 5, 7, and 9 were devoted to collecting the data. In case study, research data can be qualitative, quantitative, or both (Miles & Huberman, 1994). Data can come from many places, but in qualitative case studies common sources of case data include documents, observation and interviews with key informants. The present study utilised all three of these sources. However, the core of the data came from interviews with the key informants from the focus firms of the study. The researcher conducted a total of eighteen formal interviews, which totalled over twenty hours and produced over 500 pages of transcripts.

In qualitative case research it is helpful to establish the unit of analysis prior to selecting the case firms (Yin, 2008). This allows for the selection of firms that provide the richest information for the research questions and objectives. In this study the main unit of analysis is R&D and financial resources and capabilities. This unit of analysis is complex because of the many factors that influence the development of R&D and financial assets and capabilities needed in growth. However, properly selecting case firms that isolate the unit of analysis can allow for complex ideas to be captured (Eisenhardt, 1989a; Yin, 2008). Because the process is so central to the unit of analysis of the present study, it was important to isolate firms in a particular stage of growth. Following this logic, the present study identified firms that were at the commercialisation stage of development. Firms at this stage of development were chosen because it is a critical stage to survival and growth (Kazanjian & Drazin, 1989). Furthermore, Perry (1998) suggested that replication and validity is enhanced by purposeful sampling where results can be compared. Having firms in the same stage of development allowed for a basis of comparison for the present study.

The literature and informal interviews with industry experts were instrumental in choosing the unit of analysis. It is clear from both of these that the R&D and financial resources and capabilities needed in growth are best captured from high level executives who are intimately familiar with the firm's history and development, so this research follows suite. Isolating the firms to capture the unit of analysis through this lens also helped to delimit the study. It is not possible for one researcher to capture the all of the data relevant to a research topic from all possible sources (Bonoma, 1985; George & Bennett, 2005); this produces far too much data to process.

Another important factor in the collection of data for this project is its longitudinal design. A longitudinal design is important in research involving growth because it allows complex processes to be captured and broken down into steps (Johanson & Wiedersheim-Paul, 1991; Welch & Luostarinen, 1988). By definition, process studies are looking at change over time; therefore, studies that capture a static snapshot cannot convincingly explain processes. Longitudinal studies help increase the reliability and validity of a study by capturing the steps that make up the processes. Thus qualitative studies, such as the present one, increase their trustworthiness by imploring a longitudinal design, ensuring that important events that may have affected processes are not overlooked (Pettigrew, 1990). A longitudinal design is appropriate for the present study because it is interested in the R&D

and financial resources needed in firm growth. Longitudinal studies are more complex, especially in qualitative studies where thousands of pages of data can be collected (Yin, 2008). It is therefore essential to collect and analyse data systematically. Consequently, this study collected and analysed data in three systematic steps to ensure reliability and credibility. These steps are further detailed later in section 5.5.

Table 5-3 overviews the data collected for this study. The data was collected over a three year period and chiefly came from interview data, but other sources were used as well. This section further elaborates on the data, the sources of data and how it was collected.

Table 5-3: Kinds of data

	Case firm					
Data type	BA1	BA2	DD1	DD2	MD1	MD2
Interview	• Aug 2008: 55 minutes • Mar 2009: 65 minutes • Feb 2011: 52 minutes	• Aug 2008: 63 minutes • Feb 2009: 71 minutes • Dec 2010: 38 minutes	• Aug 2008: 71 minutes • Mar 2009: 77 minutes • Dec 2010: 37 minutes	• Sept 2008: 52 minutes • Feb 2009: 45 minutes • Jan 2011: 65 minutes	• Sept 2008: 65 minutes • Feb 2009: 45 minutes • Feb 2011: 52 minutes	• Sept 2008: 50 minutes • Jan 2009: 55 minutes • Dec 2010: 62 minutes
Archive	• 7 news articles: 2,800 words • 4 websites: 9,000 words	• 8 news articles: 2,600 words • 5 websites: 17,000 words • 1 industry brief: 1,600 words	• 12 news articles: 4,200 words • 6 patent records: 35,000 words • 12 websites: 18,000 words	• 21 news articles : 6200 words • 14 patent records: 45,000 words • 6 websites: 15,000 words	• 3 news articles: 900 words • 3 patent records: 11,000 words • 2 websites: 4,000 words	• 8 news articles: 2,700 words • 3 patent records: 6,000 words • 2 websites: 2,000 words
Direct observation	• August 2008: 90 minutes • March 2010: 40 minutes • Feb 2011: 50 minutes				• Feb 2010: 60 minutes • Feb 2011: 60 minutes	

Source: Author

5.4.1 Case selection

Ensuring research design to acquire an accurate sample used to represent the population is especially challenging in qualitative work, where sample sizes are usually small (Yin, 2008). On the other hand, qualitative studies are not used to create law, and therefore these studies can afford to have more latitude in their sampling accuracy. The lack of randomness does not mean that case studies should not represent the population though. Seawright and Gerring (2008, p. 296) suggest that *'a case should provide useful variation on the dimensions of theoretical interest'*. The present study is particularly interested in the R&D and financial resources of firms in rapidly changing environments. Therefore life science firms were deemed as appropriate cases for this study: life science firms are high tech and have a high propensity to use VC (Gompers & Lerner, 2001; Mayer, Schoors, & Yafeh, 2005).

Eisenhardt (1989b) suggested using between four and ten cases because this number allows for an in-depth analysis within a reasonable amount of time. Following Eisenhardt (1989), twelve firms were selected for the research. Case selection was based on the following criteria:

1. Is a life-science firm.
2. Is in the early stages of the commercialisation phase of development.
3. Has less than 250 employees.

These criteria were chosen based on the research topic. Life science firms make an excellent choice because of their dynamic nature, and the life science industry is the industry that the research has practical experience in and was most interested in. For these reasons firms from this industry served as the sample for this study. The E.U definition of small business as 250 or fewer employees was used. Firms were chosen at various points within the size spectrum (i.e. 4-225) to examine the effects of the various sizes of firms on the research question; e.g. do micro firms of four employees have different experiences than firms of 225 employees.

Figure 5-4 depicts the steps taken to identify and select the case firms for this study. In the first step the potential population of firms that met the study's requirements was identified,

which was believed to be approximately 1,500 (Van Beuzeken and Arundel, 2008). Because most firms that fit these criteria are private firms, they are not transparent with their operational information. This made it difficult to find firms.

In the second step of the selection process potential firms from with the population were identified. The areas of San Diego, San Francisco, and south Florida were targeted because of the large number of life science companies present in those areas. In order to find the names of the firms and the contact name of the founders and/or the senior management, several databases were cross referenced. The main databases crossed referenced are: 1) Grow Think Research (www.growthinkresearch.com), 2) Bio Space (www.biospace.com), 3) Jigsaw (www.jigsaw.com) and 4) 411 Lead (www.411lead.com).

The first of these databases, Grow Think Research, is dedicated to collecting research on early stage technology ventures. Several noted studies used such a database for filtering firms (e.g. Deeds, 2002; Lynsay, 2009; Rothaermel, 2001). The Grow Think Research database attempts to track all of the information available on high technology ventures. The website has a built-in search engine to locate companies that have received venture funding. It also has further options to narrow the search down by industry, size of company, size of investment received, age and location. Once the inputs are entered, a query is run, and the results are listed alphabetically. The user can then click on each firm to find out more information on the company, including its product or service offering. For this research the following inputs entered were

- Industry: Life science
- Company Size: <250 employees
- Age: <15
- Investment Received: Early Stage
- Location: San Francisco, California; San Diego, California; and Miami, Florida

The query yielded 262 companies. Subsequently, all 262 firms' profiles in the Grow Think database were reviewed. The objective of the review was to further weed out firms that did not meet the criteria of the exploratory study. The review disqualified 87 firms, which reduced the number of firms to 175. The relevant information for the 175 firms was recorded in a tracking database the researcher used as part of the research records.

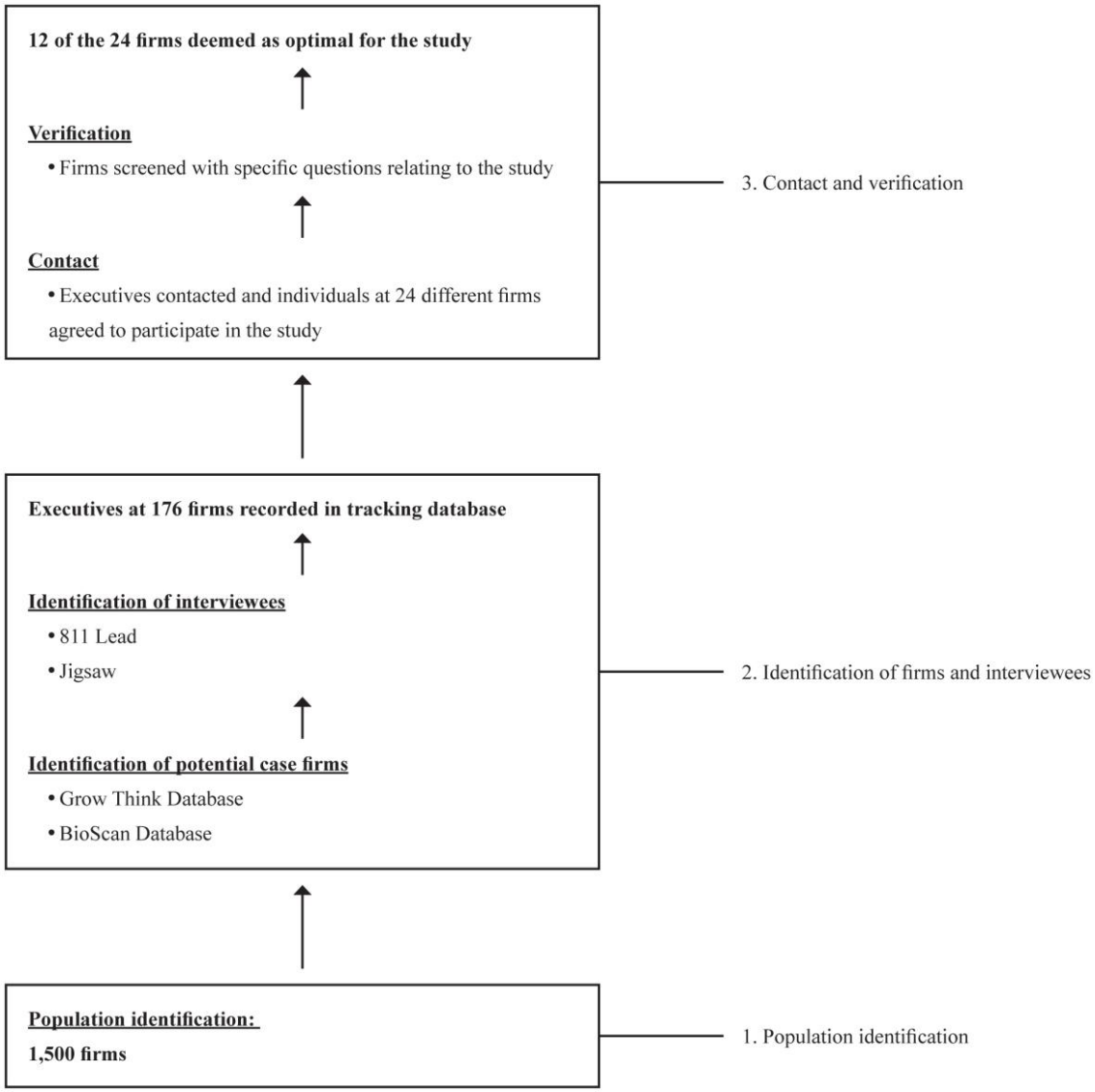
The qualifying companies were then cross-referenced in the Biospace database; which is a database of life science firms in the U.S that has been used to glean information on life science firms in several noted studies (e.g. Deeds, 2002; Rothaermel, 2001; Smith, 1999). Each company was entered into the Biospace database, and the reference found no significant discrepancies from the information found in the Grow Think database. However, for seventy-nine of the companies it found additional information that was useful and which was added to the information in the tracking database.

The resulting firms were then cross-referenced in the Jigsaw database, which contains the names of employees at companies. For each company the names, phone numbers and email address of the founders and/or the key executives was recorded in the tracking database. A similar process was followed in the 811 Lead database, one with similar information and function as Jigsaw. This process yielded the names and phone numbers of exectutives at 176 firms. These names and numbers were then recorded in the tracking database.

In the third step (Figure 5-4, step 3), all of the founders and or key executives that met the parameters for the exploratory study were contacted via telephone to see if they would be willing to participate in the study. This yielded seventeen executives who consented to participate in the study. After the phone calls, emails explaining the research and asking for help were sent out to the forty-two firms that were unable to be contacted by phone. The emails resulted in seven more firms expressing interest in assisting with the study; thus a total of twenty-four firms consented to participate in the study. These firms were then contacted a second time and asked a series of filtering questions to see which firms would be best for the study. From these questions twelve firms emerged as optimal for the study and were subsequently interviewed.

The initial round of interviews was then conducted, and the data for these interviews was analysed. At that point the researcher decided to further focus on six firms (focus firms) in order to allow for more depth with each.

Figure 5-4: Case selection



Source: Author

Firm groups

All of the firms were coded to keep their identities anonymous; to help protect the proprietary information of the firms and to also make the firms more comfortable in participating in the study. These codes are based on the firms' subsectors (Senker & Sharp, 1997), and they categorised the firms into three groups: 1) Biological Analysers (BAs), 2) Drug Development (DDs) and 3) Medical Device (MDs). Previous studies have used industry subsectors to classify firms for comparative purposes; subsectors provide variation that is a good basis for comparative purposes (Dewick, Green, & Miozzo, 2004; Feldman, 2005; Hendry & Brown, 2006). The firms used in the present study were small life science firms in the commercialisation phase of development.

Table 5-4 highlights the revenues and financing obtained of each of the firms examined in this study.

Table 5-4: Case firm profiles

Firm	Year Founded	Revenues in 2009.	Specialised financing obtained as of December 2010.
BA1***	2004	<$1 million	$1.1 million
BA2***	2003	<$1 million	$4 million
BA3	2005	$8 million	$75 million
BA4	2005	$42 million	$40 million
DD1***	2001	<$1 million	$28 million
DD2***	2001	<$1 million	$8 million
DD3	2000	$15 million	$105 million
DD4	2000	$60 million	$70 million
DD5	2000	$25 million	$450 million
MD1***	2000	<$1 million	$10 million
MD2***	2003	<$1 million	<$2 million
MD3	2004	<$1 million	<$14 million

Source: Author

***** Focus firm**

The noticeable differences amongst these firms were the revenues and the amount of capital raised. Although these differences are in some cases significant, these firms are still relatively similar. Furthermore, some variation amongst cases is desirable for the sake of comparison (Eisenhardt, 1989a; George & McKeown, 1985). Thus the bounded variation in the cases is ideal.

5.4.2 Interviews

The bulk of the data for this study came from interviews. These interviews transpired over a five-year period (2006-2010) and consisted of informal and formal interviews with key personnel. There were three rounds of interviews, and each round of schedules was based on the literature and the previous round of interviews analysis. The researcher developed the interview schedules based on the Jones, Wheeler, Vlachos and De Opacua (2008) interview schedule; which was originally designed to explore the growth and internationalisation of Scottish life science firms.

The interviews started with open-ended questions to allow the interviewee to offer unsolicited insights. Close-ended questions then captured specific points. The interview schedule for each round of interviews is detailed later in this section. The interviews took place with key personnel from each firm who had been with the firm from or near inception; which is ideal in the field of management because intimate knowledge of the firms' operations is needed to capture deep insights (Eisenhardt, 1989a). Each interview was taped, transcribed and field notes were taken. Subsequently, a second round of interviews ensued with the firms to narrow down the generalisations found from the first round of interviews. These interviews were transcribed, analysed and compared to the data from the first round of interviews. Next a third round of interviews was conducted. This round was different in that it aimed to validate the first two rounds. This time the respondents were asked to validate findings from their firm.

Interviews are one of the best methods for studies intending to unearth fresh insights (Kvale & Brinkmann, 2008). Gillham (2000) suggests that one of the biggest benefits of interviews is the flexibility to probe new paths that were not originally considered, whilst still capturing specific information. Interviews using open-ended and close-ended questions encourage two-way conversation between interview and interviewee, allow for flexibility to further probe for relevant information and allow the interviewers to offer insights that may not have been considered before the interview. These insights are captured through interpretive content analysis of the interviews, whilst close-ended questions allow for specific points to be captured (Seawright & Gerring, 2008). The close-ended responses also help with in-site validation of key issues and are useful for cross-case comparisons. The research topics in the present study are in the earlier stage of development, but there is some theoretical development on the topics. For this reason an

open and close-ended interview schedule provided the best means to capture new concepts whilst still capturing specific data to compare to existing theories.

The interviewer is an essential part of the research process, especially in open-ended interviews (Yeung, 1995). Researchers should first make the interviewee comfortable. For the present study this was particularly important as the case firms were all high tech, which tend to be sensitive about divulging information about their operations (Unikel, 1997). In order to gain the confidence of the interviewee, three main tactics were used: 1) a thorough description of the research project and its aims and objectives was given to the interviewee, 2) a confidentially agreement was given to each of the interviewees before the interview was conducted and 3) the questions in the interview avoided asking specifics about trade secrets. Another challenge for an interviewer is asking appropriate questions to probe for information; if appropriate questions are not asked, then irrelevant or no information would emerge from the interview (Benjamin, 1974). To overcome this challenge, the interview schedules stemmed from the existing literature, the informal interviews, and information gathered on the case firms.

A third challenge for the interviewer is to make sure that the interviewee understands the questions being asked (Easterby-Smith et al., 2002). The present study ensured that the questions were clear and concise; all possible unfamiliar terms were defined and the respondent was encouraged to ask the interviewer clarifying questions. Furthermore, the interviewee first told his or her own story of the firm and its growth, allowing for fresh insights to emerge and helping to increase the credibility of the interview by reducing the possibility of directing the respondent towards certain responses (Gillham, 2000). Multiple interviewers also helped ensure the emergence of accurate and meaningful information. The primary researcher and his supervisor, Professor Marian Jones, conducted the first round of interviews. A fourth challenge for interviewing is eliminating the interviewer's bias. The researcher attempted to eliminate all preconceived biases; mainly though the development of unbiased interview schedules.

Another mechanism used to eliminate bias was to get feedback on the interview schedules from subject experts before the interviews were conducted. Furthermore, a number of triangulation techniques, which are discussed in the next section, were employed to help eliminate researcher bias. The fifth challenge in interviewing and arguably the biggest challenge for a researcher conducting interviews is listening (Benjamin, 1974; Yin, 2008).

Interviews yield massive amounts of data, and during the open interview process, the interviewer must filter the most relevant data to use for probing questions during the interview. In order to filter information during an interview, Kvale and Brinkmann (2008) suggest taking field notes, listening for key terms and asking clarifying questions throughout. The present study followed this advice. Furthermore, at the end of the session the interviewer presented the respondent key points taken from the interview to verify (Yin, 1983).

5.4.3 Interview Design

Conducting multiple interviews and designing the subsequent interviews from the prior is an ideal method to capture specific theoretical concepts (Hurmerinta-Peltomaki & Nummela, 2004). Based on the first round of interviews, a second round of interviews on a narrower set of topics was conducted with the six focus firms. This set of interviews intended to draw further information on what had emerged from the first set of interviews. The third set of interviews confirmed findings from the first two rounds of interviews with the focus firms, but also left room for new insights.

Interviewing respondents intimately familiar with the phenomenon of interest helps to increase the validity and reliability of the data gathered from an interview (S. Kvale & Brinkmann, 2008). Qualitative research in management often involves gathering information from high-level executives because they are knowledgeable in all of the firm's operations (Harrigan, 1983); thus they are able to offer data which is more reliable. To increase the reliability and validity, many studies on small firm growth (e.g., J. Bell, Crick, & Young, 2004; Boter & Holmquist, 1996; Burgelman, 1983; Knight & Cavusgil, 2004) have used interviews with executives as a source of data. The fact that all of the interviewees in the present study were with the firm from (or really close to) its inception also helped increase the trustworthiness of the data. Table 5-5 further details each informant's relationship with the firm.

Table 5-5: Data collected from

Firm	Informant(s)	Notes
BA1***	CEO; Board member	Founder
BA2***	CEO	Founder
BA3	CEO	Founder
BA4	Operations manager	His father started the business, and he has worked there since inception.
DD1***	CEO Chairman Director of research	CEO is not technically a founder but has consulted with the firm since the beginning and owns a significant amount of the firm.
DD2***	CEO Chairman	Founder
DD3	Chief scientific officer	Founder
DD4	Chief operating officer	Came on within three months of the firm's founding.
DD5	CEO	Founder
MD1***	CEO	Founder
MD2***	CEO Founder	CEO is not a founder, but has been with the firm since year 2.
MD2	CEO	Founder

Source: Author

***** Focus firm**

First round of interviews

At the time of the first round of interviews the research had four objectives: 1) gaining a background on the firms, 2) exploring the resources and capabilities needed in growth, 3) probing out what general effects the VCs non-financial resources had on the firms and 4) giving the interviewees a chance to offer unsolicited insights on the research topic (from the general open-ended questions) to draw themes from. The first point of interest in the study was the development of key resources. In order to examine it, the first interview schedule looked at six areas:

A. The firm's current position
B. The foundation process of the firm

C. The critical events of the firm
D. The impact of international activity
E. The firm's boldness, creativity, and innovativeness
F. The firms R&D and product portfolio management

The first category of questions intended to provide an overview of the firm's competitive positions in both domestic and international markets. These questions were designed to establish the competitive position of the firm and what the important contributors to getting in that position were. The interview schedule consisted of a series of open and close-ended questions. This category stemmed from the assets and capabilities literature, which suggests that several factors such as unique resources (Oviatt, McDougall, & Loper, 1995), R&D spending (Burgel & Murray, 1998), executives with international backgrounds (Westhead, Wright, & Ucbasaran, 2001), important CAs (Teece 1986; Rothaermel 2001) and growth orientation (Autio, Yli-Renko, & Salonen, 1997) affect firm growth.

In the second category of questions respondents were asked to 1) provide a history of the firm, 2) establish why the firm was founded, 3) establish how the firm was funded, 4) see if there were any international activities that were important in the foundation of the firm and 5) see what the aims and objectives of the founders were when they started the firm. This set of questions was aimed at probing what the main drivers of the firm's foundation were in order to probe the motivation of the firm's foundation and what major assets influenced the firm's early growth.

The third category of questions probed the significant milestones that influenced the direction of the firm. This category gave the interviewee an opportunity to discuss any major events that affected the growth and development of the firm. There were probing questions asked to get the respondent to discuss the effect that equity investors had on the process. Studies suggest that VC is an important milestone in the development process of firms (Gompers, 1995; Timmons & Bygrave, 1986); the questions were designed to see the importance of the VC, especially relative to other major milestones. In a similar vein, the questions in category four explored the important activities that impacted the firms' development.

Categories five and six aimed to unearth insights on the influence of innovation on the development of the firms. Innovation is critical to the growth of new technology-based

firms (Löfsten & Lindelöf, 2002). The main purpose of these questions was to see what the effect of innovation was, as well as to see what the sources of innovation were. Moreover, innovation is a driver of internationalisation (Bloodgood, Sapienza, & Almeida, 1996), and studies indicate that VC has a significant positive impact on innovation (R. Florida & Smith Jr, 1990; R. L. Florida & Kenney, 1988; Kortum & Lerner, 2000; Timmons & Bygrave, 1986). Thus these questions also explored the impact of VC on the firm's innovation and internationalisation.

Second round of interviews

A second round of interviews was conducted with the case firms. The interview schedule was based largely on the analysis of the first set of interviews. The first round of interviews established the background on the case firms in this study and also raised three major themes: 1) R&D and financial assets and capabilities are at the heart of early growth, 2) unique paths, positions and processes lead the development of R&D and financial resources and capabilities and 3) VC has various effects on the growth of life science firms, but these effects are not always positive.

Results from the first round of interviews suggest that R&D and financial resources and capabilities are vital to the firms' foundation and growth. The second and closely related theme that emerged is that R&D and financial resources and capabilities come from a variety of sources: internal resources, industry partners, university partners, the government and VCs. Furthermore, there are a unique set of paths, positions and processes that lead to the development of R&D and financial resources and capabilities. The third theme that emerged from the first round of interviews is that the VC business model is inherently flawed. There is little extant literature on this topic. Therefore the questions were drawn on the basis of the first round of interviews. Although this topic is not directly related to the first topic, it does have an effect on the development of firms.

Like the first round of interviews' schedule, the second round schedule used both open and close-ended questions. This type of interview schedule allows for new themes to emerge, whilst still being able to capture specific points (Labaw, 1981). The questionnaire consisted of five sections. It started off with questions pertaining to the R&D and financial assets and capabilities important to the firms' growth. It then moved into questions about where R&D and financial assets and capabilities stem from. Subsequently, the

questionnaire asked questions relating to the effect of the VCs business model. Each section of the interview schedule is further explained below.

Section A

This section hones in on the key resources important to the firm's early growth, namely, which R&D and financial resources are paramount. The open-ended questions in section A provided the respondents an opportunity to provide fresh insights on these questions; whilst the questions in section A1 captured specific information relating to paths, positions and processes leading to the development of key resources and capabilities. Another objective of this group of questions was to probe the source of the key resources and capabilities. Questions 1.1-1.16 in A1 specifically ask about how alliances led to the development of the key resources and capabilities. These questions were developed on the basis of alliances literature (Coombs & Deeds, 2000; Lindsey, 2008) and the resources and capabilities literature (Teece, 1986; Trispas, 1996).

Section B

This section follows a similar rationale to section A in that it aimed at going into further depth on the events that led to the development of key resources by focusing on the major milestones. Miles and Huberman (1994) suggest that insights on major events in time can help to establish important facts in theory building. Similarly, Yin (2003) suggests critical events are important to establishing the context of a case. Thus the purpose of the open-ended questions in this section was to probe the time frame and events that led to the development of the critical resources and capabilities. Moreover, this section also included some questions to probe the effect that resources and capabilities had on the growth of the firm.

Section C

The first two sections aimed to establish the resources and capabilities important to firm growth. Section C goes into more depth on the role of VC. The rationale for this section comes from the literature on VC networks (Lynsey, 2009; Sorenson and Stuart, 2001; Wright and Lockett, 2003) and VC value-added literature (Gompers and Lerner, 1996; HSU, Hellman and Puri, 2002). However, this literature is vague and there is only specific coverage on the value of VC networks in aligning future financing. For this reason the section starts out with open-ended questions to let the respondents offer new insights on the influence of VC on the firms' growth. These were followed by a set of more specific

questions on whether resources and capabilities were created from VC inputs or VC networks.

Section D

The first round of interviews suggested that firms tended to have a few partners that provide inputs. This section presents a table to capture data relating to these partners. It is intended to see if any patterns from the top partners emerge. This table is based largely on resources literature, which suggests that partners are important sources and that firms tend to have a few key partners (Arora & Gambardella, 1990; Graff et al., 2003; Rothaermel, 2001a, 2001b). The table captures specific points relating to how the partners influenced the firms' growth.

Section E

One of the themes that emerged from the first round of interviews is the inherent flaws in the VC business model. Almost no literature exists on this topic. For this reason the section starts off with open-ended questions that are based on the results of the first round of interviews. The questions in section E1 ask close-ended questions to capture specific points about the problems with the funding models available to life science firms.

Third round of interviews

This round of interviews was intended to validate the findings of the first two rounds of interviews. Pragmatic validation, a powerful means to triangulate findings, is a form in which the perspective of the findings is judged by the sample of interest (Kvale, 1987), which in this study is the case firms. One of the main validation techniques that this study uses is a survey on the major findings. Each of the major influences that the study found important to the development of R&D and financial resources and capabilities was presented in a survey to each of the case firms in this study, and the respondents rated the importance of each influence. This data does not serve for statistical testing, but instead each response is compared to the analysis from the qualitative data for each of the firms. This serves to validate the findings. In general, most of the findings were validated, but there were a few small discrepancies. In those instances more information was gathered to clarify the discrepancy, and an explanation for the discrepancy was established.

Archives and observation

The research supplemented the data collected from the interviews with all publicly available data for each of the case firms. This included new articles, websites, analyst reports, patent records and articles in scholarly journals. All of this data was recorded in a case record for each firm. Case records help to organise a study, keep track of information and provide a common framework for tracking data for each case in a study (Stake, 1999). Observation was also utilised in the data collection. The researcher spent a total of twelve hours (four hours each at three different case firm sites) observing the operations, sitting in top management meetings and touring facilities. Copious observation notes were taken and recorded in the case records for each of these visits. Collecting data from multiple sources is a good way to triangulate a study. Data from other sources offer potential new insights and can confirm or disconfirm ideas from other sources of data (Yin, 2008); the supplementary data collected in this study served this purpose.

5.5 Steps 6, 8, 10: data analysis

The analysis of case research depends on the type of case study, the number of cases used and the objectives of the study. The present study used six case studies, is concerned with unearthing new insights on the development of life science ventures and relied primarily on qualitative data. Eisenhardt (1989b) suggests that for qualitative case research there are two main approaches to analysis: within-case and cross-case. In within-case analysis the goal is to narrow down the massive amounts of data into manageable amounts that can be properly analysed in a scientifically valid manner; whereas cross-case analysis is concerned with comparison and theme narrowing and replicating (Eisenhardt, 1991). However, using both within-case and cross-case analysis is often the preferred choice for research involving multiple cases (Miles and Huberman, 1994; Yin, 2008). That this study used multiple cases as well as the nature of the study made using both approaches of analysis appropriate. Each case was analysed individually and the emergent data was recorded for each case. Data was then analysed across groups and cases. The within-case allowed the findings from each to be analysed individually, whilst the cross-case provided a means of replication.

The core of the data for this study emanated from a series of interviews that consisted of three separate rounds of interviews. However, the study also captured numerical data consisting of financial and operations data (e.g., number of employees, revenues, etc.) and

is presented in tables. Rather than being statistically tested, it is used to help construct case histories. The cross-case analysis tables were constructed for each major category with each case represented.

5.5.1 Data coding

Before discussing the reduction and packaging of the data, it is important to discuss the techniques used to identify the codes. These codes emanated from the literature (priori codes) and the emergent inductive themes found throughout the analysis. Below the multiple step process used to code the qualitative data is described.

In the first step, coding of the text, transcripts and the field notes was done using four techniques outlined by Ryan and Bernard (2003): 1) identifying repetitions, 2) looking for transitions, 3) identifying similarities and differences and 4) cutting and sorting notable quotes. For each of these techniques the data was uniquely read (i.e. the transcripts were read four separate times during this step), and the elements were coded along the lines of the particularities of each technique, and were then recorded on a coding sheet. Repetition is one of the most basic ways to identify themes and was the first technique used. Essentially the researcher is looking for ideas that reoccur throughout the text (Silverman, 2006). Examples that reoccurred throughout the first set of interviews were the importance of finances; several key R&D and financial resources and capabilities critical to growth; and that the VC business model is flawed. The second data analysis technique searched for transitions in the data. Abrupt pauses or shifts in a interviewee's thoughts often indicate significant events or issues, and these are often a basis for themes (Ryan & Bernard, 2003). The third analytical technique used in this study identified similarities and differences. Glaser and Strauss (1967) call this constant comparison, which is essentially comparison occurring across units of data. There are several approaches to constant comparison. The most detailed is line-by-line analysis where every line is compared. The least detailed constant comparison technique is comparing blocks of texts. The text block method is much less time intensive than the line by line method, and because of the large amount of data collected, this study used the text comparison technique. Notes were taken for each section of text and compared to each other. Cutting and sorting of notable quotes is the fourth text analysis technique used in this study. These were placed into categories based on themes. There are many techniques to sort amongst themes, ranging from sorting into many different themes to sorting into broad themes. This study used a relatively broad

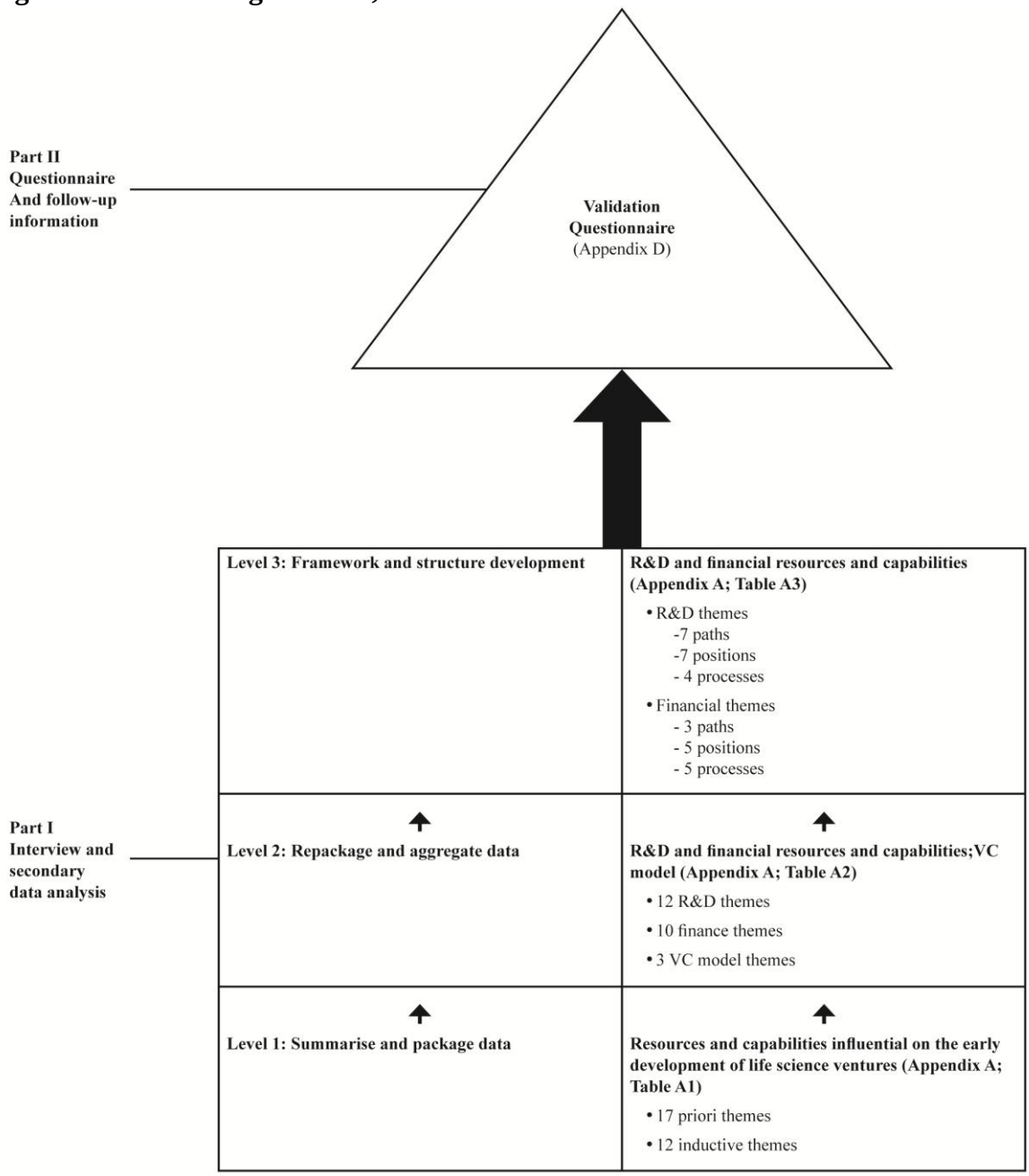
sorting system of twelve categories for the emergent themes. A comparison of the four analytical techniques produced the broad categories of themes for the study's framework.

The first four coding techniques yielded almost twenty-five themes, but in order to more finely glean the data, two more coding techniques suggested by Russell and Bernard (2003) were used. The first is theory matching. In this step the interviews were searched for themes relating to prior and emerging theory. Sections of text were analysed and compared to the existing literature on life science firms, the RBV, dynamic capabilities and CAs. The second step taken in the second stage of the refinement process looked for missing data. Often respondents will intentionally or unintentionally leave out pertinent information in responses that are important to a topic (Taylor & Bogdan, 1984). Entrepreneurs are known to overemphasise their role in a venture (King & Roberts, 1992). Since most of the interviewees in the present study are the entrepreneurs who started the firm, it follows that the interviewees may have left important information out of their responses to emphasise their role in the firm's development.

5.5.2 Data categorising, reduction and structure

The coding processes described above serve to identify the themes of the study. Figure 5-5 depicts the steps in the analytical process used to summarise, reduce and aggregate the data. In the first part the researcher gathered data from interviews and secondary data and analysed each part using Miles and Huberman's (1994) three level analytical abstraction process. At the first level major themes were summarised and packaged together in major categories. At the second level data was abstracted and categorised along narrower themes. At the third level data was reduced to major themes and an explanatory framework was developed. Part II then deductively validated the findings from the first part.

Figure 5-5: Data categorisation, reduction and structure



Source: Author

Part I of the data analysis began with the coding techniques described in section 5.4.1 above. Seventeen of these codes stemmed from literature (a priori codes) and twelve inductive codes emerged during the analysis (Appendix A, Table A1). At this stage in the analysis it emerged that R&D and financial resources and capabilities drove the early development of the firms, as was evidenced in over seventy-five per cent of the codes related to R&D and finance, despite the fact that only a few of the questions asked in the interview directly probed these areas. Consequently, step two of the analysis repackaged the data along the lines of R&D and financial resources and capabilities (Appendix A;

Table A2). At level three of the analysis the research then further refined and created a structure for the data categorising it into two main groups (R&D and financial) with each of the groups having three sub-group: paths, positions and processes (Appendix A: Table A3). At the third level in the data analysis Miles and Huberman (1994) suggest that data should be tested. In order to do this the study then presented the findings to the respondents (Part II of Figure 5-5).

In part II the research created a questionnaire (Appendix D) aimed at validating the findings. The questionnaire is based on pragmatic validation, which is a powerful means to triangulate findings. This is a form of validation, which the perspective of the findings is judged by the sample of interest (Kvale, 1987). The respondents from each firm were presented with each of the themes produced from the first part of the study on a scale of 1 (not important) to 7 (very important). Based on the first two parts of the analysis, the questions were pre-coded for each of the firms. These codes were then compared to the responses from the key informant from each firm. The researcher then gathered more information on any major discrepancies between the pre-coded responses and the responses by the respondents.

The careful coding and analysis techniques described above are important, as researchers often have no systematic approach to coding data; they often rely on intuition to come up with categories whilst they are reading through the transcripts (Ryan & Bernard, 2003). This is often a good initial technique, but it limits the information that can be gleaned from the transcripts. Even in a grounded study a more structured approach to analysing data is needed. The systematic approach taken in the coding of the data in the present study helped to uncover ideas, and it also added to the credibility of the study by ensuring that the themes and ideas were drawn from all angles of the data.

One particular challenge for researchers analysing qualitative data is managing their data. To aid in this, the present study used software and a case database. RDQA is a qualitative data analysis program. This relatively new program has powerful functions to store, trace and query data. Qualitative data analysis software such as this is quite popular in qualitative management studies (Yin, 2008). A custom-created database by the researcher also aided in tracking the key case information for all of the firms. On top of the electronic filing, the researcher printed, labelled and filed each page of data.

5.5.3 Reliability and credibility

There are several shortcomings of the methods implored for this study. Quantitative purists might fault it for the lack of generalisability. However, this is not one of the main objectives of the study. Rather the main objective is to capture rich insights on the R&D and financial resources and capabilities needed in the growth of life science ventures, and as discussed earlier, these are best captured through qualitative techniques such as the case methodology used in this study (Bell & Bryman, 2003; Easterby-Smith et al., 2002). Qualitative research is also criticised for lack of rigor. However, even quantitative purists recognise that a properly designed and executed qualitative study can be just as rigorous as the best quantitative study. Closely related to rigor, and the source of the third and biggest criticism of qualitative work is the lack of reliability and credibility. In many cases this criticism is valid: qualitative researchers often dismiss the importance of reliability and credibility.

Reliability is an elusive term to define in qualitative research. In quantitative research it refers to the ability of the results to be replicated (Bell & Bryman, 2003). By the nature of qualitative work it is difficult, if not impossible in many instances, to produce results that are completely replicable. For this reason reliability takes on another meaning in qualitative research. Lincoln and Guba (1985, p. 317) contend that reliability is best described as '*dependability*' in qualitative research. Dependability comes from the quality of the processes and products of the work. To capture dependability, the present study took careful consideration to create consistent measures and processes to explore the research questions. The first way dependability is captured is through the design. The study used consistent processes throughout the research, the three most important being the design of the interview schedule, the selection of the case firms and the analysis of the data. The interview schedule was carefully crafted on the basis of the literature and discussions with industry experts. This produced theoretically sound questions. The selection of the case firms is the next major process that was carefully controlled for. As discussed previously in this chapter, the study used life science firms, which are used extensively as samples in studies on the major theories related to this project. The study also carefully controlled for the analysis of the data. As discussed above, the study used several commonly accepted and rigorous techniques to draw themes. To further ensure reliability, the study took careful consideration to use the same techniques for all of the case firms' data.

The reliability discussed above is a prerequisite to the validity of the study (Lincoln & Guba, 1985); i.e. the findings could not be valid unless the reliable processes discussed above were used to find them. Like reliability, validity in qualitative work is elusive to define. Denzin (1970) sees validity scales as dependent on the accepted body of knowledge in the research community. He says they *'are only symbolic – they have no meaning other than that given by the community of scientists'* (p. 106). The main way that validity is established in this study is through using reliable processes and basing the work off of existing theories and methods that are accepted in the literature. Ultimately validity and reliability in qualitative work is judged by how credible and trustworthy a study is.

Table 5-7 summarises the steps taken in this study to establish trust. These steps were taken from the beginning to the end of the study to ensure trustworthy findings were produced. Often qualitative researchers only consider reliability and credibility issues in certain parts of a study, such as in the data collection or analysis, but unless a concerted effort is made throughout a study, the results are not seen as trustworthy (Denzin & Lincoln, 2005; Yin, 2008). For this reason the present study made a concerted effort to keep reliability and credibility at the forefront of each step of the research process. One of the best ways to increase the credibility and trustworthiness of a qualitative piece is to use strong triangulation techniques. The next section further delineates the triangulation techniques used to establish trustworthiness in this study.

Table 5-6: Trustworthiness approaches

Steps	Approaches taken to ensure trustworthiness
Steps 1-3: Research background	-A thorough literature review was conducted, which helped to identify and properly position the study. -Scholarly and industry experts were consulted to establish an appropriate research paradigm.
Step 4: Study design	-Systematic approach was designed from the onset. -All philosophical influences were properly analysed before the study was designed. -Design peer was reviewed by multiple experts.
Steps 5,7, and 9: Data collection	-Triangulation through an iterative data collection process from multiple sources. -The bulk of data came from high level executives intimately familiar with the firm's history. -Six cases used; a sufficient number for comparative purposes, but still a manageable size to analyse.
Steps 6,8, and 10: Data analysis	-A systematic approach to analysing the data: • Data triangulated by analysing it through different approaches • Looking at the data through multiple theoretical lenses • In site validation -Results presented in different formats, which allows for different angles of comparison.

Source: Author

5.5.4 Triangulation

Triangulation is one of the main tools that qualitative researchers have to establish reliability and validity. O'Donoghue and Punch (2003, p. 78) see triangulation as a '*method of cross-checking data from multiple sources to search for regularities in the research data'*. Denzin and Lincoln (2005) identify four main types of triangulation: 1) data, 2) multiple researcher, 3) multiple theory and 4) multiple method. The present study utilised all four.

Collecting data from multiple sources is one means to triangulate case research (Yin, 2008). Data for the present study emanated from several sources. The main data source of data came from the interviews with key informants from the firms. The secondary sources

of data came from news articles, patent records, industry reports, SEC filings and the internet. The internet data was collected from the case firms' websites, life science industry websites and life science web blogs. The web can provide rich qualitative data for academic research (Robinson, 2001; Romano Jr et al., 2003; Sixsmith & Murray, 2001). For this study web data served for comparative and confirmatory purposes; i.e. the study compared the secondary data to the data from the interviews. Until recently data collected from the web has not been used in academic research. However, Herring (2001) provides strong evidence that the web is becoming an accepted place for academic studies to draw from. Furthermore, the prolific use of the web has made it a large and rich source of data appropriate for academic research (Lefever, Dal, & Matthiasdottir, 2007). Few management studies use netnography or secondary data from the web as a source of data. Liu and Arnett (2002) is one of the few examples; this study assesses the web content of the fortune five hundred companies by using the firms' websites as a means of data collection. Feinberg and Kadam (2002) also used web sources in their assessment of customer service. Jones (1999) suggests it is especially useful to triangulate primary data with web data. However, he also emphasises the ethical concerns involved with using the web to glean data. Using only web data for the present study would have been hard to justify. However, using it for comparative and triangulation purposes is well justified.

A second way this study is triangulated is through the multiple theoretical perspectives that were taken to look at the research. Often researchers fixate on one theoretical lens and thereby miss insights from other theories (Denzin and Lincoln, 2005). The present study looked at the research questions from three main theoretical perspectives: RBV, dynamic capabilities/CAs, and VC value added; which provided additional, multiple angles for examining the questions. The third means of triangulation that this study draws on is validation. As discussed above, the findings were validated by a questionnaire that the case firms completed, which provided another powerful means of triangulation (Kvale, 1987; 2004).

5.6 methods conclusions

The purpose of this chapter is to detail the methods implored to investigate the research questions of this study. These, as well as the case methodology used, are relatively complex. To simplify this, the complex process was broken down into manageable steps

that are outlined in Figure 5-1 (at the beginning of the chapter). Investigating the questions in this research was very similar to a detective investigating a crime (Yin, 1981). It took many sources of data and many hours of collecting and analysing clues, and piecing all of the clues together in a coherent way to produce a compelling argument for the themes that emerged from the study. The case method taken in this research is inductive in nature but also drew on some deductive techniques. It relied on interviews as the primary source of data, but several other sources of data also helped to supplement the interview data. The methods implored allowed the researcher to uncover important insights on the R&D and financial resources and capabilities important to the early growth of life science ventures.

The methods used in this study are not perfect. There are no perfect research methods in business (Bell & Bryman, 2003). Quantitative purist might argue that this study lacks validity and generasability. Whilst some qualitative experts may argue the case method lends itself to narrow and idiosyncratic theory. However, the methods are well justified given the current state of development for the theories of interest to this study. Moreover, the methods produced trustworthy findings that contributed to the literature on the research topics. The next chapter discusses these findings.

Chapter 6 – Results and Analysis

Chapter Objectives

- Present the structure of the analysis.
- Present the findings from the within-group-analysis.
- Present the findings from cross-case analysis.
- Present the triangulation questionnaire responses.

6.1 Introduction

This chapter and chapter seven present the findings of the study. Following Senker and Sharp (1997) the firms are divided into three groups for analysis purposes. The analytical framework is constructed based on the firms' industry subsector: medical device (MDs), drug development (DDs) and biological analysers (BAs). A within-case and within-group analysis is presented in the first part of this chapter. Followed this is the responses from the questionnaire that was administered to the case firms is presented. This serves as a framework for the cross-case analysis and to present the findings from a different perspective.

A within-case analysis presents data in meaningful and logical manner and allows for capturing depth (Miles and Huberman, 1994). However, it does not give a contextual base for comparison. Information from a within-case analysis is often used as basis for a cross-case analysis where such comparisons are made. Although this is common practice, depth is often lost in the transfer from the within-case analysis to the cross-case analysis (Yin, 1981). To minimise this, the present study first presents a short within-case analysis and then presents an in depth analysis of the main themes from the study in a cross-group analysis. The within-case analysis provides a contextual basis for each firm and the small number of firms in the cross-group analysis allows for a basis for comparison, but still allows depth in the analysis (Miles & Huberman, 1994). The findings for each group are presented in terms of the major themes that were identified in the study. The structure of the analysis is outlined below.

A. Within case analysis

A within case analysis for each firm from the group is presented in this section. A narrative of the major events and motivations behind the development of R&D and financial resources and capabilities is presented. This section serves to provide a contextual basis for each firm, which underpins the cross-group analysis.

B. Cross-group analysis of R&D resources and capabilities development

This section identifies and discusses the key paths, positions and processes that led to the development of the firms' R&D resources and capabilities. The matrix of the key paths, positions and processes that led to the development of the firms R&D is first presented. These matrices are not intended to quantify the data from the study; rather the intent is to

present the data in a structured manner (Miles and Huberman, 1994; Yin, 2008). The development of these matrices was detailed in the research methods chapter, but to summarise, each matrix was developed from each case using an abductive approach drawing on the data techniques offered by Ryan and Bernard (2003) and Miles and Huberman (1994). The ideas in the table were initially formulated based on the qualitative data; i.e. the interviews. Themes were coded and the software RDQP was used to compare codes along multiple lines.

Followed by this the paths, positions and processes are each individually analysed. This part of the analysis follows Maitlis and Lawerence (2007) and Lawerence (1998) in presenting evidence trails to support the analysis. These evidence trails consist of textual representations, close-ended questions and secondary data that supports the finding (Lawerence, 1998; Maitlis & Lawrence, 2007).

C. Cross-group analysis of financial resources and capabilities development

This section identifies and discusses the key paths, positions and processes that led to the development of the firms' financial resources and capabilities. It follows the exact format as Section B and is based on the same analytical techniques.

Code blocks corresponding to the themes from the study are presented throughout the chapter to help connect the major themes of the study with the analysis. Table 6-1 presents the code blocks for the themes that were yielded from the data reduction techniques discussed in section 5.4.2. For example:

> The pursuit of this technology cost the firm over $15 million in the first five years [Fin-pa – costly innovation].

In this example the code block identifies that this text relates to the theme of innovation having an influence on the financial paths of the firm.

Table 6-1: Themes and text coding

	Text Code
R&D PATHS	
Core technology R&D demands	R&D-pa core tech
Path – university partnerships	R&D-pa uni partners
Government partnerships	R&D-pa govt partners
Industry partnerships	R&D pa industry partners
New technologies influenced firm's direction	R&D-path new tech
Government approvals: e.g. patent or FDA	R&D-pa govt approval
Scientific developments	R&D-pa scientific dev
R&D POSITIONS	
Core Technology	R&D-pos core tech
Patents	R&D-pos patents
Founders	R&D-pos founders
Skilled scientists	R&D-pos scientists
Star scientists	R&D-pos star scientists
Industry partnerships	R&D position industry inputs
University partnerships	R&D-pos uni input
Government partnerships	R&D-pos govt input
R&D facility and research equipment	R&D-pos facilities
R&D PROCESSES	
Sensing and seizing scientific opportunities	R&D proc S&S
Finding and developing research partnerships	R&D proc partnering
Navigating government approval	R&D-proc patenting
Filing patents	R&D-proc patenting
Learning from earlier research	R&D-proc learning
Transforming R&D	R&D-proc transforming
FINANCIAL PATHS	
Costly innovation	Fin-path costly innovation
Raising capital	Fin-pa – raising capital
Public stock offering	Fin-pa IPO
VC	Fin-pa VC
Revenues	Fin-pa revenues
FINANCIAL POSITIONS	
Scientific capabilities	Fin-pos scientific cap
Founders	Fin pos founder
Executive staff	Fin-pos TMT
Core innovation	Fin-pos core tech
Firm's staff	Fin-pos– staff
FINANCIAL PROCESSES	
Raising capital	Fin-proc RC
Integrating financial resources	Fin-proc int
Dealing with Investors	Fin-proc inv rel
IPO	Fin-proc IPO
Transforming financial resources and operations	Fin-proc trans
COMLEMENTARY ASSETS	
R&D complementary asset	R&D CA
R&D specialised complementary asset	R&D SCA
R&D co-specialised complementary asset	R&D CCA
Financial complementary asset	Fin CA
Financial specialised complementary asset	Fin SCA
Financial co-specialised asset	Fin CCA

Source: Author

The chapter is structured as follows:

6.2 Drug development firms
6.3 Medical device firms
6.4 Biological analyser firms
6.5 Triangulation and cross-case analysis
6.6 R&D and finance interdependence
6.7 Analysis conclusions

This chapter presents the findings of the study. For the sake of parsimony, the findings are not at this point compared to the literature; this is done in chapter seven.

6.2 Drug development firms

This section overviews the evolution of the drug development firms. This group is constituted by two small drug development firms that are pursuing novel drug technologies. In this section a narrative of each case is presented followed by an in-depth cross group analysis.

6.2.1 Drug development firm one (DD1)

DD1 is a small drug development and diagnostic firm. The firm's core technology revolves around cardiovascular disease treatment and prevention. The firm was founded in 2000 by two scientists and a medical practitioner. Currently the firm employs eighteen staff members and is generating less than $1 million in revenues. However, the firm has mainly focused on R&D in the first ten years and has just started selling its first product.

The core technology that the founders conceptualised set the central direction of the firm; as the CEO puts it,

> *Our technology has driven all of our major decisions and is still driving everything that we do today*. (DD1's CEO) [R&D-pa and fin-pa core tech]

The founders came up with the idea of combining multiple cardiac techniques together into a drug platform [R&D-po founder]. In 2000 they formed DD1 to pursue its development

[R&D-pa core tech]. The initial capital for the development came from personal funds [Fin-pos founder]. After the founders developed the model for their technology, they then started to seek outside capital. To help with this process and to structure the firm, the founders hired a highly experienced CEO in the second year of the firm's operations. The CEO's first priority was raising capital. In order to do this he created processes to raise money from physicians. The firm created routines of finding, contacting and presenting the companies technology to physicians and then asking the physicians to invest in the firm [Fin-proc RC]. At the time the main positions that the firm leveraged to 'sell' the potential investors was the market potential of the core technology and the experience the CEO had in developing young firms [Fin-pos TMT]. These processes quickly yielded $3 million.

In the first four years the capital went primarily to developing their drug technologies. The initial R&D assets and capabilities emanated from the founders, a small staff and research partners. Early on the firm did not have any major research partners, but instead developed routines for identifying researchers doing complementary work [R&D-proc partnering]. They looked for these researchers through their work in scholarly, scientific journals and conferences. Once DD1 identified potential researchers, they then presented the prospect of using DD1's technology and research to attract them, which turned out to be a mutually beneficial arrangement, as the researchers got access to useful information and technology from DD1, and DD1 received inputs from the independent researchers [R&D CCA]. These routines proved highly beneficial to DD1 as they were able to forge important relationships with independent researchers.

> *The independent researchers were very important to helping us advance technology for a low cost. Several of their studies advanced our technology and provided important independent research backing.* (CEO, DD1)

A partnership in year three with the U.S. FDA also had a major impact on the firm's R&D path [R&D-pa govt partnerships]. This partnership was on a joint study for the firm's main drug application. The study looked into the estimated development time and cost of the drug. Results from the study suggested it would take four years and $10 million to develop. At about the same time the firm ran into issues on its patent applications; most notably, it was taking longer to obtain the patents than the firm had anticipated [R&D-pa scientific dev]. Due to the patent problems and the long time to develop the drug, the firm decided to

put their project on hold and focus on an application for a diagnostic device. According to the CEO,

> *The patents were taking too long and we did not have the time or money to get the drug to market* [R&D-pa govt app]. *For this reason we focused on developing a diagnostic device from our technology. We focused on this because it could be brought to market more rapidly.* (DD1's CEO) [R&D-pa core tech]

Due to the high development costs of the core technology, the firm has had to constantly raise capital. In the first four years this came primarily through private investors, but in year four the firm needed substantial capital to finance the change in the firm's R&D focus [Fin-pa costly innovation]. The firm turned to a public stock offering for this. Although a complex ordeal [Fin-pa IPO], the firm was able to navigate it based on the CEO's vast experience in taking companies public:

> *I have taken four companies public, so I knew how to do this. I knew that a reverse public offering from a shell company would be the fastest and best way to raise a large amount of capital.* (DD1's CEO) [Fin-pos TMT]

Due to the CEO's experience the firm successfully raised over $10 million from its first stock offering. This capital went to focusing on the development of their diagnostic device. The capabilities in raising capital proved vital as the capital that they yielded allowed the firm to continue its R&D. These advanced capabilities proved to be important auxiliary assets throughout the development of the firm [Fin SCA].

Developing the diagnostic device also proved difficult. The firm expanded its research staff and continued to forge relationships with independent researchers [R&D-proc partnering]. The firm also established a relationship with the government on a joint research project. From the agreement with the government, DD1 received $1 million dollars for the research and access to some government labs and research inputs [R&D-pos govt inputs]. This helped advance the firm's technology, but did not help as much as they hoped it would, largely because the government bureaucracy slowed the research and the government wanted too much ownership of the IP that was yielded from the study. Because of these problems the firm has not looked to enter into other research agreements with the government:

> *The government is too difficult to deal with and wants too much of the IP (intellectual property) from the research. So we are not going to be pursuing partnerships with the government.* (DD1's CEO) [R&D-pa govt partners]

DD1 formed another important partnership with the University of Mississippi Medical Centre in the fifth year [R&D-pa univ partners]. It emanated from a relationship with one of the firm's private investors, a physician there. The physician lobbied the chancellor to enter into a joint research agreement with DD1. The agreement established a relationship whereby the university got access to DD1's technology in exchange for research services [R&D CCA]. This proved vital to DD1's development as the research inputs from the university greatly helped the firm advance their diagnostic device [R&D-pos Uni inputs]. The fact that the firm received the inputs from the university at almost no cost was particularly beneficial as the firm was in a very tight cash flow situation. This relationship, along with inputs from the firm's scientists, greatly helped progress the firm's device in years seven and eight.

These advancements helped the firm in year eight to raise an additional $10 million through a combination of an additional stock offering and private investment. This investment proved vital, as the firm needed it to navigate their device through FDA approval [Fin-pa costly innovation]. Moreover, all of this transpired in the midst of the economic downturn of 2008 when capital became in short supply.

> *The capital markets dried up. The VCs pulled out and nobody wanted to invest in early stage biotech firms. So we were lucky to get the capital to keep us afloat.* (DD1's CEO) [Fin-pa VC]

The firm successfully navigated FDA approval and received clearance for their device in 2010 [R&D-pa govt approval]. This was a long and strenuous process, but the firm successfully leveraged its scientific capabilities and strategic partnerships to get over this hurdle. In 2010 the firm also received full clearance on five patents. The firm just started marketing its device in 2010 and is hoping that revenues will pick up so that it can start to refocus on the drug development path that it set out to pursue. These scientific capabilities to progress the core technology and navigate the patenting processes proved instrumental in the firm's early development [R&D SCA].

Although the firm is generating less than $1 million in revenues, it has still enjoyed growth since its inception in 2010. The growth is seen in its five domestic and thirty international patents; a fully developed device with FDA approval; staff of eighteen employees and a relationship with a major university and its network of independent researchers. From a financial perspective its growth is most evident from the $28 million that the firm raised from 2000 to 2010.

6.2.2 Drug development firm two (DD2)

DD2 is a small drug development firm that is pursuing a platform technology for the prevention and treatment of disease. Their technology is based on toxins from snake venom. The firm was founded in 2001 by a scientist to pursue the development of a technology that was being developed by a firm that went bankrupt. As of 2010, DD2 employed eleven people and was generating less than $1 million in revenues. In 2009 the firm just started marketing its first product, and it anticipates revenues to jump substantially. Moreover, it has several applications that will be ready in 2010 and 2011.

The core technology that the firm is pursuing has provided the central path for the firm's R&D and its overall strategic direction. To date almost all of DD2's resources have been dedicated to this technology.

This technology has been in development since the late 1980's. Two other firms developed and worked on it, but both of these ceased operations, largely due to mismanagement. Both had scientists leading them who were not doing a good job from a business perspective. As the CEO put it,

> *DD2 came about primarily as a motivation from a failure of a predecessor company to that one. Our interpretation, or my interpretation, the motivator behind the whole thing really was that a lot of what was previously done, failed more due to bad management than to a poor product. And frankly I thought that they'd do a better job.* (DD2's founder and CEO) [R&D –pa core tech]

The founder of DD2 worked for the second firm that advanced the technology. He was the lead researcher on the project, and from a scientific standpoint, he saw that the technology

had considerable potential [R&D-pa core tech]. For this reason he decided to create a firm to pick up where the last firm left off. In order to capitalise the firm, the CEO used a relationship he had with a VC that had invested in the predecessor firm [Fin-po founder]. He had worked closely with the VC, and the VC felt that he could revive the technology. Without this relationship with the VC, DD2 might not have ever gotten started:

> *I had a contact with a New York group who were willing to look at financing the initial phase of the company. That clearly is one of the biggest breaks that we needed. If I did not have this contact, then we would not have got going. Just trying to figure out how you're going to launch this thing and start the revenue generation part of it, or at least attracting the investment because very rarely do you get revenue depending on the type of product. Thus, this prior relationship proved as an important position to obtaining the capital needed to get the firm started.* (DD2's founder and CEO) [Fin-po founder; Fin-pa VC]

Once DD2 was started, the main challenge was reviving the technology and the research. The research sat dormant for a few years, and DD2 needed to revive what had been done and construct a strategy for their R&D. The founder provided the main scientific position to accomplishing this:

> *So it came from experience. I didn't jump into it blind. I was very well aware of the history, I was very aware of the potential asset of the potential product to be developed.* (DD2's founder and CEO) [R&D-po founder]

This scientist is widely considered one of the main snake venom experts in the world, and he was able to use his knowledge to jump start the firm's research [R&D-po star scientist]. To help him the firm hired three other highly trained scientists who helped with this task [R&D-po scientist]. Their routines revolved around their vast scientific experience. Put differently, the scientists possessed tacit routines on strategizing and executing research. This allowed the firm to make several steps toward proving the efficacy of their drug technology. However, they burned through a greater amount of capital than expected and within two years had to attract another $1 million investment [Fin-pa core tech].

For this round of investment the firm leveraged the background of the founder and the firm's technological progressions to obtain the needed capital [Fin-po core tech; Fin-po

founder]. This capital allowed the firm to continue its technological development, which drove the need to establish a partner for specialised testing. More specifically, the firm required specialised research equipment and capabilities [R&D SCA]. The firm's founder's relationships provided access to the university facilities; from his previous dealings with the universities he was able to swiftly forge agreements for testing DD2's drugs [R&D-po uni inputs]. Moreover, the firm also established research relationships through activity in the scholarly community. Through scientific journals they were able to locate several other researchers looking at snake venom. The researchers agreed to work with DD1 because of the firm's unique technology and the fact that this technology had been backed by independent tests. In the third year of operations a high profile scientist became a director for the firm. He is associated with several top universities and is highly experienced in the field. His inputs have opened access to the wider scientific community and have helped the firm establish important research links; including links with research partners in Europe and China. These inputs have already helped in the firm's growth by providing science that has helped progress DD2's technology, but more importantly, they have opened up future research paths and market opportunities.

Its progress and the new director's networks allowed the firm to forge a relationship with a partner firm in the field [R&D-pa industry partner]. The partner firm was developing similar technologies that complemented DD2's research. DD2 formed a relationship with the firm to share resources and technologies. Capital is a particularly important resource that DD2 received from the partnership. In the fourth year of operations the partner firm infused around $2 million, which kept DD2 viable. At the time, capital was hard to obtain in South Florida where the firm is based because of the tight venture capital markets:

> *Florida has a huge potential for biotech, the financial support isn't there. And so all these universities have great science, but because there's no mechanism to allow for funding to allow companies to take out the technologies and see if they can commercialise these innovations, it's made raising capital difficult for us.* (DD2's founder and CEO) [Fin-pa VC]

The cash infusion also provided the capital to sanction the firm's first clinical trial in the UK. DD2 made a conscious effort not to first apply for FDA approval because of the costs, time and bureaucracy involved [R&D-pa govt approvals]. The CEO drove this decision as he has extensive experience in navigating government drug approval:

> *He has worked and negotiated with drug regulatory agencies in the US, Canada, EU, South America, South Africa, and China, enabling companies to move ahead, save millions on research and testing in clinical trials, and gain IND approvals.* (Chairman of DD2) [R&D-po founder]

Based on his experience he felt the UK would be the best place to start clinical trials because of their favourable testing procedures for drug applications such as theirs. Furthermore, the founder held important relationships in the UK that helped facilitate testing procedures; he is Irish and received his PhD from the Imperial College in the UK. His background and relationships helped navigate the clinical trials in the UK [R&D-po founder].

The clinical trials helped the firm raise an additional $500,000 from private investors [Fin-po scientific cap]. The firm used this capital to further develop and test their drug for HIV and multiple sclerosis applications. These tests revealed that the firm's applications for these diseases are effective and inexpensive treatments for these diseases. This provided validation to the firm's research, which the firm built on in the sixth year when they clinically proved their drug's effectiveness for analgesic applications. These applications spurred more interest in the firm and allowed it to continually develop important research relationships. Amongst these relationships were several with elite universities and labs. The breakthroughs created interest from other firms as well. Most notably, this interest led to a merger in the eighth year of DD2's existence [R&D-pa industry partner].

Although the firms merged they still operated autonomously. However, the two firms share some important resources like scientific assets; the firms have access to one another's scientists, facilities and networks [R&D CCA]. Shared financial resources are even more important, and the partner firm is the one that handles most of the financial matters for DD2. This merger has provided the important resources that DD2 needed in order to continue its research [Fin CCA]. However, raising capital still remains important to DD2.

The increased R&D and financial resources allowed DD2 to expand its clinical development. In late 2009 the firm introduced an over the counter pain medication. Even though the firm had a more potent version of the drug that could realise higher profit, the firm chose to pursue this version because approval is much more streamlined and

inexpensive for over-the-counter drugs [R&D-pa govt approval]. Its approval is significant because it marked the beginning of commercialisation for the firm. Another milestone in year nine came in the form of one its major patent approvals [R&D-pa govt approval]. This patent protects one of the main applications that the firm had worked on for over eight years. In year ten the firm received another important patent approval. These are major milestones because they give the firm more leeway in how they can license and distribute their drugs.

These milestones are building blocks to the firm's future. It is anticipating rapid growth over the next five years. They have proven their technology and have market-ready applications and a network of partnerships and financial resources to back the firm's future growth. In the first ten years the firm's growth is evidenced in its two key patents; full FDA approval for two drugs and UK approval for one drug; network of partnerships and the $5 million in outside investment capital that the firm has received.

6.2.3 DDs cross-group analysis

The narratives above provide a contextual basis for the evolution of the DD1 and DD2's R&D and financial resources and capabilities. This section delves deeper into the key paths, positions and processes that led to the development of the firms' R&D and financial resources and capabilities. It analyses and compares the paths, positions and processes that led to each firm's R&D resources and capabilities. A similar approach has been taken to explore the financial assets and capabilities developed in the early stages of growth.

6.2.4 R&D resources and capabilities development

In the early stages of growth both firms focused on the development of their technology, the impetus of developing R&D resources and capabilities for both firms. This section highlights the paths, positions and processes central to the development of the firms' R&D resources and capabilities; the paths are the past decisions and actions, and the future opportunities that influenced the firms' strategic pursuits; the positions are the resources that the firms leveraged in their development; and the processes are the routines that the firms used to leverage their positions in order to take advantage of their paths (Teece, 2007; Winter, 2003). Table 6-2 presents the matrices of the paths, positions and processes that were yielded from the data reduction techniques discussed in the research methods

chapter, and this collates with the text code table presented at the beginning of the present chapter. Based on the analysis of the interviews and the close-ended questions, each path, position and process for each firm is placed in one of four categories based on its influence on the firm's development: high (H), medium (M), low (L) or no (N) influence. The major paths, positions and processes are discussed in detail below.

Table 6-2: DDs' R&D paths, positions and processes

	D1	D2
INFLUENTIAL ON FIRMS' PATHS		
Core technology conceptualised at a university	N	N
Core technology conceptualised at another firm	H	N
Core technology conceived by the firm	L	H
Government partnerships	L	L
Industry partnerships	M	L
New technologies influenced firm's direction	H	M
Government approvals: e.g. patent or FDA	H	H
Scientific developments	H	H
IMPORTANT POSITIONS		
Patents	L	H
Skilled scientists	H	H
Star scientists	H	H
Industry partnerships	L	H
University partnerships	L	L
Government partnerships	L	L
R&D facility and research equipment	L	L
Core technology	H	M
KEY PROCESSES		
Sensing and seizing scientific opportunities	H	H
Finding and developing research partnerships	M	L
Navigating government approval	H	M
Filing patents	M	H
Learning from earlier research	H	H
Transforming R&D	H	M

Source: Author

Paths

Several paths influenced the strategic R&D pursuits of the firms. Table 6-3 presents evidence depicting the importance past decisions and future opportunities that dictated the development of DD1 and DD2's R&D resources and capabilities has had.

The most prominent path for the firms emanated from their core technologies. Table 6-3 (1-6) below provides sample evidence depicting this and also depicting that both firm's strategic direction was firmly established by the technology that the firms set out to develop and commercialise [R&D-pa core tech]. DD2's technology was initially discovered and developed at other organisations, and the efforts of those organisations set the research path for the firm (Table 6-32; 1, 2 and 5). The early stage technologies that DD1 conceived and incubated set the central path for the firm's R&D, but unlike DD2, the firm's technology was totally new. The technologies impacted the R&D resources and

capabilities needed [R&D-pa core tech]. However, R&D proved vital for both firms, but the exact combination of resources and capabilities required differed. DD2's technology moved the firm to primarily focus on developing specialised testing resources. In comparison, DD1's path dictated that the firm develop R&D resources for creating a technology. Simply put, the technologies that the firms pursued set their strategic directions and dictated the R&D resources needed for growth.

Future research opportunities also greatly influenced the R&D paths of the firms. Table 6-3 (7-9) presents a representative sample of the evidence supporting this. Opportunities to develop new applications motivated the firms to develop the research capabilities that were needed to develop these applications [R&D-pa new tech]. An opportunity to develop a diagnostic device changed the strategic path of DD1 (Table 6-3; 7) [R&D-pa scientific dev]. The firm needed to find a product that could quickly be brought to market, and an application using their technology for a diagnostic device presented an opportunity for this. Thus, in the fifth year of the firm's operations it changed R&D paths to focus on this device. DD1 almost completely stopped working on drug applications and devoted all of its resources to this product. In year eight several progressions related to the firm's diagnostic device brought them to FDA clearance [R&D-pa govt approval]. This clearance allowed the firm to start marketing their device and allowed them to refocus their resources on their original path of developing drug applications.

Similarly, DD2 pursued the development of four new applications for their drug technology [R&D-pa scientific dev]. These new drugs greatly affected the firm's R&D paths: the firm developed research resources and capabilities to test and commercialise these drugs. Moreover, motivated by the need to quickly generate revenues, DD2 pursued the development of an over the counter drug in year eight of their existence (Table 6-3; 8 and 9). The firm pursued development of this drug because of how quickly an over the counter drug could be brought to market [R&D-pa govt approvals]. This new path stemmed largely from the need to show investors the firm could produce a drug that could generate revenues. This made DD2 devote a significant amount of revenues to this project. Several of their other research projects on their other drugs were slowed or halted so that they could focus on the over the counter drug.

Gaining government approval (FDA or other government clearance) has also greatly influenced the paths of the firms' research (Table 6-3; 10-15) [R&D-pa govt approvals].

Initially both firms pursued drug applications that required high level government approval. This forced the firms to devote significant resources to pursuing it. DD1 invested over $250,000 in a joint research project with the FDA to try to streamline the approval process of their main drug application. The results were less than desirable and indicated that the drug would take more time and capital to bring to market than originally anticipated. The fact that a diagnostic device could more readily be brought through FDA approval triggered the firm to refocus their R&D on applying their technology to developing a device (Table 6-3; 7) [R&D-pa govt approval]. Although the device required a less rigorous FDA process, the firm still devoted several million dollars towards getting the device through FDA approval.

Government approvals have also had a major impact on DD2's R&D paths, as the firm has put several drugs through government testing (Table 6-3; 13-15) [R&D-pa govt approvals]. Interestingly, government approvals have motivated the firms down an internationalisation path. In order to save on costs and streamline the approval process, DD2 went for their first major approval in the UK because of their more efficient approval processes for drugs like DD2's. The firm has also put three drugs up for FDA approval in the US, which has greatly influenced the strategic direction of the firm. This forced the firm to devote a significant portion of its R&D resources to FDA-related functions. It has also made the firm develop routines for meeting FDA processes. There are dozens of processes that the firm has to follow in order to stay in compliance with FDA approval.

Path rigidities have also resulted from the substantial resources invested in government approvals (Table 6-3; 10-13). Both firms committed a substantial amount of their resources to FDA approval, which limited the investment that they could make in other areas related to their technology. The commitment to government approvals made success in these endeavours paramount. DD2 enjoyed success in their approvals, but the resources the processes consumed also restrained the firm from making investments in other areas of R&D that they would have liked to have pursued. DD1, on the other hand, had some major FDA setbacks that forced the firm to reconfigure its R&D to focus on the development of a device instead of the drug it originally set out to pursue.

Government approval also presented opportunities for both firms. Major milestones in the approval process helped the firms attract additional capital and resources needed for their technology. It also helped the firms develop several key relationships. For example, DD1

entered into an important research collaboration with a university medical centre that was largely facilitated because of FDA milestones [R&D-pa uni partners]. Similarly, DD2 entered into a strong partnership with another firm within the industry [R&D-pa industry paths]. These relationships proved influential on the firms' R&D paths.

Table 6-3: DDs' R&D paths

FIRM		
		The core technology drove R&D demands of the firms.
DD1	1.	*The technology set the stage for the firm. It drove all of our basic functions. Our R&D and entire company revolves around it.* (DD1's CEO)
	2.	*The technology has been everything to us. All of our functions revolve around it and we wouldn't be here without it.* (DD1's CEO)
	3.	One hundred per cent of the $28 million invested in the firm went directly or indirectly to developing the firm's core technology. (Close- ended question; analysis of firm's financial statements)
DD2	*4.*	*DD2 came about primarily as a motivation from a failure of a predecessor company to that one. Our interpretation, or my interpretation, the motivator behind the whole thing really was that a lot of what was previously done failed more due to bad management than to a poor product. And frankly I thought that they'd do a better job.* (DD2's founder and CEO)
	5.	*So we tried to revive the innovative property, that's perceived to be the asset to the company.* (DD2's founder and CEO)
	6.	Ninety per cent plus all of DD2's capital expenditures in the first nine years went to developing their core technologies. (Close-ended question; analysis of firm's financial statements)
		New scientific opportunities impacted the strategic direction of R&D.
DD1	*7.*	*The cumbersome approval procedure is one of the main reasons that we decided to re-strategize on developing a device. We hated to shelf the drugs, but we needed to get a product to market, and we found that our technology could get approved much quicker and cheaper through a diagnostic device.* (DD1's CEO)
DD2	8.	*We re-focused on an over the counter drug because these could more readily be brought to market.* (Close-ended question; analysis of firm's financial statements)
	9.	*Marketing not only generates revenue, but it also helps to give us credibility. For this reason we decided to refocus for a short tem attention on developing an OTC drug.* (DD2's founder and CEO)
		FDA and government approvals have impacted the strategic direction of R&D
DD1	*10.*	*We have put a lot into FDA and have had to make our products work because of this tremendous investment.* (DD1's CEO)
	11.	*When you're a small firm, and you commit $10 million to FDA, you have to make sure that it works.* (DD1's CEO)
	12.	In the first nine years the firm has invested over $4 million in FDA related matters. (Analysis of financial statements)
DD2	*13.*	*FDA approval is costly, lengthy and consumes the firm. (DD2's Chairman)*
	14.	*We were familiar with the UK and knew that this process would be more streamlined and more efficient.* (DD2's founder and CEO)
	15.	*That (UK approval) was a major success from that perspective to kind of get on the board with regard to demonstrating that our products are worthy of administration. A certain level of credibility is garnered from this. It is helpful in developing relationships and looking good to investors.* (DD2's founder and CEO)

Source: Author

Positions

The firms leveraged several positions in their strategic R&D pursuits. Table 6-4 presents sample evidence supporting the most important resources that the firms leveraged in the development of their R&D.

The most ubiquitous resource for both firms was their core technology [R&D-po core tech]. Table 6-4 (1-5) depicts a representative sample of evidence that underscores the importance of the firms' technologies to the firms R&D. Both firms leveraged their technology to help them attract important inputs. Capital proved to be one of the most important assets that the core technology helped the firms attract [R&D and fin co-specialisation]. The firms' core technologies have also allowed them to attract research partners that have been vital to progress their technologies [R&D-po core tech].

DD1's technology complements research related to many areas of cardiac disease, and this has been a resource that has allowed the firm to enter into many different mutually beneficial partnerships with independent researchers who gained access to inputs that help in their studies. DD1 benefited from important independent testing that helped progress their technology (Table 6-4; 1) [R&D CCA]. DD1's technology also allowed them to enter into a partnership with a large university that was interested in gaining access to DD1's science (Table 6-4; 2) [R&D CCA].

Quite similarly, DD2's technology is a resource that has helped the firm attract inputs from a number of universities and independent researchers (Table 5-2; quotes 3, 4 and 5) [R&D-pos core tech]. Many of these relationships were facilitated through scholarly journals and conferences. The researchers were motivated to work with DD2 largely because their technology had been verified in the scientific journals. Moreover, it also provided the impetus to the firm's most important partnership; a firm that they later merged with in year 7. DD2's R&D resources and capabilities complemented the partner firm's research [R&D CCAs] and thus was the motivating factor to the partnership, which has provided invaluable inputs that have helped the firm to grow and develop.

A second position that has been vital to the firm's development is their scientific staff. DD1's staff is made up of five scientists of whom three are PhDs. These scientists have made consistent contributions that have helped advance the firm's technologies (Table 6-4; 6) [R&D pos scientists]. The founders' provided particularly important early resources to

the firm's R&D. They are the ones who conceptualised the technology and developed the drug prototype [R&D-pos founder]. All three of the founders have had substantial success as scientists. One of the founder's publication records put him in the top five per cent of all research scientists, and the other two hold multiple patents for innovations that have gone on to great commercial success.

The founders' designed the firm's research and hired the scientific staff from whom for the first two years most of the firm's inputs came (Table 6-4; 7). The firm's scientific board, which is also made up of several noted scientists, has also helped the firm progress its core technology.

In a slightly different vein, DD2's R&D revolved around the founder who is a star scientist (Table 6-4: 8 and 9) [R&D-pos star scientist; R&D-pos founder]. The founder is the one who came up with the main progressions for the firm's technologies. He is well-published, holds six patents and is recognised as one of the leading experts on snake venom. His knowledge and talents provided vital resources that contributed significantly to the firm's innovations. DD2 also had a small team of scientists who helped the CEO on the technology, and their contributions were important [R&D-pos scientists] but were not specialised in the sense that they could not have been performed by other trained scientists.

Another important resource for DD2's is their specialised research facility. DD2's lead scientists designed and fitted a facility specific to their operations [R&D-pos facilities]. It is highly advanced and customised for their research purposes. Although research facilities are important to DD1, they are not highly specialised since the building and equipment were readily available on the free market. Some of the testing equipment for DD1 required some customisation, but this only constituted one small part of the research facility. Put differently, a specialised R&D facility has been an essential resource to DD2, but such a facility has not been essential to DD1.

Table 6-4: DDs' R&D positions

FIRM		**The firm's core technology helped attract and develop other resources.**
DD1	1.	*We were able to develop a following of independent researchers because they were interested in our technology. This was crucial as they made contributions to our product that did not cost us anything. Having these free researchers was important to the firm's development.* (DD1's CEO)
	2.	*The medical college was interested in being a part of what we are trying to do. They saw that our technology could help some of their research projects.* (DD1's CEO)
DD2	*3.*	*This discovery is significant to our continued research and development, as it identifies the mechanism of action for RPI-78M. We believe that our drug is the first to induce the expression of IL-27, which represents a novel way to approach the treatment of several autoimmune diseases. This makes it of interest to a wide variety of firms and organisations.* (DD2's founder and CEO)
	4.	*The biotechnology research and development field is extremely competitive and is characterized by rapid change. Our competitors have substantially greater financial, scientific, and human resources, and as a result, greater research and product development capabilities. Our competitors have competitive advantages with greater potential to develop revenue streams. Our competitors are located in the United States as well as around the world. We attempt to compete by establishing strategic partners or alliances with pharmaceutical companies, academic institutions, biotechnology companies and clinical diagnostic laboratories which will enter into joint ventures, emphasizing our drugs' superior properties*. (DD2 Chairman)
	5.	A 2007 article discussing the importance of DD1's technology to entering into an important partnership with a Chinese biotech firm: *DD2's technology shows great promise to helping the 1.3 million people living with tuberculosis*. (November 23, 2005 Business Wire)
		The scientists provided important inputs to the firms' R&D.
DD1	*6.*	*Our scientists have continually made progressions that have moved the technology along. The staff had not made any ground-breaking findings, but they have consistently moved things along.* (DD1's CEO)
	7.	*The founders were the ones that came up with the breakthroughs. Their novel ideas is what got the research going and what we have based all of our products on. One founder in particular had worked in a number of fields and used his knowledge and capabilities to bring together all of the science needed to develop our platform.* (DD1's CEO)
DD2	8.	*We have a small firm here and I guess without me it would never have happened. I've been more of the driving force on directing the R&D projects.* (DD2's founder and CEO)
	9.	*By leveraging his comprehensive understanding of regulatory requirements, he has guided us on new projects through the correct protocols at a minimum budget, advancing products, positioning for licensing, and setting up manufacturing. The application of his knowledge of laboratory practices to select new technologies that enhance production, quality control, and product formats.* (DD2's Chairman)

Source: Author

Processes

The firms relied heavily on processes related to identifying and integrating scientific innovations and techniques. Table 6-5 (1-5) presents a representative sample of evidence that underscores the importance of sensing, filtering and integrating processes.

Both firms' founders had vast experience in identifying and evaluating scientific technologies for DD1 and DD2 [R&D-proc S&S]. These processes were held uniquely within the founder's own scientific and conceptual knowledge and could not be replicated (Table 6-5; 3 and 4) [R&D-pos founder]. They could not explain how they are able to evaluate technologies other than that it is intuitive based on their years of experience in evaluating them.

As the firms developed, sensing complementary technologies also became important. The firms created processes for finding scientific inputs for their R&D. For example, DD1 developed routines for identifying potential researchers working on complementary research [R&D-proc S&S]. These routines revolved around scouring journals to look for researchers working in similar areas. Once a researcher was located, the firm then contacted the researcher(s) about the prospect of joint research projects. This yielded over fifty relationships that led to important contributions to DD1's technology. Moreover, this routine helped the firm conserve capital as the firm had received important inputs, but it also had minimal related expenses.

Learning processes from their daily operations also helped advance the firm's R&D (Table 6-5; 6-8) [R&D-proc learning]. Every day they moved their technology forward based on what they had previously accomplished. Both firms have systems for tracking their progress, but these are relatively common [R&D-proc leaning]. More than anything the firms' learning was held within their scientific staff whose knowledge and insight came from their previous experience (Table 6-5; 6 and 7) [R&D-pos scientists].

Another area where learning routines proved important to the two firms was with government approval [R&D-proc govt approval]. Both firms learned how to better prepare themselves for dealing with FDA. DD1 learned from its major FDA setback that drugs are expensive and time consuming to clear through FDA approval. Similarly, DD2 learned from their early FDA dealings that this process takes a long time and the FDA approval decision can be erratic. For this reason for some of their future drugs the firm pursued

approval with other countries first. The other countries, such as the UK, have a more streamlined and predictable approval processes.

Both firms also learned from their experience with the patent process that it takes longer to pursue than they had originally intended. DD1's core patents took over nine years to execute, whilst two of DD2's most important patents took over eight years to execute [R&D-proc govt approval]. Moreover, the firms learned that upholding patents is also difficult. For this reason both firms made future strategic choices to pursue applications that did not completely depend on patents.

Transformation related processes have also been important to both firms (Table 6-5; 9-12) [R&D-proc transform]. In the fourth year of existence DD1 realised that because of changing conditions in the pharmaceutical industry, they would not be able to progress their drug applications to market (Table 5-3; 9). The FDA had changed its approval procedures and the firm's drugs were taking longer than originally expected to develop. This triggered DD1 to reconfigure its R&D resources to focus on the development of a diagnostic device that could more readily be passed through FDA approval [R&D-proc govt approval]. At that point they also they also had to focus more on new R&D routines and partnerships.

In a similar vein, DD2 came to a point where it needed a new drug that could be brought to market quickly, and used its transformational routines to reconfigure its R&D to focus on the development of an over the counter drug (Table 6-5; 10 and 11) [R&D-proc transform]. Several of its projects were stopped and those resources were then devoted to the new drug. Transformational routines proved highly beneficial to both firms, as these reconfigurations led to marketable products that kept both firms viable. These products allowed the firms to generate revenue and, more importantly, showed their ability to develop a marketable product, which helped attract more investment capital and other resources.

Table 6-5: DDs' R&D processes

FIRM		Identifying and sensing technologies
DD1	1.	*At the beginning we had to pull together a number of science to try to make our idea work. Finding the technologies was vital to making this happen. One of our founders had experience in several areas and was important to bringing everything together.* (DD1's CEO)
	2.	*Finding the technology comes from years of experience. There is no formula or set way of looking at a technology. You look at some objective things, but in an infant science the judgement comes from experience.* (DD1's CEO)
	3.	*Finding science is important. We have routines in place to find research that can help us. One of the most important sources of this is the independent researchers that we reach out to.* (DD1's CEO)
DD2	*4.*	*It was up to me to collect all these assets together and form a plan to develop products using the resources we had and finding what we needed – all in an expeditious way of getting to market revenues.* (DD2's founder and CEO)
	5.	*The firm has entered into dozens of partnerships with organisations with offerings that could help us. We have systems of searching within the community and finding these people.* (DD2's founder and CEO)
		Learning routines have helped advance the firms R&D
DD1	*6.*	*Our scientists have routines for sharing information. It is hard to pinpoint them. I mean we have standard reporting and all, but it is the scientists who just know how to take and look at their work and figure out what to do with it. This is where the learning happens.* (DD1's CEO)
DD2	7.	*The systems we have in place for learning come from the fact that we're all experienced researchers, you know PhD's, advanced degrees, so it's just experienced research*. (DD2's founder and CEO)
	8.	*Our learning relies heavily on the existing data for the direction and determined the pathway for what type of R&D we still needed to do in order to move forward.* (DD2's founder and CEO)
		Transforming R&D has proved vital to the firms' growth and survival
DD1	*9.*	*In year four we saw that FDA approval was getting more difficult and that our drug was not progressing as well as we had hoped. This prompted us to focus on the development of a diagnostic device.* (DD1's CEO)
	10.	*We had to change direction. To stay above water we changed to a diagnostic firm. We had the resources in place, but they had to change things around.* (DD1's CEO)
DD2	11.	*So effectively operations were fairly low key, low numbers of staff until 2009 when effectively we existed for the best part of eight years just researching before we really started to get any traction. And the only way we started to get traction was to develop a product that was on the market*. (DD2's founder and CEO)
	12.	The 2009 quarter fourth report for the SEC has an entire section dedicated to the importance of the over the counter drug market and the fact that the firm dedicated a substantial amount of its resources to this effort. (Q4 2009 SEC 10k Report)

Source: Author

6.2.5 Financial assets and capabilities

The firms' R&D demanded significant capital to get their products to a point of commercialisation. For the most part, generic financing was not available. For this reason, the firms turned to specialised investment sources for the needed capital, which required the firms to leverage a unique set of paths, positions and processes to obtain the needed capital. This section highlights the paths, positions and processes central to the development of the firms' financial assets and capabilities. Based on the coding and close-ended questions, each path, position and processes for each firm is placed in one of four categories based on its influence on the firm's development: high influence (H), medium influence (M), low influence (L) or no influence (N). The analysis for the major paths, positions and processes is detailed below.

Table 6-6: DDs' financial paths

	D1	D2
INFLUENTIAL ON FINANCIAL PATHS		
Costly innovation	H	H
Raising capital	H	H
Public stock offering	H	M
VC	L	L
POSITIONS		
Scientific capabilities	H	H
Founders with strong industry background	H	H
Executive staff	H	L
Core innovation	H	H
Firm's staff	L	L
PROCCESSES RELATED TO		
Raising capital	H	H
Integrating financial resources	H	H
Dealing with Investors	H	M
IPO	H	M
Transforming financial resources and operations	H	M

Source: Author

Paths

Table 6-7 highlights the paths important to the development of the firms' financial assets and capabilities. There were several past decisions and future opportunities that impacted the strategic pursuits of the firms.

In general, the largest influence on the firms' financial paths was their technology. The impetus for developing financial assets for the firms stemmed from the high cost of developing a novel drug technology, which is supported by the representative evidence in Table 6-7 (1-7) [Fin-pa costly innovation]. DD1 and DD2 required substantial investment during the conceptualisation phase. Most of this investment focused on R&D. Over time

developing a platform technology proved quite costly as DD2 spent over $25 million on the development of their drugs in the first nine years of existence, whilst D3 spent over $5 over that same span. The discrepancy in investment is largely attributed to the fact that DD2's technology was based on an existing drug platform, whilst DD1's was freshly created by the firm.

The only viable early financing path for DD2 was VC. Capital from a VC financed most of the firm's early development. In contrast DD1's seed capital came from a small group of angel investors. This angel investment exhausted quickly as the drug technology proved expensive to develop. The firm looked at VC but could not raise capital there because of the changing VC funding model (Table 6-7: 3).This triggered the firm to go down an alternative path to securing capital. At this point the firm implemented elaborate mechanisms for raising funds from physicians familiar with their cardiac technology.

For DD1 and DD2 raising capital through public stock offerings was also an important path in the firms' development. However, the two firms' paths to an IPO were markedly different. DD1's CEO took the company public on a small public stock exchange through a reverse merger where the firm took over another public firm that had gone bankrupt, essentially just taking over their stock ticker. By taking over another firm, DD1 expedited the public offering process; most notably, it allowed the firm to avoid many of the filings that are required for public offerings. This proved successful as it allowed the firm to quickly list on a public exchange and raise over $20 million in capital over a five year period. In contrast, DD2 merged with another firm that already held a public stock ticker. This merger was largely motivated by the access to public funding that would result from the merger. The merger provided access to over $3 million in funds in the two years from the date of the merger.

For DD1 the public offering path did have a downside in that it consumed and continues to consume a tremendous amount of the key executives' time (Table 6-7; 9). The TMT spends hours filing reports, dealing with investors and dealing with regulatory procedures. This is time that could be devoted to more productive means. In contrast, DD2 does not have to deal with these processes. This is primarily because the firm DD2 merged with handles most of these dealings. Moreover, the merger has freed up DD2's executives by taking care of most of the financial issues. This has allowed DD2 to focus on the scientific end of the business.

Table 6-7: DDs' financial paths

IRM		**The core technology drove the strategic direction of the firm.**
DD1	1.	*The technology has cost millions to develop. We knew it was going to be expensive, but in this business you never know exactly what it is going to cost you. In the last nine years we have spent well over $25 million on it.* (DD1's CEO)
	2.	*Even with the low cost inputs we have received from partners, this has been an expensive ordeal. Here we are almost ten years later and raising capital to develop the technology remains the main issue that we have to deal with.* (DD1's CEO)
	3.	*Venture capitalised would not look at us. The model has changed and they no longer look at early stage companies. They want all of the return without any of the risk. Venture capital is not what it used to be.* (DD1's CEO)
	4.	On hundred per cent of the $28 million invested in the firm went directly or indirectly to developing its core technology. (Close-ended question; analysis of firm's financial statements)
DD2	*5.*	*Just trying to figure out how you're going to launch this thing and start the revenue generation part of it, or at least attracting the investment because very rarely do you get revenue depending on the type of product.* (DD2's founder and CEO)
	6.	*It's not cheap to apply for patents to protect your technology, and it is an important and costly step to undertake, especially when you go international*. (DD2's founder and CEO)
	7.	*Ninety per cent plus all of DD2's capital expenditures in the first nine years went to developing their core technologies.* (Close-ended question; analysis of firm's financial statements)
		IPOs have influenced the direction of the firms.
DD1	*8.*	*Because of the dry VC markets we had to go public. The VCs wanted to come along too late in the company's development and still wanted too much equity. This made the public markets an important option for us.* (DD1's CEO)
	9.	*I have to spend a lot of timing dealing with the stockholders and issues related to that, but we needed to go public to get the capital. If I had my choice, I would rather get the capital from other places so that I could avoid all of those headaches.* (DD1's CEO)
DD2	10.	*We have had to commit resources to going public and it has affected our operations, but it has been a needed source of capital for us.* (DD2's founder and CEO)
	11.	*The hope of (IPO) financing was to meet our near-term budgets and the financial leverage to allow us to become revenue generating and fund the clinical trials of our biotech investment.* (DD2's Chairman)

Source: Author

Positions

The firms leveraged several unique positions to develop their financial endowments. The most ubiquitous position was their superior technology [Fin-core tech]. Table 6-8 (1-4) provides representative evidence illustrating that one of the biggest factors that their investors looked at in their investment decisions was the potential profitability of the firms, and this potential profitability was driven by the firms' technologies.

The founders' and executives' backgrounds supplied another important resource that the firms leveraged in raising capital. Both firms had founders who had successfully started drug development firms in the past, and they used this to entice investors (Table 6-8; 6, 7 and 8). DD1's three founders leveraged their networks to raise the seed capital needed to get the firm started. To do so the firm then relied heavily on the networks and the competencies of the CEO. In comparison, DD2's founder had a previous relationship with a VC that provided the central position that led to the VC funding of DD2. Put differently, had DD2's founder not had this relationship, then there would have been little chance the firm would have been created to pursue the technology (Table 6-8; 9).

Partners also provided important financial resources. As discussed above, DD2 developed a close partnership with a publicly traded firm that resulted in a merger. This merger gave DD2 access to capital and financial capabilities (Table 6-8; 13 and 14). The partner firm has a highly experienced CFO who has taken away much of the financial responsibilities from DD2. This has allowed DD2 to focus on developing their technology. Prior to the merger DD2's CEO, who is the firm's main scientist, devoted a significant amount of his time to financially related matters, which diverted him from time in the lab where he is most valuable. In contrast, DD2 has only directly received cash from the FDA, but partners' organisations have provided research inputs that have saved the firm substantial financial resources (Table 6-8; 11).

Table 6-8: DDs' financial positions

FIRM		
		Core technology proved critical in the development of financial resources.
DD1	1.	*We went out and sold what the potential of our product was. This application has the potential to make a big dent in a multi-billion market.* (DD1's CEO)
	2.	*They have to see that the technology is going to make money. To invest in a risky business, they have to see there is something with big potential.* (DD1's CEO)
DD2	*3.*	*The potential of our science is what the investors are looking at. This is why we have been able to get the money that we have.* (DD2's founder and CEO)
	4.	*The assumption is you're many years away from revenue, you're delayed from revenue. So you're going to be relying on earning cash for the product every five years or longer. So the investors have to believe that his technology is going to take off and that you have the capabilities to get it to market.* (DD2's founder and CEO)
		The founders proved critical to developing the firms' financial assets and capabilities.
DD1	*5.*	*The founders were the main source of capital early on, and on an on-going basis their backgrounds and networks have helped us get more investment.* (DD1's CEO)
	6.	*We (the founders) have been the main reason why the firm has been able to raise $28 million.* (DD1's CEO)
	7.	*I had experience raising capital and knew how to do it. Sure my access to financiers helps, but more importantly I have done it many times in the past.* (DD1's CEO)
DD2	8.	*Management is the key element to get money in. It's best to have a track record, in order to give investors comfort factor. Myself and Rik are highly experienced and have helped with this.* (DD2's founder and CEO)
	9.	*Had I not had the existing relationships with the investors the company may not have been viable; the product may have never gotten off the ground.* (DD2's founder and CEO)
	10.	*The Chairman of the firm has personally invested over $2 million in the firm and has also lent the firm in excess of $2 million.* (10k SEC filing 2010).
		Partner firms contributed important financing.
DD1	*11.*	*We got a million from the FDA that was helpful. It financed one of our key research projects on our drug platform.* (DD1's CEO)
	12.	*Partners have not really contributed much cash, although the partnership with the medical school has provided us with valuable research inputs. It is hard to quantify how much those inputs are worth, but it could be worth millions. For that matter the independent researchers have also provided some valuable inputs that would have cost us a lot to develop.* (DD1's CEO)
DD2	13.	*The merger gave us access to large sums of capital. That has been quite helpful to us*. (DD2's founder and CEO)
	14.	*The firm has entered into five different partnerships that have contributed in access of $3 million towards the firm's research.* (Closed ended question with CEO)

Source: Author

Processes

The firms developed several processes that led to the development of their financial endowments. The first set revolved around prospecting and securing capital. Both firms' paths of developing a platform technology were quite costly [Fin-pa costly innovation]. Table 6-9 (1-4) depicts representative evidence of how the firms developed skills and competencies in prospecting and negotiating for capital. Developing these routines proved critical as the economic downturn of 2008 adversely affected the firms' ability to raise capital.

The shortage of capital also made the firms develop routines for reconfiguring their financial resources to focus on fewer and more immediate projects [Fin-proc trans]. This shortage of capital was one of the main motivators behind DD1 reconfiguring its resources to focus on the development of a diagnostic device. Similarly, DD2 abruptly refocused its research efforts in year seven to focus on the development of an over the counter drug. The firm cut funding to other projects and focused its investment on this [Fin-pa core tech].

A closely related set of processes that the firms developed revolved around integrating and conserving capital (Table 6-9; 6-9) [Fin-proc int]. The firms ran into serious problems early on because of miss-forecasting their budget needs. They received what they anticipated as a sufficient amount of capital, but burned through it quicker than they projected. This made them develop systems for monitoring their cash flows and projected spending. Closely related, the firms religiously practiced routines in cost savings. They operated with as few employees as possible, purchased as little equipment as possible and outsourced many non-essential functions.

Similarly, both firms developed routines for strategically investing their capital in the most appropriate areas. This was particularly difficult early on as the firms were not certain which technological paths they would pursue. Both firms pursued platform technologies that had many potential paths. The experience of founders provided an important position for these firms in this process. These founders possessed knowledge in this area from their experience in start-up life science firms, and they used this to help strategically guide their new firm in investing and budgeting their capital.

Table 6-9: DDs' financial processes

FIRM		**Prospecting for capital has been vital to the firms.**
DD1	1.	*From day one raising capital has been the most important routine. We are constantly seeking more investment from our current investors and seeking new investors.* (DD1's CEO)
	2.	*I am the main fundraiser, but I have a few staff members to help with this. The board also helps with this on occasion. My title is CEO, but it might be more appropriate to call me Chief Fundraising Officer.* (DD1's CEO)
DD2	*3.*	*On an on-going basis has raising capital been important. Raising capital becomes an all-consuming event in a start-up operation.* (DD2's founder and CEO)
	4.	*Our ability to continue into our tenth year of operations relies on our ability to raise capital. Raising capital is vital.* (DD2's Chairman)
		Conserving capital is a vital routine.
DD1	*5.*	*In this business there is only enough cash on hand for a few months. It is important to pick and choose the best place to invest this money. This decision is made off of what has the biggest impact. There is no way to describe how we do this other than it comes from our experience in start-ups.* (DD1's CEO)
	6.	*We had to pick where to invest our money. In a perfect world we could have kept the drug and diagnostic research both going, but because of the limited funds, we have to choose one.* (DD1's CEO)
DD2	7.	*The public markets helped us raise capital to invest in our research. We have had to commit resources to going public, and it has affected our operations, but it has been a needed source of capital for us.* (DD2's founder and CEO)
	8.	*This (IPO) financing provides us with the capital to meet our near-term budgets and the financial leverage to allow us to become revenue generating and fund the clinical trials of our biotech investment.* (DD2's Chairman)

Source: Author

6.2.6 Drug development firms' conclusion

DD1 and DD2 were started to develop and commercialise drug technologies. This path made R&D and financial resources and capabilities paramount during the early phases of growth. The strategic R&D pursuits drove the need for specialised financing: the firms' technologies were costly and time consuming to develop, which caused the firms to sustain years from inception without any revenues. Thus the firms required specialised financial resources and capabilities to acquire investment capital.

In order to pursue the path of developing a novel technology, the firms leveraged their scientific talents and founders' experience. From these the firms created processes to develop the needed financial and R&D resources and capabilities. Generally speaking, the firms relied on sensing, seizing, learning and organising processes to leverage their positions to take advantage of the strategic paths available to them. Although there were distinguished similarities in the development of the firms' R&D and financial resources, there were also numerous differences. The most noticeable difference was the amount of capital obtained and the different IPO paths that the firms went down. D1 raised substantially more capital than D2 did, and D2 went public through a merger, whereas D1 filed for an IPO.

Despite the differences, both firms successfully leveraged a unique set of paths, positions and processes to develop the R&D and financial resources and capabilities needed to navigate the early growth process. Moreover, key individuals were the driving force behind the firm's growth. The founders of DD1 and the CEO are the ones that discovered the technology, raised the needed capital and provided access to networks. Similarly, the founder of DD2 discovered their technology, attracted the early investment, established key relationships and made scientific breakthroughs that advanced the firm's technology.

6.3 Medical device firms (MDs)

This section overviews the development of the medical device firms. This group consists of two firms that are pursuing the development of novel medical devices. In this section a narrative of each case is presented followed by an in-depth cross- group analysis.

6.3.1 Medical device firm one (MD1)

MD1 is a small firm that was founded in 2000. Since then it has developed a device for back and spinal treatment. Their device elongates the spine, which alleviates muscle tension and back pressure, and in many instances, this relieves pressure that otherwise would require invasive surgery. Currently the firm employs a staff of seven and is generating less than $2 million in revenue. In the first six years it focused on the development of the device. In year six the firm started generating revenues.

An idea for a device that allows for greater flexibility in spinal treatment motivated the inception of the firm. The founder had been a practicing physician for many years and had conceived the device whilst working with patients on another device. He noticed that there might be a way to give the patient greater flexibility. From this he sketched out some ideas and started working on a prototype in his basement. After a couple of years he developed a working prototype, which led him to formalise MD1. The initial idea for the device has driven the path of the firm:

> *The idea for the machine is the whole business. This is why we are here* (MD1's founder and chairman) [R&D-pa core tech].

Initially the founder was the only one working on the product's R&D. After he formalised the firm, he then contracted a couple of engineers to help him develop a prototype. The founder provided all of the inputs to the engineers, and they worked with him on designing the device and guiding him on what would be practical [R&D-po founder]. Over a three year period this iterative process yielded two different prototypes. The prototypes functioned and proved more effective than other devices on the market, but the founder still felt the device could be improved. Up until that point the founder worked on the project part time and financed the development out of personal funds [Fin-po founder].

In the third year the founder decided to make a more substantial commitment to the device. Specifically, he decided he needed to dedicate himself full time to this project, hire a full time engineer and lease a production facility. To finance this commitment he liquidated his assets:

> *And here, we liquidated and moved from Florida, I mean, from New York to Florida, partnered with a colleague, hired new engineer, and began new prototype.* (MD1's founder and chairman) [R&D and fin transformation]

He also decided to move the firm's operations to Florida where substantial cost savings could be realised [Fin-pa costly innovation]. Florida had much less expensive facilities available, and contractors in the area were also much less expensive. When he moved to Florida, he re-connected with a former colleague who had also moved there. Eventually he decided to bring the colleague on as a partner. This was a big boost to the company as the new partner is highly experienced in developing devices and has two doctorates: a physician doctorate and a PhD in electrical medical science. The partner brought knowledge in developing the device and also committed financial resources to the firm.

Upon moving to Florida, the priorities for the firm were establishing the R&D facility, hiring an engineer and developing a new prototype. They quickly accomplished these goals, and in the fourth year they developed a new prototype that they pursued FDA approval for.

The firm was not experienced in the FDA approval process, so the founder took it upon himself to navigate it himself [R&D-pos founder]. He quickly became proficient in FDA procedures and successfully filed all of the paperwork and had the testing done for the device. In less than two years the firm traversed the FDA process and gained full approval for the product. What also aided the firm in this is the fact that this is not an invasive device, so the FDA approval is not as long or as entailed as it is for invasive devices.

The FDA approval triggered the firm to start its first production run in year six. They contracted with a manufacturer to build the devices for them. Based on the successful test results of the device, the firm was able to pre-sell ten units. This provided capital to the firm that allowed it to avoid outside financing. Sales quickly expanded in the seventh year, but then when the economic recession hit in year eight, the firm's sales quickly dropped off:

> *In fact, the series tipped after that one, and then in 2008 the economy went boom. Everything fell.* (MD1's founder and chairman)

The sudden decrease in sales adversely affected the firm and forced the owners to open up a medical practice to help subsidise it. As the recession carried on, practitioners were not making large capital investments in devices such as MD1's, which continued to weigh on MD1 as they had substantial overhead to pay for:

> *Doctors suddenly didn't want to spend anything for equipment, unless it was cheap, cheap, cheap, and this was an expensive machine. This stuff is expensive to make and our R&D is expensive to maintain. If you don't sell a certain volume, you can't support this. So we have managed to hold on.* (MD1's founder and chairman) [R&D-pa costly innovation]

In year eight a financial break came from foreign sales [Fin-pa revenues]. The firm had done no overseas marketing, but physicians from outside of the US had learned of the technology and solicited MD1 to purchase devices. In year nine the firm quickly received and filled orders from Asia, the Middle East, Europe and Canada. This forced the firm down an internationalisation path. The firm does not have substantial overseas operations, but they do have to provide training to the overseas customers. The firm either had to fly to the overseas location or they have had to bring in the overseas customers to train them at their Florida headquarters. These sales are helping to finance the firm's continued growth.

MD1 is constantly improving their product and production techniques. Every week they spend time brainstorming on how to make it better by experimenting with new ideas [R&D-proc learning]. Due to these routines, in year nine the firm received ISO 13485 certification, which is extremely difficult to obtain and which is significant because it indicates a high degree of quality for medical devices. Having the certificate itself has been a boost to the firm's marketing efforts.

In year ten the firm leveraged its international sales to help with its domestic operations:

> *But, we feel confident that the international market is going to keep this company going until the domestic market regains its momentum.* (MD1's founder and chairman) [Fin-pa revs]

It is also for the first time actively seeking outside investment. The founder had looked into VC early on in the venture, but could not generate a lot of interest because of the niche

nature of the device. However, now that the device is fully developed and market-proven, they are confident that they will be able to obtain an equity investment of some type. Moreover, the increased activity in international markets is helping to finance the firm, and at the time of the study, the economy had started to pick up and domestic demand had increased.

Although the firm is not generating significant revenues, it has still enjoyed considerable growth. The growth is most evident in an FDA approved and market-tested device. It is also evident in the six patents the firm holds, the eleven employees working at the firm and the many independent tests that have validated their device's efficacy.

6.3.2 Medical device firm two (MD2)

MD2 is a small firm developing a diagnostic technology that tests for infectious diseases. Their technology detects active markers of diseases in infections, and their technologies' main advantage is the ability to identify active infections, unlike the competitions tests, which cannot discern between active and inactive. This is a platform technology, but to this point MD2 has been forced to cut back their scope and focus on the development of one application. The firm was founded in 2003 to further develop and commercialise an innovation that was created at the University of Florida. Currently the firm employs ten staff members and as of 2010 was not generating revenues. However, the firm has just received approval for its first application and will be generating revenues in 2011.

The technologies that the firm licensed have set the strategic direction of the firm.

> *Without these innovations we would we would have no business.* (MD2's CEO) [R&D-pa core tech]

In 2003 the firm's founder came across the patents because of his connection with the University of Florida. In previous dealings he had worked with the university on acquiring technology. He reached a favourable deal for the access to the patents whereby a small upfront fee was paid, and a portion of the future profits would be paid. Although the patents already had shown clinical promise, they were still far from a market-ready state. This created a path that demanded substantial R&D and financial resources and capabilities [R&D-pa core tech].

Raising capital became the firm's first priority. The University of Florida helped them engage with an angel investment network. This resulted in an individual investing $2 million dollars, and the initial capital funded the development of the firm's R&D. Initially the owner and a couple of scientists worked on the chemistry needed to further the technology. They made several progressions that helped the firm raise an additional $4 million in 2008. Even so this capital proved extremely difficult to raise because the capital markets had tightened up due to the recession.

> *I think we began seeing it in late 2006. Certainly through 2007 the capital markets were drying up because you could see bad things were coming, and they would see that based on that part of the business… I think that part of the financial community sees it first. And so from that period of time until literally 2009, it was extremely difficult to get capital.* (MD2's CEO) [Fin-pa VC]

Despite the tight capital markets, the firm successfully raised the amount needed and continued to develop the core technology. The research progress also helped the firm attract additional research partners. In 2008 the firm forged an important international research partnership with the University of Toronto [R&D-po uni]. This partnership was facilitated largely through the scholarly community. MD1 knew of the work the university was conducting because of the great number of papers that they were producing. Similarly, the university had seen some publications related to MD1's technology and was interested in sharing resources [R&D CCA]. This partnership provided important inputs that helped the firm develop the chemistry that they needed for their technological development.

At the same time the firm received important inputs from a star scientist who was consulting for the company [R&D-po star scientist]. He holds over ten patents and is widely regarded as one of the top researchers in the field, and he contributed important findings that helped the firm develop a saliva application for their technology. This breakthrough opened up several opportunities for the firm such as creating an interest in their technology that helped attract research inputs from a number of research institutions. However, the firm needed to develop a complementary device to deliver the new technology. At the time there was not an exact device on the market to satisfy this need. In order to find such a device the CEO, who had previously lived in Scotland, turned to a specialised company he had worked with in Inverness that possessed the capabilities to

develop one. This proved to be a vital partnership as the firm was able to quickly develop the needed device for MD2 [R&D CCA].

The quick advancement of the device triggered the firm to start the government clearance procedures for it. Due to the CEO's previous experiences with the US FDA, the firm decided first to seek approval for their saliva-based device in Europe. The CEO had much better experiences with the EU than he did with the FDA:

> *The FDA is becoming more difficult, less predictable, and actually I think selling is slowing technology down, which is why we're going to be launching in Europe first because of that.* (MD2's CEO) [R&D-pa govt approval]

The advancement of the technology towards a state of commercialisation greatly helped the firm attract an additional $8 million in private equity financing in 2010. Like the earlier rounds of financing, this one proved difficult to obtain. The firm's CEO leveraged the progress in the technology and the networks of the previous investors in order to obtain the capital needed to progress their device. However, the firm would have preferred to raise a much greater amount of capital to progress several applications. Their core technology has many different potential applications in many different areas.

However, the changing capital markets prohibited the firm from raising the capital needed to develop more than one application at a time. Furthermore, the CEO represents the main fundraising capability and is constrained by the amount of time he must devote to dealing with the current investors and other operations of the firm.

Now that the firm is at a point of commercialisation, they are projecting that the revenues from their device will help subsidise the development of other applications. However, raising capital is still a top priority for the firm as they still project to consume substantial sums of capital. The CEO emphasises the importance of raising capital:

> *Raising capital is always important in this business. You are always burning through capital, so it is important to have a continual supply coming in.* (MD2's CEO) [Fin-pa costly innovation]

Although the firm has not started to generate revenues, it has still enjoyed considerable growth. One of its proudest accomplishments is advancing its technology through the economic downturn of 2008. Small firms in this industry were particularly hit hard by the downturn, as they are reliant on VC and other forms of risk capital to develop their technologies. Growth to this point is also evident from the growth of their staff to ten employees, over twenty publications on their research and the development of a strong network of partners.

6.3.3 MDs cross-group analysis

The narratives above provide a contextual basis for the evolution of the firms' R&D and financial resources and capabilities. This section delves deeper into the key paths, positions and processes that led to the development of the firms' R&D and financial resources and capabilities. Following this the financial resources and capabilities development will be presented in the same fashion.

6.3.4 R&D assets and capabilities development

In the early stages of growth both firms focused on the development of their technology. This was the impetus to developing R&D assets. In the same fashion as the last section, Table 6-10 presents the matrices of the paths, positions and processes that were yielded from the data reduction techniques discussed in the research methods chapter. Based on the analysis of the interviews and the close-ended questions concerning each path, position and processes for each firm is placed in one of four categories based on its influence on the firm's development: high (H), medium (M), low (L) or no (N) influence. The major paths, positions and processes are discussed in detail below.

Table 6-10: MDs' R&D paths positions and processes

	MD1	*MD2*
INFLUENTIAL ON FIRMS' PATHS		
Core technology conceptualised at a university	N	H
Core technology conceptualised at another firm	N	N
Core technology conceived by the firm	N	N
Government partnerships	L	L
Industry partnerships	L	M
New technologies influenced firm's direction	H	H
Government approvals: e.g. patent or FDA	H	H
Scientific developments	H	H
IMPORTANT POSITIONS		
Patents	H	M
Skilled scientists	H	H
Star scientists	H	H
Industry partnerships	L	H
University partnerships	L	H
Government partnerships	L	L
R&D facility and research equipment	M	M
KEY PROCESSES		
Sensing and seizing scientific opportunities	H	H
Finding and developing research partnerships	L	M
Navigating government approval	H	H
Filing patents	M	M
Learning from earlier research	H	H

Source: Author

Paths

Three main paths influenced the development of the firms' R&D. Table 6-11 presents evidence depicting the importance of the firms' core technology, government approvals and research setbacks to the development of MD1 and MD2's R&D resources and capabilities.

The firms' technologies dictated their R&D paths (Table 6-11; 1-5) [R&D-pa tech demands]. Although both firms' technologies dictated their strategic paths, the two firms' technologies evolved in different fashions.

MD1's technology was conceptualised and developed by a practicing physician who had no R&D or business experience. The idea for the device emanated whilst treating patients where he had an idea for a more effective back treatment device. Thus MD1 had to come up with the idea from scratch. In contrast, MD2's core innovation was created at a university. This idea had been worked on for several years at there and had reached a point where it became commercially attractive. At this point MD2's founder licensed the rights to it and formed a company to further pursue its development. The relative state of development of the firms' innovations had a bearing on the research paths of the firms.

MD2's more developed technology required testing and refining; whereas, MD1's device required conceptualisation and development.

Although MD1's device needed more development, it still came to market quicker than MD1's device did. MD1 was able to bring their device to market within six years, whilst MD2's took over eight. This is largely attributed to the difference in technology that the two firms pursued. MD1's technology is not an invasive device or chemically based, whereas MD2's device is. Invasive and chemically-based devices take longer to develop and have more government regulation to contend with.

It is evident from these two cases that the technology that a life science venture is created to pursue can come from different sources, but regardless of source, the technology drives the R&D paths of the firm. Furthermore, these cases show that novel technology can have varying development time horizons, even from firms in the same field.

Government approvals had a large bearing on the firm's strategic paths (Table 6-11; 6-11) [R&D-pa govt approvals]. Both firms had to dedicate substantial resources to gaining government approval. MD1's founder was inexperienced, but still led the firm's product through government approval (Table 6-11; 7). In comparison MD2's founder was highly experienced in gaining government approval for medical devices, so he chose to first pursue government approval in Europe (Table 6-11; 9 and 10). The net effect of the of government approvals is that both firms strategized around this and devoted significant resources to it, and it drove MD1 down an internationalisation path.

In a similar fashion, the patent process influenced the R&D paths of the firms [R&D-pa govt approvals]. Both firms applied for and received several patents. For both firms the commitment to patents tied up substantial resources, which created path rigidities. Unfortunately this limited other R&D related activities that they could invest in.

The third major path that influenced the firms' R&D is research setbacks (Table 6-11; 11-13). MD1's first prototype did not perform as well as they would have liked, which forced the firm to significantly increase their R&D efforts (Table 6-11; 11). This triggered the founder of MD1 to sell his physician practice and liquidate his personal finances to invest in MD1's R&D resources so that the firm could build a better prototype. Similarly, MD2

ran into some troubles getting through the patent application process and also had some setbacks in their testing.

These setbacks forced both firms to reorganise their R&D. MD1 cut back on the number of projects they pursued, whilst MD2's setbacks led them to recreating their entire prototype.

The two firms' reorganisation paths were markedly different. MD1 cut back its R&D to conserve resources. In contrast, MD2 expanded its R&D; the firm hired additional staff and leased a larger research facility. Despite the fact that MD1 cut back its R&D spending whilst MD2 increased its R&D spending during their reorganisations, resources provided the central motivation behind the new paths the firms pursued. MD1 cut R&D spending and focused on developing one application, instead of the three applications it had initially pursued. This move was aimed to save resources to keep the firm viable. In contrast, MD2 increased spending because they felt the only way to keep the firm viable was to come up with a new prototype for their device. Consequently, the new prototype required the firm to expand its R&D.

Table 6-11: MDs' R&D paths

FIRM		**The core technology drove R&D demands of the firms.**
MD1	1.	*The idea for the machine is the whole business. This is why we are here*. (MD1's chairman)
	2.	*We are the only articulating 10-way adjustable positioning spinal elongation system in the world. We are the first major evolutionary improvement to spinal traction and elongation in the last 50 years.* (MD1 co-chairman)
	3.	*One hundred per cent of the $2 million invested in the firm went directly or indirectly to developing the firm's core technology.* (Close- ended question)
MD2	4.	*Without these innovations we would we would have no business*. (MD2's CEO)
	5.	*Almost all of MD2's $10 million capital expenditures in the first seven years went to developing their core technologies.* (Closed ended question; analysis of firm's financial statements)
		FDA and government approvals have impacted the strategic direction of R&D.
MD1	*6.*	*We had to learn how to navigate FDA approval. This was important to the development of our device. Without it, it cannot be used.* (MD1's Chairman)
	7.	*I did not have experience in FDA, but it is essential, so I took the time to familiarise myself with the process and navigated it for the company.* (MD1's Chairman)
	8.	*There is a lot that went into the patents. It is important to devote the resources to this because the patents protect the device.* (MD1's Chairman)
MD2	9.	*The FDA is becoming more difficult, less predictable, and actually I think selling technology is slowing down, which is why we're going to be launching in Europe first because of that.* (MD2's CEO)
	10.	*The regulatory process is tedious. It's unpredictable now. The agency is inconsistent and erratically changes directions. It's now kind of coming back to a more centred position, but what used to take in our industry for relatively safe products you could predict that if you made your submission, then within 90 days you got an answer. It's much less determinant (sic) now.* (MD2's CEO)
		Scientific setbacks impacted the strategic direction of R&D.
MD1	*11.*	*I said to him, You know, I see what's going on here. I think this whole prototype needs to be redone. I said, Okay. Let's re-do the whole thing. That's what we did*. (MD1's Chairman)
	12.	*The firm developed three prototypes and went through over twenty designs*. (Close- ended questions with CEO)
MD2	*13.*	*We've had to restrict our expenditure R&D to focus on the first product that we hope to launch later this year*. (MD1's CEO)

Source: Author

Positions

Table 6-12 presents evidence supporting the most important positions to the development of the firms' R&D resources and capabilities.

Both firms' founders proved to be both direct and indirect critical resources to their firms' R&D (Table 6-12; 1-4) [R&D-pa founder]. MD1's founder came up with the idea for the technology He was also the driving force behind the early prototype. The partner he brought in, skilled in many technical areas, provided inputs that allowed the firm to refine the prototype with regard to the computer interface.

In a slightly different vein, MD2's founders drove the development of their R&D. He did not conceptualise the technology, but instead he used his technical and business skills to sense it out (Table 6-12; 3) [R&D-po founder]. He then used his experience to put together a staff and a plan to further develop and pursue the commercialisation of the technology. Although the founders' inputs were substantially different, the founders of the two firms were the key resources behind the R&D.

Scientists are another position that significantly contributed to the development of the firms' R&D (Table 6-12; 5-9). MD2's scientific staff is made up of seven researchers as compared to MD1's staff of three, and both firms' scientific staff proved to be important resources. Moreover, both firms received large contributions from star scientists (Table 6-12; 6 and 8) [R&D-po star scientist]. The co-owner of MD1 is an accomplished scientist in the field and has substantial experience in developing devices. His contributions, along with the contributions of the founder's inputs, are what enabled the firm to create and progress their core technology. Two star scientists renowned in the field proved particularly important to MD2's technology.

The firms' core technology also provided an important resource to the firms' R&D (Table 6-12; 10-13) [R&D-pos core tech]. MD1's technology quickly progressed to a state of commercialisation in year six. At this point they used the revenues from the sale of the devices to supplement the R&D of the firm (Table 6-12; 11). In contrast, MD2's technology took over nine years to get to market, but the technology proved more beneficial to attracting other R&D inputs than MD1's. More specifically, MD2's technology complemented many areas of research related to the treatment of infection (Table 6-12; 12) [R&D CCA]. This triggered several key research partnerships that led to

important R&D resources. For example, the firm developed a close relationship with the University of Toronto, which wanted access to MD1's technology. This relationship proved mutually beneficial as MD1 received important testing and access to specialised technology, and the university received access to MD2's technology, which helped in several of their research projects [R&D CCA]. In addition the firm developed a relationship with a Scottish firm that proved mutually beneficial.

The different effects the firms' core technologies had on the development of their R&D is largely attributed to the nature of their innovations and the protection status of the innovations. By its nature MD2's technology complements several areas, whereas MD1's technology does not. Also MD2's technology is harder to copy, and it is easier to defend their intellectual property than MD1's technology is. For this reason MD2 was more relaxed about working with partners. They were not afraid that their technology would be stolen. Despite these differences, both firms' technologies proved to be important resources that aided in the development of their R&D resources and capabilities.

Table 6-12: MDs' R&D positions

FIRM		**The founders provided important R&D inputs.**
MD1	*1.*	*So, I started to fabricate, in my basement, a prototype to test certain positions' postures and movements. And when I felt that this was something that could work, I then hired an engineer and I had some drawings done, and I went back and forth with the engineer on the drawings, to fine tune what I wanted, and I had a, actually two prototypes in New York, made.* (MD1's Chairman)
	2.	*Oh yes, I was the one driving the design of the device*. (MD1's Chairman)
MD2	*3.*	*He evaluated the patents and saw that they had large profit potential. He is a PhD and has many years of experience in the industry that helped with this.* (MD2's CEO)
	4.	*The founder and Chief Scientific Officer holds over twenty patents and has helped three other companies successfully develop and commercialise medical devices in the past.* (Information taken from firm prospectus.)
		The scientists provided important inputs to the firms R&D.
MD1	*5.*	*The new engineer actually built the new working prototype. He took those prototype drawings and made it out of extruded aluminium, and from this we got patents and made it into production material drawing that could brought to a and made*. (MD1's Chairman)
	6.	*He (co-owner) has extensive experience and was able to make some critical contributions right away. He has an extensive electronics background that was a big help to creating the controls.* (MD1's Chairman)
MD2	*7.*	*The company's technical progressions could not have been made without our scientists.* (MD2's CEO)
	8.	*There is a researcher we have in California who has made some significant contributions to our technology. He is well known and has a substantial scientific background.* (MD2's CEO)
	9.	*The company has a scientific advisory board made up of top scientists and researchers who are leaders in their fields. The scientific advisory board provides input and advice.* (MD2's CEO)
		The core innovation proved important to R&D.
MD1	*10.*	*We have interest from hospitals from all over the world that are interested in working with us because of it is a revolutionary device.* (MD1's founder)
	11.	*We were able to get to start selling it in 2006, and these revenues really helped with the continued development of the device*. (MD1's founder)
MD2	*12.*	*There are a number of organisations that are interested in our technology because of its ability to identify active infections.* (MD2's CEO)
	13.	*We have been able to reach out to a number of universities because of their interest in using our science. They want to stay at the cutting edge, and our product is at the cutting edge*. (MD2's CEO)

Source: Author

Processes

Table 6-13 presents a representative sample of evidence depicting the important processes that led to the development of MD1 and MD2's R&D resources and capabilities. They relied on several of the same routines with some small differences.

One set of routines that both firms developed is transformational capabilities (Table 6-13; 1-4). Early on in the venture MD1 had to rapidly redefine its R&D to produce a new prototype that could effectively treat spines and get through FDA testing [R&D-proc trans]. The firm quickly reorganised its R&D resources to focus on this development. It hired new staff members, brought a new partner into the ownership structure and came up with a drastically different design (Table 6-13; 1 and 2). The founder orchestrated the transformation as he saw the need for a new prototype.

Similarly, MD2 ran into some early research issues that, coupled with financial constraints, forced the firm to refocus its R&D on its main application (Table 6-13; 3 and 4). Similar to MD1, the founders and the CEO drove this transformation. They saw this need and redesigned the firm's research to focus on just one application.

Clearly the ability to reconfigure R&D resources and capabilities is critical. Had these firms not adjusted, then they would not have survived. MD1 would not have been able to get their device through FDA approval and MD2 would have exhausted their resources trying to develop four applications and would not have gotten them to market.

In addition the firms' R&D revolved around learning daily from their earlier research (Table 6-13; 5-8) [R&D-proc learning]. Neither firm had an advanced system for this but instead relied on the tacit abilities of their staff. MD1's learning mainly emanated from the two owners and the engineer they employed. They did not have a formal system but instead shared ideas and independently worked on tasks aimed at progressing their technology. Likewise, MD2's scientific staff did not have many formalised procedures. Rather they worked independently and shared ideas and updates relevant to the firm's research.

One set of processes important to MD2, but not MD1 is sensing complementary technology (Table 6-13; 9-11) [R&D-proc S&S]. MD2 was established through the founder's abilities to sense out technology. The routines they developed relied heavily on

the networks of the founders and CEO. The firm also developed systems for scouring scientific journals to find complementary technologies. In contrast, MD1 did not have such routines in place. The founder is where the core technology emanated, and the firm's scientific progressions came almost exclusively from internal sources.

These differences are largely attributed to the difference in the two firms' technologies. MD2's technology complemented many other areas related to infectious disease [R&D CCA]; whereas, MD1's technology is unique and does not have widespread application. Some of the difference in the importance of technology sensing is also attributed to the background of the founders. MD2's founders and TMT are highly connected and these connections resulted in access to complementary technologies. In contrast, MD1's founders are not highly experience and connected (Table 6-13; 9). This is one of the reasons that they did not have access to complementary technologies, and did not take in knowledge from outside sources.

Table 6-13: MDs' R&D processes

		Transforming R&D has proved vital to the firms' growth and survival.
MD1	1.	*You know, I see what's going on here. I think this whole prototype needs to be redone. I said, Okay. Let's re-do the whole thing. That's what we did and within a year we had an FDA cleared device.* (MD1's Chairman)
	2.	*This needed to be formalised, so I brought in an engineer and brought an old colleague on board to really refine the machine.* (MD1's Chairman)
MD2	3.	*We have reorganised our research to focus on our main application. Ideally we would like to focus on three applications, but because of resource constraints, we have had to focus on one application*. (MD2's CEO)
	4.	*I think we were fortunate to just make it through there and stay alive, which is why it has taken us as long as it has for what should have been out in three years instead of six years; primarily because of the inability to raise capital. This has forced us to reorganise and focus on one application*. (MD2's CEO)
		Learning routines have helped advance the firms' R&D.
MD1	5.	*It was an iterative process of seeing what worked and what didn't. It was a continual learning process.* (MD1's Chairman)
	6.	*It was a long process to develop the first prototype. They say, Well, how about? No, I want the machine to do this. Well, then they show me something. Well, how about we do it like that? and I was, Well, well, that will work. Or That won't work. You need to make it go like this. And we'd go back and forth, until what I wanted was achieved. That started probably 2000, up until 2003*. (MD1's Chairman)
MD2	7.	*We have a chief scientific officer who coordinates all of the scientific activity. There are many different things going on, so it is important to coordinate these things. We learn from our earlier tests and apply these to refining our device*. (MD2's CEO)
	8.	*Our learning routines have led to several significant progressions of our technologies*. (MD2's founder and CEO)
		Sensing and taking in outside knowledge proved vital to R&D.
MD1	9.	*I am a doctor (medical physician) and I have never developed anything before, so I did not have any contacts with alliances that could help me out. All of this came from my practical experience and experimentation with the machine.* (MD1's Chairman)
MD2	10.	*The rest of the technologies were either developed here at Gene Ex in Miami or through partners and consultants that we have used under contract. We have taken in knowledge for our product from a number of source*. (MD2's CEO)
	11.	*We're really bringing a bunch of science together. Some of it is fairly new here, but much of what we like so much—I think innovation—is bringing a kernel of new stuff together with other stuff, but I've found over the years the most successful accomplishments are the things that have been developed in other spaces and you bring them together; and we've done a bit of that.* (MD2's CEO)

Source: Author

6.3.5 Financial assets and capabilities

Table 6-14 highlights the paths, positions and processes central to the development of the firms' financial resources and capabilities. Based on the coding and close-ended questions, each path, position and the processes for each firm is placed in one of four categories based on its influence in development: high influence (H), medium influence (M), low influence (L) or no influence (N). The analysis of the major paths, position and processes is detailed below.

Table 6-14: MDs' financial paths, positions and processes

	MD1	MD2
INFLUENTIAL ON FINANCIAL PATHS		
Costly innovation	H	H
Raising capital	L	H
Public stock offering	N	N
VC	L	L
POSITIONS		
Scientific capabilities	M	H
Founders	H	H
Executive staff	H	H
Core innovation	H	H
Firm's staff	L	M
PROCCESSES RELATED TO		
Raising capital	L	H
Integrating and conserving financial resources	H	H
Dealing with Investors	N	M
IPO	N	N
Transforming financial resources	H	h

Source: Author

Paths

Table 6-15 highlights the paths important to the development of the firms' financial resources and capabilities. There were several past decisions and future opportunities that impacted the financial demands of the firms.

The core technology had the largest bearing on their financial paths [Fin-pa costly innovation]. Both firms' financial strategies revolved around their core technology. MD2's core technology required $3 million in the first three years. This investment went to developing important chemical technology and testing for the device. Moreover, the firm has also invested substantially in items related to government approval for their device; most notably, patents and EU product approval. The substantial costs forced the firm down a path of attracting outside investors. Early on an angel investor emerged to provide most of the early capital. Followed by this a VC investment came in. Throughout the first nine years of existence MD2 has invested over $10 million in their technology. In consequence of choosing to develop costly technology, raising funds has been at the forefront of MD2's strategic direction (Table 6-15; 5). The firm's research is dependent on it, and the firm's ability to raise capital is dependent on progressions in its research (Table 6-15; 6) [R&D and finance co-specialisation].

In contrast, MD1's technology was less expensive to develop, largely because of the path of developing a non-intravenous device and the fact that the founder provided most of the early scientific inputs. This allowed the founder to self-finance the early development of the firm. The nature of the core innovation also made raising capital difficult, as they could not get a lot of interest in the device because of its niche nature (Table 6-15; 2) [Fin-pa VC]. It has profit potential, but it does not have the large scale profit potential that VCs look for in a potential investment, yet another reason the firm went down a self-financing path.

The device's continued development consumed hundreds of thousands of dollars, which triggered the founder to bring on a partner in year four. In year six the firm started selling its device and these revenues opened up new financial paths for the firm [Fin-pa revs]. These revenues helped finance the development of the firm's technology. This also helped to deter the need for outside investment. The firm also got a big boost in year eight when the technology helped them attract international customers. In that year several foreign customers solicited MD1 to purchase their device. Their interest stemmed from MD1's

superior technology. At that point the firm had done no overseas marketing, but the foreign customers had heard of MD1's technology and located the company on the internet. Consequently, the firm received revenues that have essentially kept the firm viable.

Apparent in these cases is that the owners' experience levels influenced the financial paths of the firms. MD2's experienced founders sought out and found early stage investors, which helped to minimise the personal investment they had to contribute to the venture. In comparison, MD1's founder was not experienced in starting a device firm and was not familiar with raising capital. However, both firms' strategies proved effective, as they both successfully financed the development of a marketable device.

These cases also show how external events can greatly influence the financial paths and outlooks of small life science ventures. The recession of 2008 greatly hindered the firms' abilities to finance their R&D, and because of this both firms had to drastically change their financial strategies (Table 6-15; 8-11). For MD1 the sales of their device greatly dropped off. This adversely affected their ability to finance their R&D (Table 6-15; 9). Moreover, it left them with great overhead costs that proved difficult to meet. This triggered the owners' of MD1 to open new financial paths including opening a clinic to generate revenues.

In comparison, MD2 found it more difficult to raise the capital in the midst of the recession (Table 6-15; 10 and 11) [Fin-pa VC]. The markets had largely dried up because of the recession forcing MD2 to downsize its operations and focus on the development of only one of its applications, instead of the four that it had originally set out to develop.

Table 6-15: MDs' financial paths

FIRM		**The core technology drove the financial strategies of the firm.**
MD1	1.	*The machine took a significant dollar amount to develop. The costs for the design and development have cost a substantial amount.* (MD1's Chairman)
	2.	*The main word that the venture capital people use is scalability. See, scalability. A machine like mine, you may have a few thousand treating doctors in the world, and only a percentage of those might buy the machine. So, it's not a big scalability. So, it's a real boutique-y market.* (MD1's Chairman)
	3.	*But we feel confident that the international market is going to keep this company going until the domestic market regains its momentum.* (MD1's Chairman)
	4.	One hundred per cent of the capital invested in the firm went directly or indirectly to developing the firm's core technology. (Close-ended question)
MD2	*5.*	*The core technology has driven our need to raise capital.* (MD2's CEO)
	6.	*So, the sell to the investors has been this is great technology. It's a great market. If we can finance it we should have a very successful commercial enterprise.* (MD2's CEO)
	7.	*Because of the cost of developing the innovation - that makes raising capital paramount.* (MD2's CEO)
		Environmental factors have influenced the firms' financial strategies.
MD1	8.	*In fact, the series tipped after that one, and then in 2008, the economy went boom. Everything fell.* (MD1's Chairman).
	9.	*Doctors suddenly didn't want to spend anything for equipment, unless it was cheap, cheap, cheap, and this was an expensive machine. This stuff is expensive to make and our R&D is expensive to maintain. If you don't sell a certain volume, you can't support this. So, we have managed to hold on.* (MD1's founder and chairman).
MD2	10.	*And so from that period of time until literally 2009, it was extremely difficult to get capital. I think we were fortunate to just make it through there and stay alive.* (MD2's founder and CEO)
	11.	*We saw it first. The capital markets dried up and many of the investors were on the side line. Then when things got better, investors went to the stock market because it was so easy to get great returns as the market rebounded. This made it difficult for firm like to get the high risk – high reward capital.* (MD2's CEO)

Source: Author

Positions

The firms relied on two main positions to develop their financial resources and capabilities; their top management team (TMT) and their technology. However, the way the firms leveraged these varied substantially.

The TMTs of the firms provided the most important positions in the development of the firms' financial resources and capabilities [Fin-po TMT]. Table 6-16 (1-7) depicts a representative sample of evidence that underscores the importance of the firms' TMT to developing its financial resources and capabilities. MD1's founder provided all of the seed capital to fund the firm in the first three years. He then brought on a partner who also contributed financial resources. MD1's founders' capabilities in conserving capital also provided an important position because it saved money that otherwise would have had to come from outside investors; the founders used their scientific capabilities to reduce the amount that had to be spent in the development of the firm's product. For example, the founder navigated the FDA approval process for the firm, which saved the firm upwards of a million dollars. The founder and his partner also opened a clinic in the ninth year to generate more revenues for the firm. This proved vital as these revenues provided resources that allowed the firm to stay viable during the economic recession.

Similarly, MD2's TMT provided the important inputs to the financial resources and capabilities of the firm, but in a different way than MD1's did (Table 6-16; 5-7). MD2's founder's background proved vital to the early investment that the firm received. He is well known and well connected, and he used this to help the firm attract the early investment the firm needed to get started. In year two the firm hired a highly experienced CEO who has been its main fundraiser. He used his experience and networks to attract $10 million in capital. Moreover, MD2's TMT's capabilities in reorganising and cutting costs have kept the firm viable (Table 6-16; 7) [Fin-po TMT].

Interestingly, the two firms' TMTs had drastically different backgrounds and approached the financing of their respective firms drastically differently (Table 6-16; 8-11), but both firms' TMTs supplied vital resources that significantly contributed to the capabilities of their firms [Fin-po TMT].

Technology is the second position that the firms drew on to develop their financial resources and capabilities, but like the TMTs, the firms leveraged their technology in

different ways. MD1 quickly moved its product to commercialisation and used the revenues the technology generated to help finance the continued development of the technology. In contrast, MD1 used its technology to help attract investors. The technology showed promise to lead in a highly profitable market, which MD1 used to help attract investors. Although the two firms' technology differed greatly and had different impacts on the firms' finances, both technologies proved to be vital resources.

Table 6-16: MDs' financial positions

FIRM		**The founders and top managers provided key financial positions.**
MD1	1.	*I paid for all of the early development of the firm.* (MD1's Chairman)
	2.	*Since he came on board, we have shared the expenses in developing the machine.* (MD1's Chairman)
	3.	*I was able to keep costs down by doing a lot of the functions of the firm myself and strategically finding the lowest cost inputs.* (MD1's Chairman)
	4.	One hundred per cent of the capital has been provided by the founder and his partner. (Close-ended question)
MD2	*5.*	*The founders were important to bringing in the capital. They knew some key people and had a background in business that the investors liked.* (MD2's CEO)
	6.	*It is important to know how to find investors and work with them. Myself and our CFO are experienced in this, and this has helped us bring in the capital that we need to continue the technology's development.* (MD2's CEO)
	7.	*The board had to sit back and make some cost cutting decisions to stay viable.* (MD2's CEO)
		The firms' technology helped develop financial resources.
MD1	*8.*	*The sales of the machine took off initially, and this helped us develop the company.* (MD1's Chairman)
	9.	*In 2008 the international revenues picked up and these have given us a big boost. These have really helped us through the recession.* (MD1's CEO)
MD2	10.	*The investors look at how profitable a device can be, and ours is in a profitable market, so that's one of the tools that we used to attract investors.* (MD2's CEO)

Source: Author

Financial processes

Both firms relied on a number of routines to develop the financial resources necessary for their firm's growth. Table 6-17 presents a representative sample of evidence of the key processes that the firms used to develop their financial resources and capabilities. For the

most part the firms' routines were quite similar, but there were also some noticeable differences.

One of the main differences is the importance of routines in prospecting and raising capital. This proved highly important to MD2, whereas these processes did not play a major part in MD1's operations. The routines that MD2 developed for raising capital came from the tacit knowledge and abilities of the founders and the TMT. They had raised capital for new life science ventures in the past and knew how to prospect and negotiate with early stage investors (Table 6-17; 3 and 4). The outside investors that MD2 brought in also made the firm develop investor relation routines, the most important of which revolved around communications with investors [Fin-proc inv rel]. This was handled primarily through the efforts of the CEO and CFO.

It is evident from these two cases that new innovations are costly to develop and that capital is paramount to the development of innovation, but this capital can emanate from different sources. The source of capital has a major bearing on the processes that a firm must develop. MD1 self- financed the venture and did not have to develop routines related to raising capital. In contrast, MD2 financial strategy revolved around attracting outside capital, which made routines related to prospecting capital paramount. There are merits and demerits of each source of capital. Outside investment capital lessens the risk to the founders, but it takes a substantial resource commitment to processes related to raising it and dealing with the investors, especially the time the TMT has to devote to these functions. Regardless of the source of capital, it is evident that key individuals – i.e. the founders and TMTs – are the ones who drive the processes related to raising it.

One set of routines that both firms relied heavily on revolved around conserving funds (Table 6-17; 6-8) [Fin-proc int]. Because of the costly nature of their products and their shortage of capital, both firms had to save money in every way possible. This proved difficult, as the firms' innovation was expensive. To conserve funds MD1 internally performed as many design functions as possible. This was led by the firm's two owners who contributed most of the R&D functions. The owners even attempted several functions that they were not versed in. For example, they produced the technical drawings for some of the designs, and the founder navigated the FDA approval process for the firm's device, even though he had no experience in these areas. MD1 also constantly looked for ways to save capital in their production. They constantly negotiated with suppliers and found new

ones (Table 6-17; 5 and 6). In a similar vein, MD2 developed processes for keeping their operations as lean as possible. Whenever possible they outsourced functions to university partners who would perform the functions for little to no costs. MD2 also learned how to use cost effective contract researchers for many functions (Table 6-17; 7 and 8).

Clearly cost cutting routines are vital to the development of a life science venture's financial resources and capabilities. Cutting costs in every way possible without adversely affecting R&D greatly helped both of these firms, as both firms successfully developed a medical device whilst still controlling for costs.

Closely related to conserving funds, the firms also developed routines for transforming their financial resources (Table 6-17; 10-13) [Fin-proc trans]. In year three MD1 transformed from a relatively informal operation of just one founder to a formal organisation. The firm hired a staff and leased an R&D facility. The firm's owner had to come up with capital to finance this transformation, which he did by liquidating his personal assets and moving the firm to Florida because of lower operational costs that the state offered (Table 6-17; 11). MD1 also had to transform its finances again in year eights because of the recession of 2008, which caused MD1's sales to quickly drop off, greatly affecting their ability to finance their R&D and operations. In response the firm's owners opened a medical clinic to help finance the firm. After seeing the recession would have a prolonged effect on the firms, the owners quickly leased a facility for a medical clinic and started generating revenues from this to supplement the firm's financial resources. At about the same time MD1 started receiving international orders, which helped to augment the financial resources of the firm [Fin-pa revs]. Then the firm quickly reorganised its operations to focus on international markets by ramping up their international sales and marketing efforts, which helped to increase revenues.

Similarly, the recession of 2008 forced MD2 to use it transformational routines to alter its financial strategy. The firm's CEO knew that they did not have the capital to sustain four major research projects, and that additional investment would be difficult to raise. In response the CEO and the board of directors made the decision to cut three of the R&D projects and scale back the firm's operations. Although this hurt the firm, as the three projects that were cut showed great commercial potential, the quick move proved beneficial because it allowed it to stay viable during the recession that loomed from 2008 until the time of this study (winter 2010-2011). The firm also transformed itself when a

major investment of $6 million in year seven was received, allowing it to expand its operations, causing it to revamp its financial strategy. Moreover, this capital allowed the firm to bring their device to a point of commercialisation, which has made the firm invest in related areas.

These two cases demonstrate how life science ventures have to create processes to adjust their financial resources and reorganise their financial strategies in response to internal and external events. It is also evident that these processes are driven at the individual level; i.e. the TMTs are the ones leading the processes related to financial transformation. They are the ones that recognise the need for change, and they are the ones that determine the strategic changes to be made.

Table 6-17: MDs financial processes

FIRM		**Prospecting for and dealing with investors has been vital to MD2.**
MD1	1.	*We just sent a few VC prospectuses out, but it had been all self- financed to this point.* (MD1's CEO)
	2.	Close-ended question: has the firm spent significant effort pursing outside investment: No. (Close-ended question)
MD2	*3.*	*Raising capital is critical in this business. We are consistently meeting with our investors and new investors to raise capital.* (MD2's CEO)
	4.	*We have experience and know how to raise capital. It is something that we know how to do from our experience.* (MD2's CEO)
	5.	*We have routines in place for dealing with investors. They want updates and there is a good amount of time that goes into working with them.* (MD2's CEO)
		Conserving capital is a vital routine.
MD1	*6.*	*We constantly looked for ways to keep our costs down. From performing functions ourselves to finding lower cost suppliers. We are always looking to do things more efficiently.* (MD1's CEO)
	7.	*Lean and mean is how we operate. Self-financing a business forces you to keep costs down in every possible way.* (MD1's CEO)
MD2	8.	*It is easy for costs to run up in this business. For this reason you have to watch costs closely and constantly look for the most cost-efficient but still effective way of doing things*. (MD2's CEO)
	9.	*There are a number of things that we do on a regular basis to keep costs down, such as having partners and research contractors provide certain functions.* (MD2's CEO)
		Transformation capabilities have been important to the firm's financial resources.
MD1	*10.*	*We constantly looked for ways to keep costs down.* (MD1's CEO)
	11.	*I decided to cash in my chips, liquidate all my assets, and cut my living expenses down by coming to Florida. I cut my engineering and fabricating cost down by coming to Florida.* (MD1's Chairman)
MD2	12.	*We had to focus on only one project. We needed to control costs where we could*. (MD2's founder and CEO)

Source: Author

6.3.6 MDs conclusion

Both firms had a similar end goal: to develop and commercialise a novel medical device. This decision made R&D and financial resources and capabilities paramount during the early phases of growth. Although there are noticeable similarities in the development of the firms' resources and capabilities, there are also numerous differences. The most noticeable difference is the type of financing that the two firms obtained. MD1 was financed by the owners and proceeds from the revenues from their device, whilst MD2 acquired its capital from private investors and VCs. Consequently, MD1 did not have to devote substantial time to investor-related matters. In contrast, MD2 developed advanced capabilities in raising capital and working with investors. The most striking similarity of MD1 and MD2's resources and capabilities was the importance of key individuals in driving the development of the firms' R&D and financial resources and capabilities.

6.4 Biological analyser firms (BAs)

This section overviews the development of the biological analyser firms, which consist of two firms that are pursuing the development of instruments that analyse biological and molecular matter. In this section a narrative of each case is presented followed by an in-depth cross group analysis.

6.4.1 Biological analytics firm one (BA1)

BA1 is an engineering micro-firm that has developed an instrument for detecting and analysing biological materials and particles. They have a platform technology with widespread applications. One of the applications with the most potential is for identifying viruses and bacteria: from a cheek swab on a human their technology can break the sample into simple particles that can be analysed within minutes. The main advantages of this are twofold: one is that the sample takes minutes to analyse, which is unlike the current testing procedures which can take weeks. The second main advantage is that, unlike the current testing procedures, every virus a person has can be identified; whereas with the current testing procedures only the viruses being tested for will be detected. Another application for the machine is for testing for explosive and biological materials, which is especially of interest to security agencies.

The company is a spin-off from Yale University. However, the technology was not actively marketed by Yale. Rather the professor who founded the technology at Yale was contacted by the founder of BA1 who was a former student who had stayed in close contact. BA1's founder knew of the innovation because of his relationship with the professor, and because of recent events in global terrorism, he saw that the technology had the potential to help in the defence of bioterrorism. Specifically he envisioned that the technology could be coupled with electronic systems to quickly identify harmful biological agents. Based on this vision he convinced the professor to commercialise the innovation, which in turn has driven the entire strategic direction of the firm:

> *The idea for the device has set the entire stage for the company. This is what we have been doing for the last seven years.* (BA1's CEO) [R&D-pa core tech]

After licensing the technology from Yale in 2004, he then opened an R&D facility in south Florida. There he and a small team of two other engineers have further developed the device. They formed an early research partnership with the US Army that has proven critical as the Army has supplied important inputs from a biotechnology standpoint. The firm's product pulls together three areas: biology, physics and electronics. BA1's founders held advanced knowledge in electrical engineering and physics, but not biotechnology. In this area the Army researchers have provided most of the main inputs needed to construct BA1's instrument:

> *We complement one and another. They need our instruments' ability to break down and analyse particles and we need their biotechnology to understand what to look for in the particles.* (BA1's CEO) [R&D CCA]

Initially BA2 financed the development of the device mostly from personal funds and a small amount of investment from friends and family. Due to the small amount of capital that the firm started with, keeping costs down became an important routine:

> *It has been a struggle. We have boot-strapped and cut costs in every way possible.* (BA1's founder and CEO) [Fin-proc int]

At the end of the first year the firm received a boost in funding from a SBIR grant for $183,000 to aid in the R&D of their instrument. The firm had been able to quickly navigate

the small business innovation research (SBIR) grant process because of the founder's skill and experience. Previously he had applied and been awarded dozens of SBIR grants. He used the capabilities and skills to help BA1 quickly get a grant:

> *I have filed over 150 grants, so I could complete one of these applications blindfolded. This was not a problem because of my experience.* (BA1's CEO) [R&D-po founder]

Even though the firm spent less than $500,000 on R&D in the first two years, they were still able to develop an instrument that successfully particalised and analysed several viruses. The efficacy of the tests helped the firm develop several partnerships. Because of this they received interest from some of the largest and most prominent research organisations in the world, such as Scripps and the National Institute of Health. The firm received some important inputs from these organisations, but kept their distance from larger organisations in order to protect their ideas and technology; several of the breakthroughs for the firm's device are not patented because the firm wanted to preserve its capital for functions other than patenting. The firm does have several patents they will file for, but at the time they were able to protect their innovations without patents by not sharing too much information with partners. The only partner the firm shared information was with the US Army, but only because of a very strong non-disclosure agreement between them.

The firm quickly refined and improved their main instrument, and in year two came out with a miniaturised version that is less than four inches by four inches [R&D-pa new tech]. Its portability increased the interest in the product. Several more defence agencies became interested in it because such a device could be used where there could be harmful biologic agents. In addition, this device also captured the interest of the US agriculture department because at that time several harmful diseases had started to enter the US from agriculture imports. The agency had had to kill many animals and destroy large stocks of fruits and vegetables that were suspected of having certain diseases. BA1's instrument had the potential to quickly test and identify whether or not the disease is present, and if it is not, then the agriculture product would not have to be destroyed.

Because of these potential government uses, BA1 received several small government research contracts from years three to five that totalled over $500,000 [Fin-po govt]. In addition, in years four and five the firm received over $200,000 in orders from universities for components related to their devices technology [Fin-po revs]. They received these orders because components of BA1's device are useful with certain lab machines. Interestingly, BA1 did not actively market these components, but the universities found out of the firm's components through networks. Also interesting is that over half of these sales were to foreign universities.

This additional funding went to further refining the technology. In collaboration with the Army, the firm successfully developed an electro spray aerolisation source, which increased the range of bacteria and viruses that the firm's instrument could analyse [R&D-pa new tech]. Prompted by this the firm and the Army decided to apply for a major grant to further develop and apply the technology to defence applications. This grant would be for over $7.6 million of which BA1 will receive $5.3 million. At the time of this study the firm was a month away from hearing from the grant committee. If the firm receives the grant, it will drastically change the direction of the firm:

> *This grant will transform the company. It will bring in resources that will allow us to fully execute the technologies potential. Five million dollars is an incredible boost to a small company.* (BA1's CEO)

Simply put, the firm will have the financial resources to patent the technology, which will allow it to quickly and drastically increase its revenues. Moreover, it will afford the firm the capital needed to develop other applications for the instrument that have even greater market values. For example, the medical applications have market potential well into the billions. To this point the firm has not pursued that path because the defence path they have taken has provided them access to grants and contracts that have financed the development of the technology. In addition, the medical path will require FDA approval, which is costly and lengthy to obtain [R&D-pa govt approval]. However, if the firm receives this grant, it will open up several potential paths, and medical applications is one of the first the firm will look to pursue because of its market potential.

By traditional measures the firm has not seen much growth since its inception seven years ago. Its revenues are less than $250,000; it has a small R&D facility and only three

employees. However, the firm has developed and proven a revolutionary device that has the potential to have a major impact in several large and profitable areas. Moreover, it has developed several key relationships and built a strong image in the industry. So although the traditional measures of growth are not significant, the firm has still seen significant development.

6.4.2 Biological analytics firm two (BA2)

BA2 is small firm that makes instrumentation for analysing molecular agents. The firm's core technology revolves around the ability to measure chiral drugs and biopharmaceuticals. Initially the firm was founded in 2000 by a PhD graduate student in chemistry along with a professor to pursue the commercialisation of the graduate student's chiral research; she had come up with a unique technique for analysing chiral drugs, and saw that this could have major market potential. This innovation has been the driving force behind the firm's strategic direction:

> *We were working on my research and I suggested that we commercialise the technology. So I did the marketing study and wrote the business plan and the business formed around it.* (BA2's CEO) [R&D-pa new tech]

Early resources for the firm came from the university [R&D-po uni]. She had access to labs and one of the professors provided important inputs. From these resources the firm was able to develop a successful prototype for an instrument that could finely measure chiral drugs. This triggered her to start BA2. Because of the policy of her university on her particular type of research, she was able to maintain full rights of the innovation. Initially the firm was funded out of personal savings; the founder drew on her credit cards and took a loan of $150,000 from her mother [Fin-po founder]. She used these resources along with inputs from universities to develop her product. The professor who had worked with her during her research had moved to one of the top universities in chiral science, which opened up inputs for BA2. At this point the professor became a partner in the firm, and he and his new university offered valuable inputs. From a scientific standpoint BA2 got access to a wide variety of equipment and personnel, which provided important inputs to progressing BA2's technology. Moreover, the university also had an incubation program for helping small technology firms grow. This helped the young firm in strategic planning

and making connections. These early resources enabled BA2 to develop a functional prototype in year two that they were able to patent.

The patent proved vital as it afforded the firm the intellectual property protection to form a partnership to commercialise the instrument. The founder was able to strike an agreement with a large biopharmaceutical for producing the instrument, whereby BA2 provided the intellectual capital for the instrument and the partner firm produced and marketed it. According to the terms of the agreement each firm was given fifty per cent of the revenues. This event proved critical to BA2's development, as it provided important revenues that helped finance the continued development of the firm's technology [Fin-po revs].

The increase in revenues afforded the firm capital to continue to develop applications from their technology. It allowed them to hire additional scientists and develop a network of relationships that helped the firm make several developments in their applications. One particular relationship that the firm formed was with the University of Glasgow's life science department where one of the leading researchers in chiral drug technologies was based [R&D-po uni]. He provided important inputs that in conjunction with the firm's internal developments allowed them to develop a revolutionary new instrument. This instrument was named in *R&D Magazine's* 'Top 100 for 2004'. This prestigious award given on the basis of a rigorous review process is particularly impressive because it is amongst every type of innovation – not just life science innovations.

This award gave BA2 a big boost of credibility within the scientific community. It helped in marketing their products and it also helped them attract research partners:

> *It gave us a lot of credibility because it's a very prestigious award. It gave us a lot of credibility. So that gave us credibility. So sales with big companies came shortly after.* (BA2's CEO) [Fin-po core tech]

The award also helped the firm relocate to south Florida. A city in south Florida was actively recruiting firms to move there with tax incentives, and this award made BA2 attractive to the town. Moreover, the award aided the firm in landing its first government grant. In year six the firm applied for a small business innovation research grant (SBIR) and was awarded $500,000 [Fin-po govt]. The SBIR grants are for small firms that have innovative products that have great potential to help society and the US economy. This

$500,000 research grant provided a big boost to the firm and has provided capital to expand BA2's research staff and spending on needed equipment and testing.

In year six the firm also received an important patent that allowed it to market its second instrument. The boost in revenues provided financing to continue the development of two more applications of BA2's technology [Fin-po revs]. To develop these applications the firm relied on their founder's inputs along with their scientific staff. By that point their staff had grown to twelve researchers who were almost all PhDs. These scientists provided important support, but the two founders provided the main scientific inputs to the new applications:

> *We (the founders) have provided essential science to our products.* (BA2's CEO) [R&D-po founder]

Not only were the founders' scientific inputs vital, but so was their access to networks. Both were well-connected within the greater scientific community. The second founder is one of the leading experts in chiral drug science. He is one of the most cited professors in the field, is the head of the department at the top university in the field and is the editor of one of the top scientific journals in field. From this he has gained name recognition that has benefited BA2.

The first founder is also well-connected, but she became so in a different fashion. She attends over twenty tradeshows a year where she participates in networking events [R&D-proc net]. In addition, she chairs many industry-related organisations. From these she has become well known in the life science community:

> *I served as the president of the society for our field of spectroscopy and I got to know a lot of people. I serve on many different committees, I chair a conference and the people recognize my name.* (BA2's CEO) [R&D-po founder]

These connections have provided access to partners that have provided important inputs. One important input that came from her networks in year eight is angel investment. Her networks also helped the firm expand sales and service capabilities in Europe in year nine. This has proved vital to the firm's growth as European sales have quickly picked up and are helping to finance the firm's continued growth [Fin-po revs].

At the time of this study (year ten) the firm had just come out with an updated version of their chiral measurement instrument that is even more effective than their current instrument. The firm is confident that it will see sustained growth in the next few years as they have four fully developed products and several new applications under development.

Until this point growth is evidenced in the over $3 million in annual sales, the four patents the firm holds, the staff of fifteen and the extensive relationships they have with other firms and research institutions.

6.4.3 BAs cross-group analysis

The narratives above provide a contextual basis for the evolution of the firms' R&D and financial resources and capabilities. This section delves deeper into the key paths, positions and processes that led to their development. It analyses and compares the paths, positions and processes that led to each firm's R&D resources and capabilities. Following this the financial resources and capabilities development is presented in the same fashion.

6.4.4 R&D assets and capabilities development

In the early stages of growth both firms focused on the development of their technology. This was the impetus of developing R&D assets and capabilities for both firms. In the same fashion as the last section, Table 6-18 presents the matrices of the paths, positions and processes that were yielded from the data reduction techniques discussed in the research methods chapter. Based on the analysis of the interviews and the close-ended questions, each path, position and processes for each firm is placed in one of four categories based on its influence on the firm's development: high (H), medium (M), low (L) or no (N) influence. The major paths, positions and processes are discussed in detail below.

Table 6-18: BAs' R&D paths, positions and processes

	BA1	*BA2*
INFLUENTIAL ON FIRMS' PATHS		
Core technology conceptualised at a university	H	H
Core technology conceptualised at another firm	N	N
Core technology conceived by the firm	N	N
Government partnerships	H	L
Industry partnerships	L	M
University partnerships	L	H
New technologies influenced firm's direction	M	M
Government approvals: e.g. patent or FDA	M	M
Scientific developments	H	H
IMPORTANT POSITIONS		
Patents	M	M
Skilled scientists	M	M
Star scientists	H	H
Industry partnerships	L	M
University partnerships	L	H
Government partnerships	H	L
R&D facility and research equipment	L	L
KEY PROCESSES		
Sensing and seizing scientific opportunities	H	M
Finding and developing research partnerships	H	H
Navigating government approval	L	L
Filing patents	L	M
Learning from earlier research	M	M
Transforming R&D	M	M

Source: Author

Paths

Several paths influenced the strategic R&D pursuits of the firms. The most ubiquitous path emanated from the firms core technology. Table 6-19 (1-4) presents a representative sample of evidence illustrating the importance of the core technology to the firms R&D.

Both firms' technologies came from universities [R&D-pa uni partners]. For both of these firms the technology that emanated from a university set the central R&D path of the firm (Table 6-19; 1-4). BA2's founder created the technology whilst she was at graduate school; whereas, BA1's founder convinced his former professor to release a technology developed some years past. BA1's technology required the firm to develop competencies to bring together techniques from the areas of electronics, physics and biotechnology. In comparison, BA2 developed competencies revolving around measuring and analysing chiral drugs. Both firms' technologies required substantial resource investment and forced them to acquire specialised financing to pay for their R&D [R&D and Fin co-specialisation].

Internal and external events also impacted the firms R&D paths (Table 6-19; 5-9). For BA1 the fear of global terrorist attacks triggered a demand for an instrument that could quickly detect and analyse harmful biological agents (Table 6-19; 5). This outbreak also provided government resources that influenced the direction of BA1's R&D. Similarly, a

change in drug technology increased the demand for chiral drugs and created the main path for BA2's technology.

Internal breakthroughs by the firms also influenced the strategic paths of their R&D (Table 6-19; 5 and 9); i.e. the firm made substantial discoveries that greatly affected their R&D. For example, BA1 successfully miniaturised its instrument, which opened up new potential applications for their product [R&D-pa new tech]. Likewise, BA2 found new applications for its technology that opened up R&D opportunities. Thus it is apparent from these cases that environmental factors can have a major impact the strategic path of a life science venture.

The pursuit of partnerships had a major bearing on the firms R&D paths (Table 6-19; 14-17). An opportunity with the US Army allowed BA1 to synthesise their electronic and physics capabilities with the Army's biotechnology [R&D CCA], which enabled BA1 to develop a device that could detect and analyse viruses and bacteria. Without this partnership the firm's R&D would have taken a much different direction.

Slightly less drastic, BA2 received R&D inputs from one of the leading universities in chiral chemistry allowing them to progress their chiral instrument technology [R&D-pa uni partner]. This partnership had a particularly large bearing in the firm's early R&D paths as it supplied the resources needed to develop the firm's core technology. Another partnership with the University of Glasgow allowed the firm to develop their second application enabling them to pursue this path.

BA1 clearly was more reliant on partners then BA2; however; both firms' strategic R&D paths were significantly affected by partners. Had these firms not had these partnership opportunities, then their R&D would have evolved in a much different fashion, and there is a good chance that the firms might not have been able to have successfully developed their products. From these two cases it is apparent that partners affect the R&D paths of the firms. Nevertheless, path rigidities can prevail from partnerships. For example, BA1 had strong agreements in place with the US Army that have limited the latitude of the applications that it can pursue. These constraints are partly contractual and partly a result of the substantial resource commitment that BA1 has made to the Army. Such narrow path rigidities have not resulted from BA2's partnerships.

Government approval processes, particularly patenting, also affected the firms R&D paths (Table 6-19; 10-13) [R&D-pa govt approval]. BA2 pursued and received four patents. To get the patents the firm had to devote substantial resources, particularly scientific ones, to the application process. An advantage that the patents provided was affording the firm the protection to introduce new products and develop new research partnerships. In comparison, BA1 licensed four patents that their core technology is based on, and they have several ideas that they plan to patent. However, in order to conserve resources they decided to wait to start the patent application for these newer ideas in order to conserve resources for other functions. It has also challenged the firm to choose strategically whom they work with in order to protect their ideas. In other words, they do not want too many close partners, especially industry partners, because they fear that their ideas could be stolen.

Another path that has impacted the firms' R&D paths is the FDA (Table 6-19; 14 and 17) [R&D-pa govt approval]. Both firms' technology has human applications, but the cumbersome FDA approval process has driven the firms away from these. Rather than committing substantial resources, they chose instead to focus on applications that do not require approval. Although the FDA has not directly influenced the strategic pursuits of the firms, it has had an impact on their strategies.

Table 6-19: BAs' R&D paths

FIRM		
		The core technology drove the R&D demands of the firms.
BA1	1.	*The idea for the device has set the entire stage for the company. This is what we have been doing for the last seven years.* (BA1's CEO)
	2.	*The patents from Yale are what it all started with. The product has revolved around those patents.* (BA1's CEO)
BA2	3.	*We were working on my research and I suggested that we commercialise the technology. So I did the marketing study and wrote the business plan and the business formed around it.* (BA2's CEO)
	4.	Almost all of BA2's $3 million capital expenditures in the first seven years went to developing their core technologies. (Close-ended question)
		Internal and external events impacted the firms R&D endowments.
BA1	5.	*Bioterrorism has become a big problem and has created a need for a device like ours that can quickly analyse biological agents.* (BA1's Chairman)
	6.	*Now, the hallmarks of it (BA1's instrument after it was redone) are; it's very fast. Like, in five minutes, you have results, and there's (*sic*) no chemicals involved. So, for a variety of reasons, it's very attractive to virologists, biologists and we confirmed that presentation of impressive test results.* (BA1's CEO)
	7.	*There is a lot that went into the patents. It is important to devote the resources to this because the patents protect the device'.* (BA1's Chairman)
BA2	8.	*Chiral drugs are becoming the standard in the pharmaceutical industry. I saw this and knew that a technology that complemented chiral drugs would be a good market to get into. It has as almost 80% of drugs are chiral based.* (BA2's CEO)
	9.	*We have been able to adapt our technology to create ideas. This has opened up new research paths that have led to new products.* (BA2's CEO)
		The pursuit of partnerships had a major bearing on the firms' R&D.
BA1	10.	*The Army has been a very important partner. We have a key patent from them that has really affected our instrument.* (BA1's CEO)
	11.	*The Army has really helped shape the firm. Their biotech inputs are important and having them as a partner has helped to get grants.* (BA1's CEO)
BA2	12.	*The partnership with Syracuse has been very important. It provides a lot of science that has helped the firm develop.* (BA1's CEO)
	13.	*Networking is important to getting inputs that we need. We have established a wide variety of partners, which has helped us in developing our technology.* (BA2's CEO)
		Government approval processes affected the firms R&D.
BA1	14.	*We have several applications that will need FDA approval. We have strategically stayed away from these to avoid the cost and time associated with this.* (BA1's CEO)
	15.	*There are several ideas that could be patented, but the patenting process triggers a series of events and forces us to invest in this. Instead the ideas are protected because we control all of the information and do not share it with anyone who might try to take it.* (BA1's CEO)
BA2	16.	*The pursuit of the patents has been an important influence on our R&D. We have had to put a lot into these, and gaining these patents has opened up opportunities for us. (BA2's CEO)*
	17.	*Our products do not require FDA approval, so that has allowed us to avoid having to devote R&D resources to this.* (BA2's CEO)

Source: Author

Positions

Several positions proved important to the development of the firms' R&D. Table 6-20 presents evidence supporting the most important ones.

The firm's core technology is one of the most important resources that the firms used to develop their R&D resources and [R&D-po core tech]. Table 6-20 (1-4) depicts a representative sample of evidence that underscores the importance of the firms' technologies to the firms R&D. One important input that the firms' core technologies helped with is attracting research partners. Both firms' technologies are ground-breaking and have the potential to fundamentally influence the industry, motivated other organisations to reach out to BA1 and BA2.

BA1's technology has potential to change homeland security procedures. Specifically their technology can quickly identify and analyse diseases from a sample of small particles, which could allow homeland security to become more effective in looking for biological weapons. This ability is a position that the firm has leveraged to enter into several key relationships – most notably with the US Army and the US department of Agriculture.

In a similar fashion, BA2's technological positions facilitated several key relationships. Their relationship with a top university stems largely from the universities desire to be attached to a leading edge technology. Moreover, the firm has attracted relationships with several of the top biopharmaceutical firms in the world who want to use BA2's technology to aid in the development of their drugs.

The firms' scientists have also proven important resources to the firms' R&D [R&D-po scientists]. BA1's is constituted primarily by the two founders who have developed many innovations in the industry and have a combined fifty years in new product development experience. They have drawn on this experience to help progress BA1's instrument. Moreover, they have deep connections that allow them to draw on the knowledge of others when they have questions about their research (Table 6-20; 10 and 11).

In a similar vein, BA2's founders have been critical resources to BA2's R&D (Table 6-20; 12 and 13) [R&D-po founders]. The founders came up with the idea, and one of the founders is renowned in the field. He is the chair of the department at a university that is widely regarded as one of the top in this field [R&D-po star scientists]. Moreover, the

founders of BA2 are well-connected, and their networks and networking abilities have been an important resource that has contributed to the development of their technology. For example, their relationship with a University of Glasgow professor provided access to science that allowed them to develop one of their main applications. Unlike BA1 though, BA2 also has a scientific staff of fifteen members that is an important asset to the firm's R&D [R&D-po scientists].The staff has not made any breakthrough discoveries, but they are versed in many areas and make incremental contributions that have collectively made a large impact on the development of BA2's technology.

It is evident from these cases that founders are an important resource to the development of life science ventures. The founders of BA1 and BA2 contributed much of the key research inputs, and drove the development of the other R&D resources that their firms needed.

Table 6-20: BAs' R&D positions

FIRM		**The core innovation proved important to R&D.**
BA1	1.	*Our technology is why the Army wanted to work with us. It has the potential to greatly help with what they are doing with terrorism.* (BA1's CEO)
	2.	An Army report showing BA1's instruments superior technology and recommending to the government enter into a research partnership with BA1 because of this technology. (Government report)
BA2	3.	*All these big organisations wanted to work with us because of our superior technology.* (BA2's CEO)
	4.	*Over the last several years the vibrational circular dichoism (BA2's core technology) technique has dramatically revitalised the utility and spectroscopy within pharmaceutical drug discovery.* (Dr. Don Pivonka, research director of a large multinational biopharmaceutical firm)
		Partners provided vital R&D inputs.
BA1	*5.*	*We got important inputs from a number of partners. The patents come from Yale and the Army has provided all of the biotech inputs.* (BA1's Chairman)
	6.	*Without partner inputs we would not have been able to put it (their instrument) together.* (BA1's Chairman)
BA2	*7.*	*We have gotten important help from a number of different places. Syracuse has certainly been important, but Glasgow and a number of other places have been important as well.* (BA2's CEO)
	8.	*We have a network of strong partners that provide information and testing that have been critical to the firm.* (BA2's CEO)
	9.	The firm has relationships with ten of the top biopharmaceutical organisations in the world. (Information from company prospectus)
		Founders have provided critical R&D inputs.
BA1	10.	*I was the one who found the core patents and had the idea to bring everything together.* (BA1's founder)
	11.	*My partner and I have been the ones developing the device. We have help from a number of partners, and we have some part- time staff, but it is us driving this.* (BA1's founder)
BA2	12.	*My partner and I were the ones that came up with the science for the technology. This is the basis of the products.* (BA2's CEO)
	13.	*We (the two founders) are still important to the research. He performs a lot of research and is involved and comes up with a lot of our scientific ideas, and I am overseeing everything and bringing a lot of different science together.* (BA2's CEO)

Source: Author

Processes

Four main processes proved to be important to the development of BA1 and BA2's R&D endowments: sensing technology, networking, transforming and learning. Table 6-21 depicts a representative sample of the evidence supporting the importance of these processes.

One of the most important set of processes revolved around sensing and seizing technological opportunities [R&D S&D]. Table 6-21 (1-4) demonstrates this. BA1 and BA2's founders sensed out opportunities that had great market potential. However, the two firms sensed their opportunities out in much different ways. BA1's founder was highly experienced in industry and used one of his connections to find the technology for his firm; whereas BA2's founder was very inexperienced and used her academic knowledge and skills to sense out an opportunity arising due to changing science.

On a continual basis technological sensing capabilities have been important to both firms, as they have both continually sought out and found complementary technologies that have contributed to their core technologies. BA1 found complementary biotechnologies that have proven vital to the development of their instrument. Similarly, BA2 has found complementary drug and electronics technologies that have aided in the progression of their instruments.

Most of these complementary technologies have surfaced from the firms' founders' networking routines (Table 6-21; 1-4) [R&D-proc network]. Both founders have developed advanced networking capabilities that have resulted in complementary technologies and important research inputs. However, the two firms' networking routines are markedly different. BA2's founder participates in over twenty trade shows a year where she often speaks and attends networking events. She is also active on the board of several industry-related organisations. In addition she has made a routine of staying in contact with her important industry contacts. The second founder of BA2 is also highly networked, but his networks emanate from his prestigious position as the head professor of chemistry at a top university. Because of this position many people interested in his research contact him.

BA1's founders are also well-networked but these have developed from a much different set of processes than BA2's did. The main founder of BA1 has made connections from his

experience in the industry (Table 6-21; 5). He is also able to make key contacts from his informal networking routines. These routines are based on finding and contacting people whom he believes can help with his firm's research. Moreover, BA1 also has an advisory board member who is extremely well-connected.

These cases show that networking routines can be important to the development of a firm's R&D. It also shows that a firm's networks and networking capabilities can vary greatly, but still have a similar end result.

A third important set of processes revolves around learning and communicating (Table 6-21; 9-12) [R&D-proc learning]. These processes proved vital to both firm's R&D. However, BA2 has more formalised systems in place for this than BA1 does. On a regular basis BA2's staff meets to discuss their research objectives. They also have routines for sharing information, and their sub-departments have formalised research routines. In contrast, BA1 does not have such formalised systems. Instead their small staff meets sporadically and communicates with their research partners on an ad hoc basis. Although the two firms' routines differ in their formality, they are still important to both firms. These cases illustrate that different learning and communication routines can be effective.

Transformational-related processes are the fourth set of processes that have been important to both firms' R&D (Table 6-21; 13-15) [R&D-proc learning]. Early on BA2 realised that the changing conditions in the pharmaceutical industry would pose a large opportunity for instruments that specialise in chiral drugs. This motivated the firm to focus its R&D on developing instruments for these types of drug applications, and they devoted almost all of their resources to this.

In a similar vein, BA1 focused its R&D on the development of a technology that could answer the call for help from homeland security to find a device that could quickly detect harmful biological agents. Thus the firm focused its R&D processes on developing such a device and because of this, successfully developed a prototype within two years. In a similar scenario, BA1 responded rapidly when an agricultural disease outbreak created a great demand for an instrument that could quickly detect the disease. The firm reorganised its R&D resources to focus on this application, and in consequence, this helped the firm land a research grant, and has sparked interest in a large order for the firm's instruments from the US Department of Agriculture.

It is evident from these two cases that the ability to respond to changing industrial and environmental factors is important to staying viable and creating a product that is in demand. Both firms recognised and responded to outside factors and their growth to date is largely attributed to the capabilities to reorganise themselves in response to these factors.

Table 6-21: BAs' R&D processes

FIRM		**Sensing and seizing technological opportunities proved important.**
BA1	1.	*I have had to find technology that complements ours. I have ways of staying informed in the scientific community that provides this information.* (BA1's CEO)
	2.	*I knew of the patents and saw that this could be a big opportunity. I have been in industry for years and knew when I heard of this that it was going to have a lot of potential. Being able to sense the technology comes from an innate feeling based on experience.* (BA1's CEO)
BA2	3.	*We were working on the technology in my school's lab, and I saw that the competing professor's work and knew that what we had could commercialise. I knew from my research that the industry was moving towards a chiral model.* (BA2's CEO)
	4.	*We have processes for staying in touch with the scientific community. Our staff stays on top of research. We have connections with several top universities and we attend over twenty trade shows a year. These allow us to find emerging technologies and stay abreast on everything.* (BA2's CEO)
		Networking has proved vital to the firms' R&D endowments.
BA1	*5.*	*I have networks in place from my years of experience. These are helpful when I have a question or need something done.* (BA1's Chairman)
	6.	*Networking capabilities are still important. I have learned how to find key people and reach out to them. Sometimes this is just making some calls and sometimes I network through conferences.* (BA1's CEO)
BA2	7.	*Networking is very important to us. We attend over twenty shows a year and make contacts with everyone that we can. These have led to important partnership.* (BA2's CEO)
	8.	*My partner and I are well- networked. He is a distinguished professor and knows many people through this. He is the editor of a journal, and people know him because of his stature in the field. I, on the other hand, have gotten involved in many organisations and attend many networking events. From the last ten years of doing this people know me.* (BA2's CEO)
		Learning and communication have been important to R&D.
BA1	*9.*	*We consistently see what we can do to improve it (BA1's instrument). We learn from the earlier prototypes and then bring in new parts and pieces and ideas.* (BA1's CEO)
	10.	*It is important to get input from the users. From this we can learn what we need to change. So it is important to reach out to them.* (BA1's CEO)
BA2	*11.*	*We have formal meetings where we get the staff together to share ideas and update everyone on what is going on. Each unit also meets on a regular basis to strategize on what they have learned.* (BA1's CEO)
	12.	*Learning also happens at the individual level. We have PhDs who are all trained and know how to go about their research and learn from what they did earlier.* (BA2's CEO)
		Transforming capabilities has proven important to R&D.
BA1	13.	*We knew that the device had to become smaller. So we set out to develop a miniaturised version. This made us devote a significant amount of resources, but we were able to accomplish this.* (BA1's CEO)
BA2	*14.*	*We saw the changes going on in the drug industry and focused our product on a technology that could help with this. (BA2's CEO)*
	15.	*We saw a need to develop a new product and quickly devoted resources to this, and from this we were able to come out with a new unit.* (BA2's CEO)

Source: Author

6.4.5 Financial assets and capabilities

The firms' R&D demanded significant capital to bring their products to a point of commercialisation. For this reason, the firms leveraged their paths, positions and processes to obtain the capital needed to finance their growth. Table 6-22 highlights the paths, positions and processes central to the development of the firms' financial resources and capabilities. Based on the coding and close-ended questions, each path, position and processes for each firm is placed in one of four categories based on its influence on the firm's development: high influence (H), medium influence (M), low influence (L) or no influence (N). The analysis for the major paths, positions and process is detailed below.

Table 6-22: BAs' financial paths, positions and processes

	BA1	**BA2**
INFLUENTIAL ON FINANCIAL PATHS		
Costly innovation	H	H
Raising capital	L	L
Public stock offering	N	N
VC	L	L
POSITIONS		
Scientific capabilities	M	H
Founders	H	H
Networks with investors	L	L
Investors were connected within financial community	L	L
Executive staff	H	H
Core innovation	H	H
PROCCESSES RELATED TO		
Raising capital	L	L
Conserving capital	H	H
Dealing with Investors	L	L
IPO	N	N
Transforming financial assets and capabilities	H	H
Grant writing	H	M

Source: Author

Paths

Several past decisions and future opportunities guided the financial needs of the firms. Table 6-23 highlights the paths important to the development of the firms' financial assets and capabilities.

The core technology had the largest bearing on the financial demands of the firms. Both firms' financial strategies revolved around their core technology. The firm's respective novel technology required substantial capital to develop. BA1 spent over $2 million in developing their core innovation, whilst BA2 spent over $3 million [Fin-pa core tech].

Early on the firms made the strategic choice to follow a path of financing their incubation through personal investment (Table 6-23; 6 and 7). However, the firm's strategies stemmed from a much different set of factors. BA1 decided to pursue this strategy because they wanted to avoid VC because of past experiences [Fin-pa VC]. They knew that VC is hard to deal with, and they could access capital from other places that did not require equity or control in the firm. In comparison, BA2's main founder was very inexperienced and did not know how to finance a venture. The only thing she thought she could do was to self-finance. This led her to obtain a $150,000 loan from her mother to start the business. In hindsight she wished she would have considered other financial strategies, but at the time she did not know any better and she was too busy concentrating on the other functions of the business.

Both firms' strategies proved successful, as they acquired the capital needed to start their firms. These two cases suggest that previous experience influences the financial strategies of a life science venture; with the more experienced founder knowing how to source capital for a new venture, and the inexperienced scientist having to learn how to finance a venture throughout the process of starting the firm.

Closely related, SBIR grants also influenced the strategic financial paths of the firms (Table 6-23; 5 and 9) [Fin-pa govt], but in different ways. From the onset BA1's strategy revolved around obtaining an SBIR grant to finance the early development of the firm. The firm successfully obtained $180,000 in the first year, which effectively launched the venture; this provided them the capital boost to focus full time on the venture. In contrast, BA2 did not receive an SBIR grant until year six. This is largely because the firm did not know how to obtain such a grant. After learning of the grant the firm looked into the

process and decided to apply for one. This proved beneficial as the firm received a $500,000 grant that greatly helped the firm. For both firms' grants provided critical capital inputs that had a substantial impact on their financial paths (Table 6-23; 5 and 9).

The initial commercialisation of the firms' products is another area that impacted their financial paths (Table 6-23; 10 and 13) [Fin-pa revs]. In year three BA2 started generating revenues that provided capital to further invest in the firm's technology. Likewise, BA1 started generating revenues in year four that contributed capital to the firm's research.

Large capital infusions or the potential for large capital infusions have had a bearing on the financial paths of the firms (Table 6-23; 11 and 14) [Fin-pa raising cap]. In year eight BA2 received an angel investment of over $1million. This has allowed the firm to expand its R&D resources and invest in several new applications that have large market potential. Similarly, BA1 at the time of this study was in the final steps of a major grant application. This grant would award BA1 $5.3 million for the continued development of their instrument, and it would offer many new financial paths to the firm. More specifically, it would afford the firm capital to invest new applications and it would allow the firm to apply for several patents.

It is evident from these cases that major R&D breakthroughs opened up new financial paths that have had or will have a major bearing on the firms' R&D.

Table 6-23: BAs' financial paths

FIRM		
		The core technology drove the financial demands of the firms.
BA1	1.	*This has cost a lot of money, so we have had to put a lot of thought and effort into financing the development of the technology.* (BA1's CEO)
	2.	*We have had to boot strap and cut costs whenever possible to develop this technology. It has been a struggle, but we have been able to develop the device*. (BA1's CEO)
BA2	3.	*So we had to come up with money to develop it. Initially I took a loan from my mother and paid for things on my credit cards.* (BA2's CEO)
	4.	Almost all of BA2's $8 million capital expenditures in the first seven years went to developing their core technologies. (Close-ended question)
		Strategic financial choices have influenced the firms' development.
BA1	*5.*	*The grants have provided the bulk of the funding. This has allowed us to develop our product. It has also made us devote time to the grant process.* (BA1's CEO)
	6.	*We choose to self-finance and get grants. We knew that this was going force us to boot strap and cut costs*. (BA1's CEO)
BA2	*7.*	*I made the choice to self- finance the venture because I didn't know any other way to finance the business.* (BA2's CEO)
	8.	*A friend of mine put me in touch with a venture capitalist, and he started asking me a bunch of questions about business models that I had no idea what he was talking about. So I hung up because I had no idea what he was talking about and decided that I did not need venture capital. So I continued to pay for the venture through self- finance.* (BA2's CEO)
	9.	*I wish I would have used SBIR grants earlier. I just did not know what they were. Once we found out about them we applied and got them. They have been a big help to the firm's finances.* (BA2's CEO)
		New financial resources have influenced the firms' financial paths.
BA1	*10.*	*We started getting some revenues in that have been helpful to financing some of our other operations. (BA1's CEO)*
	11.	*If we get this grant, it will transform our financial picture. It will allow us to invest in many different areas and will financially transform the firm.* (BA1's CEO)
	12.	*The $5.3 million will go to us and will allow us to move forward with several different applications.* (BA1's CEO)
BA2	*13.*	*The revenues really helped generate money that we used to invest back in the company.* (BA2's CEO)
	14.	*In 2008 we got the angel investment, which has helped us get a few more projects going and was especially beneficial to our European expansion.* (BA2's CEO)

Source: Author

Positions

The firms leveraged several positions to develop their financial resources and capabilities. Table 6-24 presents evidence supporting the main ones.

The founders of the firms proved to be important resources to the development of financial assets and capabilities [Fin-po founders]. Table 6-24 (1-5) depicts a representative sample of evidence that underscores the importance of the firms' founders. BA1's founder provided much of the early seed capital and is the main reason the firm secured early grant money (Table 6-24; 1 and 2). In a similar fashion BA2's main founder also provided most of the early capital. Furthermore, both firms' founders proved important to conserving funds to keep their young ventures viable (Table 6-24; 3 and 5). They both operated on a 'shoestring budget' where they cut costs and obtained as many free or low cost inputs as possible. It is evident that the founders were the ones who were driving the early financial positions of the firm.

The second main position that the firms drew on to develop their financial resources and capabilities is their core technology (Table 6-24; 6-10) [Fin-po core tech]. BA1's technology helped it attract funding grants that allowed the firm to finance a large portion of its operations. Likewise BA2's technology helped them attract grants and an angel investor. The firms' technology showed large potential to help society, which is what the firms leveraged to attract the grants. For BA2 the large profit potential of the technology is what attracted the angel investor.

Both firms technology started generating revenues early on that helped to finance the firms' development. This revenue provided important financial resources that the firms used to supplement their development. It is evident from these two cases that the technology's cost of development is a central path that drives the demand for capital, but potential profitability of the technology provided a resource to leverage in attracting grants and investment. Moreover, these cases illustrate that technology that comes to market quickly can greatly help the firm by providing financial resources that supplement the firms' development.

Closely related, the firms' technology helped attract partners who provided capital and money saving inputs (Table 6-24; 1-14). For example, interest in a technology to help in bioterrorism defence led to a partnership between the BA1 and the US Army. The Army

provided some funds, but even more importantly they provided R&D inputs worth millions of dollars. Had BA1 had to internally develop these competencies, then the firm would have had to have acquired additional capital.

Similarly, BA2's technology helped them attract several important relationships (Table 6-24; 13 and 14). These relationships helped the firm save capital by providing low cost R&D inputs. For example, the technical inputs from one of their university relationships would have cost millions of dollars to develop.

It is evident from these cases that partnerships influence financial resources. These cases show that partners have a major direct and indirect effect on the firm's financial resources. In some instances partners directly infuse capital into the firms, and in some cases the partners indirectly supplement a firm's financial resources from the inputs that they provide. In some instances, such as BA1, these indirect financial contributions can be one of the most important financial positions of a firm.

Table 6-24: BAs' financial positions

FIRM		
		The founders and top managers provided key financial positions.
BA1	1.	*A good portion of the funds have come from personal savings, and I have been the one that has sought out the grants.* (BA1's CEO)
	2.	*I am the one that has gone after the grants and completed the applications.* (BA1's CEO)
	3.	*I have been reaching out to partners and keeping costs down in every possible way. Because of my inputs we have been able to save a substantial sum of capital*. (BA1's CEO)
BA2	*4.*	*I went out and got a 150K loan from my mother and put a bunch of expenses on my credit cards.* (BA2's CEO)
	5.	*I have kept the costs down and this is how we were able to get the business going without a big upfront investment. I was doing everything at first and was operating out of my school's lab.* (BA2's CEO)
		The firms' technology helped develop financial resources.
BA1	*6.*	*One of the main reasons that we got the grants is because the technology filled the need the grant was looking for. They put requests out for certain areas and our technology fit.* (BA1's CEO)
	7.	*We are in the running for this major grant because our technology is superior. Our product analysed the particles many times faster than the other applicant's product did. This has given us a big leg up.* (BA1's CEO)
	8.	The firm won three SBIR grants, which totalled $925,000. These grants are based on the potential of a technology to help the US government solve a problem, and these grants are ultra-competitive as less than 15% of applicants are awarded a grant (NIH, 2011).
BA2	*9.*	*Our technology is why we were able to get the two SBIR grants. The committees look at the potential of an innovation and award money largely on the potential of a technology.* (BA2's CEO)
		Partners indirectly provided financial resources.
BA1	*10.*	*The Army provided a lot of valuable inputs. It could have cost us in the millions to develop the biotechnology inputs that we got from them.* (BA1's CEO)
	11.	*The partners provided inputs that we could not have afforded to develop.* (BA1's CEO)
BA2	*12.*	*Our partners have been a big help to saving us money. The university has been a big help. The science and labs we had access to was (sic) worth a lot of money.* (BA2's CEO)
	13.	*It is hard to exactly quantify the value of the resources that the partners have contributed, but it would be quite large. From the inputs to the testing to the access to researchers. It is a lot.* (BA2's CEO)

Source: Author

Processes

A number of routines proved important in the development of the financial resources and capabilities necessary for the firms' development. For the most part the firms' routines were quite similar, but there were also some noticeable differences. Table 6-25 presents a representative sample of evidence illustrating the most important financially-related processes.

Processes revolving around conserving capital have proven vital to the firms' financial resources (Table 6-25; 1-4) [Fin-proc conserve]. These were especially important early on. BA1 has 'boot-strapped' most of its operations. It has a small staff of three who perform all of the main scientific and functional duties of the firm. They have been paid at under market wages with the intent that they will receive large dividends once the firm grows. Furthermore, BA1 has operated out of low cost operational facilities to cut down on overhead expenses. The main motivation for cost savings stems from the lack of large capital reserves, which is a result of the firm's strategic decision to avoid equity investors such as VCs. Driving the cost-saving routines is the CEO who has drawn on his many years of experience to implement cost-cutting routines without losing essential functions (Table 6-25; 1-4).

Comparatively, BA2 has also developed an advanced set of routines in cutting costs. Initially the firm was run out of the university lab where the founder was finishing her PhD. Even after completing her doctorate, she kept the business housed there to cut down on costs. For the first couple of years she was the only employee. There was ample need for other employees, but she performed all of the tasks in order to conserve capital. As the firm has grown, it has kept to its cost-cutting ways. The firm currently operates in an area that has incentivised them to be there, and it operates as lean as possible in all areas of its operations.

These two cases demonstrate clearly that cost cutting routines are especially important to life science ventures – especially in the early operations and particularly to firms that are incubated out of personal savings.

The second set of processes that the firms have become proficient in is grant writing (Table 6-25; 6-7). Their proficiencies stem from different sources however. BA1's grant writing abilities come primarily from the main founder who has written dozens of grants in his

career (Table 6-25; 5). He has used his knowledge and capabilities in this area to land over five grants for BA1. These grants have provided the bulk of the capital that has financed the firm's development.

In contrast, BA2 had to learn processes related to finding, applying and executing a grant. The firm's main founder did not know what an SBIR grant was until four years into the firm's operations (Table 6-25; 6). After learning about the grant, she created systems to apply for SBIR grants, which proved successful, as the firm has landed over $900,000 in grant funds. These grants provided a big boost to the firm's R&D and allowed them to expand from two product offerings to four.

The evidence from these two cases illustrates how influential the SBIR grants can be on small firms. Although the grants required the firms to invest substantial time and develop routines for navigating the application and maintenance processes, the capital from the grants proved vital to their early growth.

Processes related to transforming financial strategies also played an important role in the firms' growth (Table 6-25; 8-11) [Fin-proc transform]. BA1 went through several periods where they had to adapt their operations because of cash flow problems. This required the firm to cut back operations and strategically choose the areas to invest their limited capital. Most recently the firm has had to prepare for its largest possible transformation from the $5.3 million grant that they are anticipating receiving. This capital will fundamentally change the firm's financial operations and strategies. The person leading the transformation processes for the firm has been the CEO. He has drawn on his experience and successfully found a way to manipulate the firm around to accommodate the drastically changing financial situations of the firm. If BA1 receives this grant, they will have to create more formalised systems for accounting and operating the firm. Because of the size of the grant, the firm will have to put more sophisticated routines in place for reporting on how the funds have been used.

Similarly, BA2 has undergone several organisational transformations that have influenced the firm's financial resources. The firm's main founder was the only employee in the first couple of years, and she performed almost every one of the firm's functions. In the third year the firm started generating revenues, and the firm's operations expanded rapidly. Within a few months the firm realised a growth path and quickly went from a firm of one

employee to a firm of over ten employees. This growth forced them to develop routines for managing cash flows and strategizing for larger investments. The main founder and a couple of the staff members designed a reporting system that has allowed the firm to navigate its increased financial complexity.

These two cases illustrate how quickly financial situations can change in life science ventures. Cash flows quickly come and go in this industry, and it is important that firms rapidly respond and adapt their financial resources and strategies to accommodate this rapid change. When new capital is introduced, firms must introduce processes for managing their expanded financial resources, and when cash flows become tight, it is imperative that firms implement routines for strategically conserving capital.

Table 6-25: BAs' financial processes

FIRM	
	Conserving capital is a vital routine.
BA1	1. *It has been a struggle. We have constantly kept costs down in every way that we can. Paying ourselves very little, only purchasing the necessities and getting things done as cheaply as possible.* (BA1's CEO)
	2. *Boot-strapping is imperative when trying to keep costs down like we have. Since the beginning we have been operating bare bones. We have grown accustomed to saving money. It has become ingrained in us.* (BA1's CEO)
MD2	3. *When you are paying for things on credit cards you have to watch every expense and get things done as cheaply as possible*. (MD2's CEO)
	4. *We have processes for keeping costs down and strategically outsourcing to save capital. We are small and keep our operations highly efficient.* (MD2's CEO)
	Grant writing processes have proved vital.
BA1	5. *I have applied for over 150 grants, so I know how the process works. For the company these processes have importance. First you have to present your product so that it meets the need. Then you have to convince the committees that it does this. Once you receive the grant you then have to have processes in place for making the government happy with you.* (BA1's CEO)
MD2	6. *I did not even know what the grants were. Once we found out about them we then created systems for finding the appropriate grants, applying for them and then maintaining them.* (MD2's CEO)
	7. *Grant processes have served us well. Finding and writing grants has been important to learn.* (MD2's CEO)
	Transformation capabilities have been important to the firm's financial resources.
BA1	8. *When we got the larger grant in this it changed the way we did things and how we approached our products development.* (BA1's CEO)
	9. *If we get this $5 million we will revamp our operations. We will be able to move forward with initiatives such as our patents and it will make us formalise our operations.* (BA1's Chairman)
MD2	10. *The increased capital changed the company. We had to put in systems for accounting and HR and had to more formally strategize about how and where to invest*. (MD2's CEO)
	11. *As your financial situation changes, so does the company. Our systems have expanded and the strategic outlooks change as well.* (MD2's CEO)

Source: Author

6.4.6 BA firms' conclusion

Financial and research resources and capabilities drove the firms' early growth. The R&D resources and capabilities demanded substantial investment: the firms' technologies were costly to develop and took a long time to develop, which made the firms sustain several years from the inception without any revenues. This coupled with the strategic choice of both firms to self-finance the venture, made saving capital and obtaining government grants paramount. In order to pursue the path of developing a novel technology, the firms leveraged their scientific talents and founders' experience. From these the firms created processes to develop the needed financial and R&D resources and capabilities. In general the firms relied on sensing, seizing, learning and organising processes to leverage their positions to take advantage of the strategic paths available to them. Although there were distinguished similarities in the development of the firms' R&D and financial endowments, there were also numerous differences. The most apparent difference was the relative experience level of the two firms' founders; BA1 had a highly experienced founder whilst BA2 had a very inexperienced founder. These experience levels had a major bearing on the firms' R&D and financial resources and capabilities development.

In the final analysis though, both founders successfully navigated a unique set of paths, positions and processes to develop and commercialise a novel instrument for analysing particles and biological agents.

6.5 Triangulation and cross-case analysis

This section presents the responses to the validation questionnaire that each firm completed in the final step of this research. It serves to triangulate the earlier analysis, and it also serves as a framework for the cross-case analysis. Each major path, position and process that surfaced is discussed along with any discrepancy that arose between the earlier analysis of the interview data and the response to the questionnaire.

The questionnaire that the firms completed is based on pragmatic validation, which is a powerful means to triangulate findings. This is a form of validation in which the perspective of the findings is judged by the sample of interest (Kvale, 1987). In in the present study it is the key informant from the case firms. Each of the major influences found to be important to the development of R&D and financial resources and capabilities

was presented in a survey to each of the case firms in this study, and the respondents rated the importance of each influence. This data does not serve for statistical testing, but instead each response is compared to the analysis from the qualitative data for each of the firms. This serves to validate and triangulate the findings. In general, most of the findings were validated, but there were a few small discrepancies. In those instances the researcher gathered more information to clarify the discrepancy, and an explanation for the discrepancy is offered.

The questions are divided into two sections; one for R&D and one for finance. Each section is further broken into three groups of questions. The first group of questions asks about the important paths that led to the development of the firm's resources and capabilities. The second group of questions asks about the important positions used in the development of the firm's resources and capabilities. The third group of questions asks about the important processes leading to the development of the firm's resources and capabilities. The results from all of the firms' responses are presented below along with a discussion of how the results of the survey compared to the findings from the qualitative analysis.

6.5.1 Triangulation of R&D paths

The first set of questions looked at 'to what extent did opportunities and past decisions have on the development of the firm's R&D?' It is evident from the earlier analysis and Table 6-26 that innovation is the most ubiquitous influence on the R&D path of the firms. University partnerships also proved influential on the firms R&D paths. Several other past decisions and future opportunities also influenced the development of the firms' R&D resources and capabilities, but these influences varied amongst the firms. The discrepancies that surfaced from the responses and the earlier analysis are noted in the discussion below.

All of the firms rated the core technology as very important (Table 6-26; 1). This is in line with the earlier analysis and is one of the most important themes of this study. The firms' strategies revolved around a novel technology. The pursuit of this technology drove the firms to develop a unique set of R&D resources and capabilities in its pursuit. Thus the core technology has clearly been an important path in the development of the firms' R&D.

In general, VC did not have a major influence on the firms R&D paths (Table 6-26; 2). Three of the firms (BA1, DD1, and MD1) did not receive VC, so it is to be expected that VC did not have an influence on these firms R&D. However, only DD1's VC, of those that drew on VC, had a major influence on R&D paths. Their VC provided capital and management inputs that greatly affected the firm's strategic R&D pursuits; i.e. it afforded them the capital to develop their R&D resources and capabilities.

The firms ranking of the importance of industry partners on their R&D paths varied greatly (Table 6-26; 3). However, for the most part this is in line with the data gathered in the first part of this study. BA1 and BA2 relied heavily on partners for inputs, and these industry partners had a major impact on the firms' R&D paths, whereas the other firms did not have strong relationships with firms in the field and in some of the cases purposely avoided partnerships. The response from DD1 did vary somewhat from the analysis of the earlier data. For DD1, it seemed apparent that industry relationships were important to their R&D paths, but there was only one partner firm that influenced the strategic path of DD1, and they merged with this firm. Thus the respondent to this survey did not see them as a partner firm, but instead a part of DD1. The relative importance of partners seemed to revolve around the firm's strategy and availability of partners. Moreover, whilst the importance of partners varied, the study did show that partners can have a profound effect on a firm's R&D evolution. For example, industry partner inputs to BA2's R&D had a significant impact on their R&D.

An important theme from this study is the importance of university partnerships to the R&D paths of the firms (Table 6-26; 4). Three of the firms' (BA1, BA2 and MD2) innovations emanated from universities, and for almost all of the firms, university partnerships opened up research opportunities that influenced the strategic pursuits of the firms. MD1 is the one exception to this, as they had no university relationships. Overall university science opened up R&D opportunities for the firms and university partnerships influenced the direction of the firms R&D. This is one of the major themes to surface from this study.

For the most part government partnerships did not influence the strategic direction of the firms' R&D (Table 6-26; 5). The two exceptions to this are BA1 and BA2. Both of these firms entered agreements that greatly influenced their firms R&D paths. BA1 had a couple of relatively large research projects that impacted the firm, whereas BA1's entire existence

had been driven by research partnerships with the government. Thus the opportunity for government partnerships has had a major bearing on these firms' R&D paths.

Scientific discoveries by the firm had a large bearing on the strategic paths of the firms' R&D (Table 6-26; 6). All of the firms made progressions that changed the outlook of their R&D and motivated the firms to reorganise their resources to accommodate the scientific discoveries. The one discrepancy from the earlier data is with BA1 ranking this a 4. Further information revealed that this is because the founder clearly thought this was a major progression for the firm, but he did not view this as a scientific breakthrough on a large scale. However, further information clarified that internal scientific discoveries did have a major bearing on the firm's R&D paths by opening up new R&D paths for the firm. Overall scientific progressions by the firms had a major impact on the R&D paths of the firms. More specifically, these opened up new research avenues that affected the strategic pursuits of the firms.

Scientific developments in the wider industry are seen as having a low influence on the R&D paths of the firms, except for BA1 and MD2, which marked these as high (Table 6-26; 7). For the five firms there were no major events in the industry that presented great opportunities or adversely affected the firms R&D paths. MD1's rating of scientific breakthroughs as extremely high came as a slight surprise, as the earlier data suggested that these events had an impact, but not a vital impact. The follow up revealed that there were a couple of developments in the industry that allowed MD1 to develop its device, and this is why scientific discoveries in the industry was rated so highly. In general, discoveries in the industry did not have a major impact on the firms, but BA1 and MD1 show that these discoveries can have a bearing on the on a firm's R&D paths.

Five of the firms rated 'FDA, EU or other government approvals' as high to extremely high; whereas, DD1 rated this as influential and BA1 rated this as not influential at all (Table 6-26; 8). DD1's response differed a little from the results found earlier in the study, which is largely explained by the respondents' experience in the industry where FDA and government approval are simply part of the drug development process. Further information revealed that these approvals in fact have been highly influential on the strategic R&D pursuits of the firm. BA1's view of this category as having a low influence was driven by the fact that the firm has invested almost no resources in FDA approval. However, further clarification indicates that the firm has strategically planned around FDA approval, so this

did have an indirect effect on BA1's R&D paths. Overall, FDA and other government approvals have been highly influential on the strategic paths of the firms. The firms have strategized around FDA and in most cases devoted significant resources to these procedures. Moreover, in many cases the substantial resources devoted to FDA limited the other areas the firms could focus their R&D.

The respondents rated patents as influential to highly influential on the development of their R&D (Table 6-26; 9), which reaffirms the earlier findings that patents and the pursuit of patents have an impact on R&D paths. In general the firms developed their R&D based on patents or the pursuit of R&D affected what decisions were made in regards to R&D; e.g. three of the firms (BA2, DD1 and MD1) strategized largely around obtaining patents.

Table 6-26: R&D paths triangulation

			1= to no extent 7 = to a very great extent						
			1	2	3	4	5	6	7
1.	Your firm's core innovation(s)	BA1							●
		BA2							●
		DD1							●
		DD2							●
		MD1							●
		MD2						●	
2.	VCs	BA1	●						
		BA2	●						
		DD1	●						
		DD2							●
		MD1	●						
		MD2		●					
3.	Industry partnerships	BA1					●		
		BA2							●
		DD1	●						
		DD2	●						
		MD1	●						
		MD2		●					
4.	University partnerships	BA1						●	
		BA2							●
		DD1					●		
		DD2							●
		MD1	●						
		MD2					●		
5.	Government partnerships	BA1							●
		BA2				●			
		DD1		●					
		DD2	●						
		MD1	●						
		MD2	●						
6.	Scientific breakthroughs by your firm	BA1				●			
		BA2							●
		DD1							●
		DD2							●
		MD1							●
		MD2						●	
7.	Scientific breakthroughs in the industry	BA1	●						
		BA2						●	
		DD1		●					
		DD2	●						
		MD1							●
		MD2	●	●					
8.	FDA, EU or other approvals	BA1	●						
		BA2						●	
		DD1							●
		DD2				●			
		MD1							●
		MD2					●		
9.	Patenting	BA1					●		
		BA2							●
		DD1							●
		DD2					●		
		MD1							●
		MD2				●			

Source: Author

6.5.2 Triangulation of R&D positions

Table 6-27 summarises the important positions that the firms leveraged in the development of their R&D resources and capabilities. From this it is evident that four resources proved important to the firms' entire R&D: (1) core technology, (2) scientific staff, (3) star scientists and the (4) founders. Several other resources also proved important, but the relative importance of these resources varied amongst the firms. The results that surfaced in the first part of the study are consistent with the responses below.

A central theme to emerge from this study is that the core technology is an important resource that the firms leverage in the development of their R&D resources and capabilities. This theme recurred throughout the interview analysis and is validated by Table 6-27 (1) below. It is apparent that the firms leverage their core technology to attract other R&D inputs; specifically partner opportunities arise because other firms want access to the unique technology. Moreover, discoveries in the technology allow the firms to build other R&D assets such as patents from discoveries in their core technologies.

Another important resource that all of the firms leveraged in the development of their R&D are their scientists. The respondents rated their scientific staff as 'important to extremely important' (Table 6-27; 2). This is in line with the earlier analysis findings that scientists contribute important inputs to a firm's R&D. Specifically, they contributed knowledge resources that allowed the firms to progress their R&D. Not surprisingly, these cases show how vital of a resource scientists are to the development of a firm's R&D.

If their scientific staff is a core resource, this is even more so for their leading scientists. With their record of scientific discovery, as evidenced by patenting and academic citations, they are core resources to the development of life science innovations. This theme emerged from the earlier analysis and is confirmed by the rankings of this category below in Table 6-25 (3). For most of the firms the star scientists made contributions that greatly helped in the progression of the firms' technologies. For example, a star scientist for BA2 contributed several chemical techniques that allowed their instrument to analyse chiral chemicals. All of the responses to this question aligned with the analysis from the earlier part of the study that star scientists can be important resources to the development of novel life science innovations.

One of the central themes to come from the earlier analysis is the importance of the founders to the development of the firms' R&D (Table 6-27; 4). This is validated by the very high responses the respondents put for the importance of the founders to the development of R&D. All of the firms had founders who were critical resources to their firm's R&D. Specifically, they made large contributions to the development of their firms' technology. The firms' founders created or sensed out the core innovation and then continued to use their scientific knowledge and skills to help progress their firm's R&D.

The respondents' ratings on the inputs of their executive staff and board varied, which collates with the earlier analysis (Table 6-27; 5). MD1, MD2 and BA3 executive staff and board members are important resources to the firms R&D. They provided scientific knowledge and access to other scientific inputs that have been vital resources to these firms' R&D. In contrast the other three firms' (BA1, DD1 and DD2) executives and board members have been important but have not provided critical R&D resources. They have mainly contributed ideas and occasionally helped the firms make contacts that help in the firm's research.

The firms rating of the importance of university resources varied, which reflects the earlier findings from the study (Table 6-27; 6); three of the firms (BA1, BA2 and DD1) rated the importance of university resources as high to extremely high, two of the firms (DD2 and MD1) rated this as moderately important and one firm rated this as of no importance. The firms that relied on university resources received important scientific inputs from universities. These resources proved vital to the firms. For example, BA2 had research performed in a university lab that had capabilities that few labs in the world have. Firms in which university partnerships were of moderate importance mostly used the universities for testing inputs. Interestingly, the universities provided resources to all of the firms, but the relative importance of these inputs varied. There was no theme as to what drove the importance other than that prior strong connections with a university influenced the relative importance of university resources. BA1, BA2 and DD1's strong connections with the universities resulted from either the firm's founder being an alumnus of the university or the firm's founder having worked with the university in the past.

The responses to the importance of industry partner resource inputs varied amongst the firms (Table 6-27; 7), but this is in line with the earlier findings. There was not a general

theme to emerge on the discrepancy of the relative importance of partners. Each firm had a unique motivation for either working or not working closely with industry partners.

The importance of government resources to the firms varied amongst the respondents (Table 6-27; 8), but collated with the earlier analysis. Only one of the firms received vital resource inputs from the government – BA1. This firm's development revolved around these resource inputs. In comparison BA2 and DD1 received some inputs on a couple of R&D projects that helped the firms, but overall the government resources did not prove vital; whilst DD2, MD1 and MD2 received no resources from the government. Overall government resource inputs did not have a major bearing on the firms' R&D, but in certain circumstances government inputs did provide a boost, as was the case of BA1 where government resources contributed substantially to the firm's R&D.

The respondents rating of the importance of patents as a resource to the firms' R&D varied greatly (Table 6-27; 9). Three of the firms (BA1, BA2 and MD1) rated patents as an important resource. For these firms patents provided protection, which allowed them to move their product to a point of commercialisation without fear of losing intellectual property. For DD1 and MD2 the patents were not of critical importance, but they did prove to be resources that the firms leveraged to develop research opportunities. Patents proved to be of no importance to DD2's early growth. This firm applied for patents, but it took eight years to get them, so the firm's patents did not provide important R&D resources. However, the follow-up with the firm indicates that now that the firm has the patents, they will become important resources to their R&D. Interestingly, the importance of patents varied amongst the firms and the reason for the variation differed. The one theme to emerge on this is that the relative ability of the firm to protect the intellectual property without patents influenced the relative importance of patents. However, the cases only provided some indications of this, and there is not substantial evidence to put this forth. Also interesting is that patents and the patenting process was highly influential on the firms' R&D paths; i.e. the pursuit of obtaining patents affected their R&D strategies. However, the relative importance of the patents as a resource varied in importance.

Specialised research facilities are a resource varied in terms of its importance, which for the most part is in line with the earlier findings. The firms that rated this as extremely influential needed facilities that are very rare and have highly sophisticated equipment. The high rating for this from BA1 was stronger than had emerged in the earlier interviews, but

further information revealed that the Army facility where they conducted a lot of research proved vital as there are almost no other research facilities in the world that have the capabilities to bring together the three sciences that the firm's technology is based on; thus this has been a vital resource to BA1. Specialised research facilities provided some important inputs for MD1 and MD2, but these were for select R&D functions. In other words, a specialised R&D facility has only been important resource for certain functions. For BA2 and DD2 most of their research could be conducted at just about any laboratory, so specialised R&D facilities did not prove important to them.

Table 6-27: R&D positions triangulation

			1= to no extent 7 = to a very great extent						
			1	2	3	4	5	6	7
1.	Your firm's core technology	BA1							●
		BA2							●
		DD1							●
		DD2							●
		MD1							●
		MD2						●	
2.	Your firm's scientific staff	BA1							●
		BA2							●
		DD1					●		
		DD2							●
		MD1							●
		MD2						●	
3.	Star scientists	BA1			●				
		BA2							●
		DD1							●
		DD2							●
		MD1							●
		MD2					●		
4.	Founders	BA1							●
		BA2							●
		DD1							●
		DD2							●
		MD1							●
		MD2						●	
5.	Executive staff and board of directors	BA1			●				
		BA2						●	
		DD1					●		
		DD2			●				
		MD1							●
		MD2						●	
6.	University inputs	BA1					●		
		BA2							●
		DD1						●	
		DD2			●				
		MD1	●						
		MD2				●			
7.	Industry partners inputs	BA1					●		
		BA2							●
		DD1	●						
		DD2	●						
		MD1	●						
		MD2					●		
8.	Government inputs	BA1							●
		BA2			●				
		DD1				●			
		DD2	●						
		MD1	●						
		MD2	●						
9.	Patents	BA1						●	
		BA2							●
		DD1				●			
		DD2	●						
		MD1							●
		MD2					●		
10.	Specialized R&D facility***	BA1							●
		BA2	●						
		DD1	●						
		DD2							●
		MD1				●			
		MD2				●			

Source: Author

6.5.3 Triangulation of R&D processes

Table 6-28 presents the important processes used to help develop the firms' R&D resources and capabilities. It can be summarised that by trend each firm relied on a unique set of processes to develop its R&D. However, sensing technology and learning are important processes that all of the firms used to develop their R&D. Only a few minor discrepancies surfaced from the responses and the earlier interviews. These are discussed below.

One of the main themes from the earlier analysis is that sensing out technology has clearly been an important set of routines for the firms. This is validated here as all of the respondents marked this question as extremely high (Table 6-28; 1). All of the firms had routines in place that allowed them to identify a technology to develop and commercialise. Some of the firms sensed out technologies that were already in development, whilst the others used sensing routines to find an idea for a novel life science innovation. These routines revolved around scanning the scientific community for emerging science, staying in contact with people in the industry and being abreast of industry trends and developments. These routines happened at the network and firm levels, but on the individual level is where these routines transpired the most; i.e. each of the firms in this study had an individual or a small group of individuals driving their technological sensing routines.

The responses on the importance of networking routines varied amongst the firms (Table 6-28; 2), which collates with the earlier findings. These routines proved very important to BA1 and BA2. Both of these firms received important R&D inputs from their networks, and their networks resulted from their networking capabilities. For three of the firms (DD1, MD1 and MD2) networking routines proved moderately important. These firms are fairly well networked and have used their networking capabilities to capture some key R&D inputs. Lastly, networking routines did not prove important to DD2's R&D.

Key individuals (i.e. the founders and TMTs) drove the networking for the firms. Their networking processes ranged from as simple as picking up and calling a contact that might be able to help the firm to as complicated as BA2's CEO's system for embedding herself into a network through trade show attendance, volunteering in industry events and participating in formal networking events.

Learning processes have proven to be important to the firms' R&D (Table 6-28; 3). The earlier findings indicated that these processes helped the firms progress their core technology, which aided in attracting new resources. This is substantiated by the high ratings that the respondents marked for this question. These processes transpired at the network, firm and individual levels. BA1 and BA2 practised learning routines at the network level. They worked with their partners on joint research where they learned from earlier research paths. For example, with their partners they dissected why certain projects did not work.

Similarly, learning in R&D took place in all of the cases at the firm level. The firms worked with everyone within the organisation as to what progressions had been made and as to what could or could not be done based on their earlier research. The results for all of the cases also indicated that learning routines are most evident at the individual level. All of the firms have researchers who work autonomously on their individual projects and have their own systems in place for how they dissect problems and take in new information from their earlier findings.

The responses on the importance of routines related to tracking and sharing information varied amongst the firms (Table 6-28; 4), which is in line with the earlier findings. For four of these firms (BA, BA2, DD1 and MD2) these routines allowed the firms to share information amongst the various researchers working on the firm's technology. In general, the routines relied on written and oral communication, and in BA2's case they have a formalised system for tracking and sharing scientific information amongst their research team. All the firms' information-sharing routines helped their researchers collaborate and strategize on the most effective way to progress their R&D. For DD2 and MD1 these routines did not prove important. This is largely because these firms' technologies were developed by a very small group of individuals that did not need to share information to a wide audience.

Table 6-28: R&D processes triangulation

		1= to no extent 7 = to a very great extent						
		1	2	3	4	5	6	7
1.	Finding (sensing) the core technology	BA1						●
		BA2						●
		DD1						●
		DD2						●
		MD1						●
		MD2						●
3.	Networking	BA1					●	
		BA2					●	
		DD1			●			
		DD2	●					
		MD1			●			
		MD2				●		
4.	Learning from previous research paths	BA1					●	
		BA2					●	
		DD1				●		
		DD2						●
		MD1					●	
		MD2				●		
5.	Tracking and sharing information	BA1					●	
		BA2				●		
		DD1				●		
		DD2	●					
		MD1	●					
		MD2				●		

Source: Author

6.5.4 Triangulation of financial paths

The responses to the important paths are presented in Table 6-29. It is evident from this table that the core technology and government-related processes had a major impact on the development of the firms' financial resources and capabilities. Several other opportunities and past decisions also influenced the firms' financial demands, but the relative importance of these varied amongst the firms. In general the responses to the questionnaire aligned with the earlier analysis. This confirms the detailed discussions in sections, 6.2, 6.3 and 6.4 above.

An important theme from this study related to the development of financial resources and capabilities is that the costly nature of developing a novel technology dictated the firms' financial strategies and outlooks (Table 6-29; 1). DD1 is the one respondent who did not mark this as a highly influential path. Instead he marked this as low. This came as a surprise as the earlier analysis indicated that the great cost involved with developing a drug

technology drove DD1 to develop advanced financial resources and capabilities. However, further information revealed that the drug technology itself was not overly expensive to develop, but the activities involved with developing the drug were expensive. Items such as FDA testing and developing production capacities did create a demand for specialised financial resources and capabilities. Thus the core technology indirectly drove the financial paths of the firm.

In short, all of these firms were new life science ventures that were financially constrained yet pursued the development of costly technology. This dictated the financial paths that the firms went down.

Table 6-29 (2) depicts that raising capital proved as an important path to three of the firms (DD1, DD2 and MD2), but not to the other three firms (BA1, BA2 and MD1). Further information gathered from the firms which raising capital was not highly important revealed that this is because of these firms' decision to self-finance a large portion of their early growth; this meant they did not have to spend a lot time and effort on raising capital.

Only two of the respondents (MD2 and DD1) rated investor relations as influential on the financial paths of the firms (Table 6-29; 3). This is not a surprise as these responses are in line with the findings from the interviews. For the most part the firms did not have to expend considerable time dealing with investors. Interestingly, MD2 is the only one of the three VC-backed firms that had investors that impacted the financial paths of the firm. They along with DD1 had to spend considerable time meeting with investors. This has been time that has drawn from the TMTs time and has had an effect on the firms' financial paths.

For the most part an initial public stock offering (IPO) has not had a large impact on the firms' financial paths (Table 6-29; 4). Four of the firms are not publicly traded and have not looked into the process of going public. DD1 and DD2 are publicly traded, and this has greatly affected their financial paths. The need for public financing for these firms stemmed from the great cost in developing novel drugs. Surprisingly DD1 rated IPO as having no influence. However, further information revealed that this is because the firm did not go public on their own accord, but instead merged with a publicly traded firm. Further information also revealed that the public stock markets have had an effect on the firm's strategic path; mainly through the capital that it offers.

Another important theme relating to this study comes from the impact that government approvals have on the financial paths of life science firms. The earlier findings put forth that these approvals have had a major bearing on the firms' financial paths, and Table 6-29 below confirms this. These approvals are expensive and time-consuming and have had a major impact on the financial paths of the firms; i.e. they have had to strategically acquire the capital needed for this. Had the firms not have had to contend with these government-related processes, then they could have avoided considerable financial demands; which would have had a significant impact on their financial paths. BA1 is the one firm that these processes did not affect. This is because BA1 made the strategic choice not to pursue applications that required government approval. However, these processes still indirectly influenced BA1's financial paths as the firm strategized largely around avoiding applications that required FDA or other government approvals.

Table 6-29: Triangulation of financial paths

			1= to no extent 7 = to a very great extent						
			1	2	3	4	5	6	7
1.	Costly to develop innovation(s)	BA1						●	
		BA2							●
		DD1							●
		DD2	●						
		MD1							●
		MD2					●		
2.	Raising capital	BA1		●					
		BA2	●						
		DD1						●	
		DD2							●
		MD1	●						
		MD2							●
3.	Dealing with investors	BA1		●					
		BA2	●						
		DD1						●	
		DD2		●					
		MD1	●						
		MD2					●		
4.	Initial public stock offering (IPO)	BA1	●						
		BA2	●						
		DD1							●
		DD2	●						
		MD1	●						
		MD2	●						
5.	Costly government approvals such as patents or FDA	BA1	●						
		BA2					●		
		DD1						●	
		DD2						●	
		MD1							●
		MD2						●	

Source: Author

6.5.5 Triangulation of financial positions

Table 6-30 summarises the responses to the questions about the important positions (resources) that the firms leveraged in the development of their financial resources and capabilities. It is evident from this table that the firms relied on a unique set of resources to develop their financial resources and capabilities. Only a few discrepancies surfaced from the responses and the earlier analysis. These are noted in the discussion below.

One of the main themes to come from the earlier analysis is the importance of the founders to the development of the firms' financial resources and capabilities. For the most part this is validated by the very high responses the respondents put for the importance of the founders to R&D (Table 6-30; 1). All of the firms had founders who were critical resources to their financial resources and capabilities. The one exception to this is DD1 who rated this as very low. Further information from the firm reveals the initial founders were not influential in raising capital, but instead the CEO is the one who did most of the

fund raising. However, the CEO has been a part of the company almost since inception and holds significant stock. After further consideration the firm sees him as a founder, and thus with him included as a founder, the firms' founders did provide critical resources to the firm's financial resources and capabilities.

The founders' resource contributions came in the forms of the capital they invested, access to their network of investors and their capabilities in raising capital. In all of the cases the firm's founders made substantial resource contributions in these forms that greatly aided in developing their firm's financial resources and capabilities.

The responses to the question about the impact of the executives and board member's resource contributions to the development of the firm's financial resources and capabilities varied (Table 6-30; 2). This reflects the earlier findings that demonstrated how some of the firms had significant financial resource inputs from their executives and board members. Four of the firms' (BA1, DD1, MD1 and MD2) executives and boards made substantial resource contributions. More specifically, they contributed capital, access to financial networks, and capabilities in raising capital. BA2 is the only one to mark this category as low, as their executives and board members did not contribute financial resources.

For the most part VCs did not contribute many resources that helped the case firms develop their financial resources and capabilities (Table 6-30; 3). Even the firms that received VC (DD1, DD2 and MD2) only rated VC resources as having a low to moderate impact on the development of financial resources and capabilities. These firms received some capital from the VCs, and the VCs also opened up networks, but these resource inputs did not prove critical to these firms. The other three firms did not receive VC, which explains their low rating of VC influence. Interestingly, all of the firms, even the ones that received VC, expressed their displeasure with the VC model. This is largely why the firms have tried to stay away from VC resource inputs. Specifically the firms felt that VCs no longer want to invest in risky ventures and that it has become overly difficult to attract VC investment.

In general the firm's core technology helped them attract investment capital (Table 6-30; 4). All of the firms, except MD1, received some form of outside capital, and the technology is one of the reasons why the outside capital was invested. Put differently, outside investors saw the large profit potential of the technology and invested largely based

on this. For BA1 and BA2 the grant committees saw that their technologies had the potential to help fill a government need.

It came as a bit of surprise that both DD1 and DD2 only rated the technology as a moderately important resource to attracting capital, as the earlier analysis indicated that the technology provided important positions to developing the firms' financial resources and capabilities. However, further information reveals that in fact the technology did help raise capital, but there were a few times when the firms' technology hindered attempts to raise capital because it had not progressed as far as it should have. For example, DD1 ran into some delays with patent approval, and this hindered their ability to raise capital. Because of this, the investors feared the technology might not make it to market. Thus DD1 and DD2's technology did help attract capital, but there were also instances in which it hindered the firms' abilities to raise funds.

Overall all the firms' technologies provided an important resource that helped them throughout their early growth. Progressions in the firms' technologies towards a state of commercialisation provided an additional resource that the firms used to attract additional capital. For example, developing the saliva-based instrument made MD2's product marketable, which greatly aided the firm in attracting a major investment in 2009.

There is a polarised difference in how important a resource the firms' respective staff has been to the development of their financial resources and capabilities (Table 6-30; 5); with some of the firms' staff proving to be an important resource and some of the firms' staffs proving not to be. Four of the firms' (BA1, DD1, DD2 and MD2) staff was critical to the company because they lent their expertise that the firms used to help attract investment capital. BA1 and DD2 also had staff members who directly made financial contributions to the firms. On the other end, BA2 and MD1's staffs did not prove important to the firms' financial resources and capabilities. They did not help the firm attract financing and did not directly contribute financial resources.

Table 6-30: Triangulation of financial positions

			1= to no extent 7 = to a very great extent						
			1	2	3	4	5	6	7
1.	Founder(s)	BA1							●
		BA2							●
		DD1	●						
		DD2							●
		MD1							●
		MD2					●		
2.	Executive staff's and board members experience	BA1						●	
		BA2	●						
		DD1							●
		DD2			●				
		MD1							●
		MD2						●	
3.	Venture capital investor(s)	BA1	●						
		BA2	●						
		DD1		●					
		DD2				●			
		MD1	●						
		MD2			●				
4.	Core technology	BA1						●	
		BA2							●
		DD1				●			
		DD2				●			
		MD1				●			
		MD2							●
5.	Company's staff	BA1							●
		BA2	●						
		DD1							●
		DD2						●	
		MD1		●					
		MD2					●		

Source: Author

6.5.6 Triangulation of financial processes

Table 6-31 presents the important processes used to help develop the firms' financial resources and capabilities. This table shows that processes related to conserving capital and learning from earlier financial decisions had a major bearing on the development. Only a few minor discrepancies surfaced from the responses and the earlier interviews. These are noted in the discussion below.

The importance of routines related to prospecting for capital varied (Table 6-31; 1). These processes proved highly important to DD1, DD2 and MD2, and can largely be attributed to

the vast amount of money that these firms' innovations demanded. In order to obtain the needed capital, DD1, DD2 and MD2 had to develop advanced routines related to finding and selling the idea of investing in the firm and negotiating terms. For example, DD1 has a system where they contact physicians about the possibility of investing. If a physician is interested, then the CEO meets with the potential investor. Similarly, these firms have systems in place for negotiating with the potential investors. These routines have also been important to BA1 and BA2, but these are not systems that they use on a regular basis. Instead there have been select times when they have relied on these. For MD1 these routines have been of no importance because the firm has made little attempt to draw in outside investors, which is a result of the founder's decision to self-finance the venture. All of the firms' innovations have been capitally intensive to develop, but BA1, BA2 and MD1's have been less expensive, and these firms were able to source the capital for their innovations with less effort than the other three firms have been able to.

Processes revolving around dealing with investors (Table 6-31; 2) have had a varying effect on the firms' financial assets and capabilities. DD1 and DD2 have developed advanced routines for dealing with their investors. This has involved meeting with the investors, creating reports and completing compliance paperwork. For the most part these are lower-level routines that have become ingrained in the firms. These processes have had some influence on BA2, but the firm's TMT only devotes a small amount of time to these routines. For three (BA1, MD1 and MD2) of the firms these routines were reported to have had almost no influence on their financial resources and capabilities. In the cases of BA1 and MD2 this is largely because the firms have taken in a limited amount of capital from outside investors. The low response from MD2 contrasts to the earlier analysis. However, further information clarified that the respondent did not view this question correctly and that this has been influential on the firm's development.

An important finance-related theme from this study is the importance of budgeting and conserving capital. Table 6-31 (3) shows that the firms saw these as important processes to their financial pictures, which reflects the earlier findings. The firms have developed routines for saving capital that revolve around sensing out low cost inputs and strategically investing in the most cost effective projects. The firms have also developed routines for budgeting their capital. For the most part, capital flows have been erratic, leading to inconsistent cash flows. All the firms created routines for projecting spending and have put

emergency plans in place, such as short-term credit lines to pay for expenses when cash flows become problematic.

One inconsistency from the earlier analysis and the response to this question arose from MD2. The respondent only marked this as moderately important, when the earlier analysis indicated that this as being quite important to the firm. Further information revealed that the respondent felt this is very important.

Most of the respondents listed routines relating to learning from earlier financial paths as very high (Table 6-31; 5). This is consistent with the earlier findings that one of the most important factors to the development of the firms' financial resources and capabilities stemmed from the processes that they created to learn from earlier financing decisions. These processes were driven by the firms' TMTs who learnt how to identify potential investors, conserve capital and create strategies to conserve capital. However, these are not formal routines that the TMTs think about and put a lot of effort in developing. Rather these learning routines occur every day based on the cumulative experience of the past.

For the most part routines related to filing for an initial public offering did not affect the firms (Table 6-31; 6). The one exception is DD1, which had to expend considerable effort in developing routines for compliance and marketing their stock, which related to their IPO. The CEO is the one who has driven this process for DD1. DD2 is also publicly traded, but it merged with an already publicly-traded firm, so it avoided having to develop many of these routines. Moreover, the firm it merged with has a finance team that deals with the on-going maintenance routines of the firm's publicly-traded stock. The other firms did not file for an IPO because they were not ready to do so, did not have the financial capabilities to do this or they simply did not want to commit to creating the processes needed for taking the firm public. DD1 would have preferred to have not had to deal with these processes, but the high cost of developing their drug forced them down this path.

Table 6-31: Financial processes triangulation

			1= to no extent 7 = to a very great extent						
			1	2	3	4	5	6	7
1.	Prospecting for capital	BA1			●				
		BA2				●			
		DD1							●
		DD2							●
		MD1	●						
		MD2						●	
2.	Dealing with financiers	BA1	●						
		BA2				●			
		DD1							●
		DD2						●	
		MD1	●						
		MD2	●						
3.	Budgeting and conserving capital	BA1							●
		BA2							●
		DD1				●			
		DD2						●	
		MD1							●
		MD2			●				
5.	Learning from earlier financial paths	BA1							●
		BA2							●
		DD1					●		
		DD2							●
		MD1							●
		MD2				●			
6.	Filing for an initial public offering (IPO)	BA1	●						
		BA2	●						
		DD1						●	
		DD2	●						
		MD1	●						
		MD2	●						

Source: Author

6.6 R&D and finance interdependence

The analysis presents a clear connection of the interdependence of financial and R&D resources and capabilities of innovative life science ventures. Based on this analysis, Figure 6-1 presents a model as to how R&D and financial resources and capabilities developed in the six innovative life science ventures that this study examined.

Firms are started to develop and commercialise an innovative technology, which is represented in the figure by the core technology oval. The technology is either purchased from another organisation (firm, university or government) or conceptualised prior to the start of the new firm. This core technology feeds into the R&D and the financial paths and

positions. The technology's past paths dictate the development that needs to go into the innovation; i.e. how much development does the technology need? Which dictates how much financing is called for? For example, an innovation at an earlier stage requires more development than an innovation purchased at a later stage. The potential of the technology and the complementary technologies available are the key drivers to the technologies' future paths, and firms develop their innovation to pursue these paths. Often the technology comes with scientific capital, such as patents or key scientific personnel, which feed into the R&D positions of the firm.

The firm develops R&D processes based on their R&D paths and positions, and then these processes create the R&D resources and capabilities of the firm. The feedback loops (i.e. the dotted lines in Figure 6-1 from R&D resources and capabilities to the paths and positions represent the R&D resources and capabilities feeding back into the firm's R&D paths and positions; i.e. the R&D resources and capabilities create new research opportunities and strengthen the R&D positions of the firm.

The core technology is also important to the financial paths of the firm. It dictates the capital needed and what source(s) of finance are called for. In all of the cases studied, the firms required a large investment to develop the core technology. Moreover, the core technology took an extended time to develop, which made the firms sustain long periods without revenues. Thus the core technology made specialised financing necessary for the firms. None of the firms in the study could source capital from generic places such as banks. Thus from the results is clear that financial resources and capabilities for innovative start-up life science firms are often specialised resources , not generic resources ; i.e. the financial resources and capabilities cannot be easily obtained and take specialised abilities to create (Teece, 1986; Trispas, 1997).

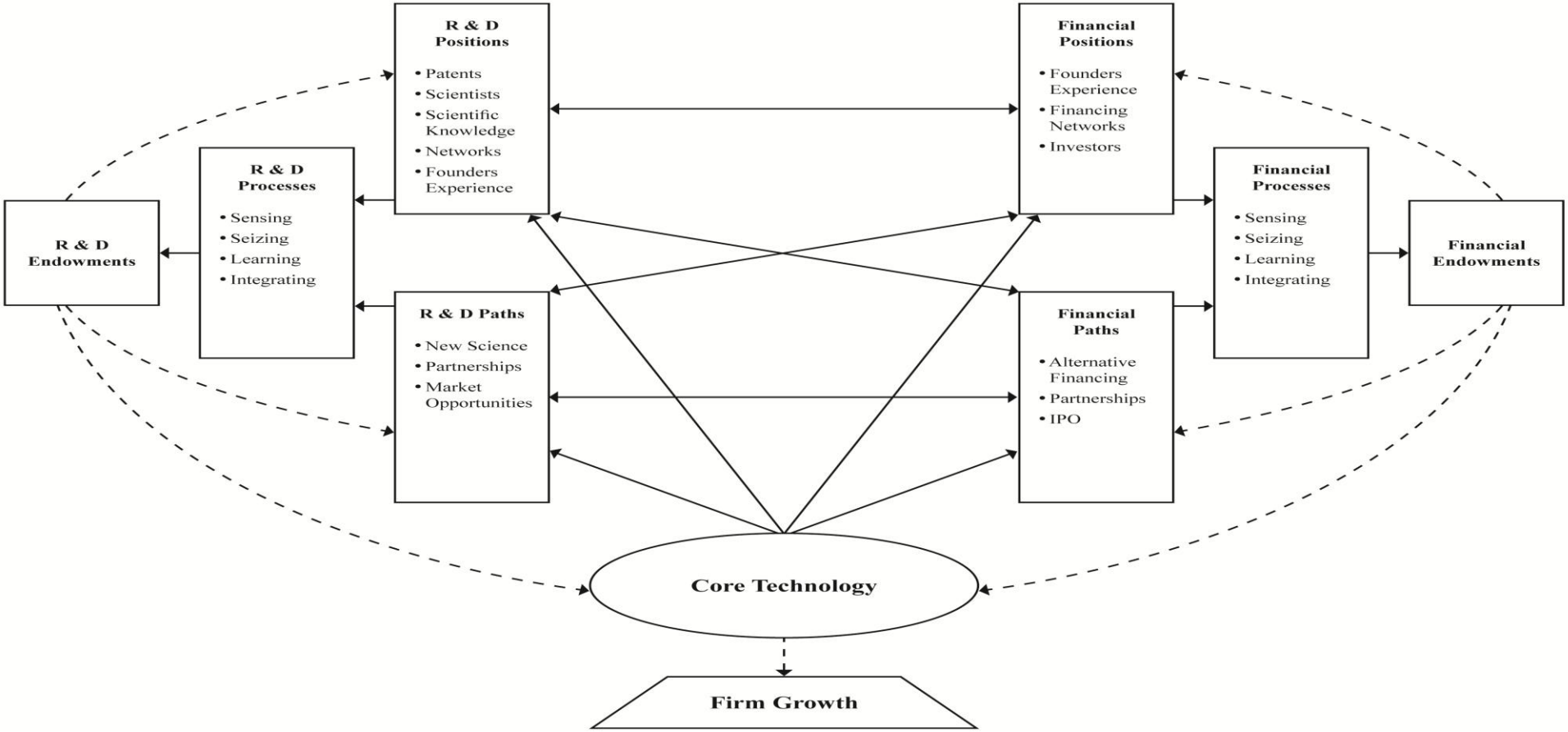
The core technology also feeds into the financial positions because the market potential of the core technology is what influences how much capital the firm can raise. All of the firms in this study raised the needed capital largely based on the potential profits of the innovation. Put differently, the investors and grant committees saw great potential in the firms' innovations. Initially the firm develops financial processes based on its paths and positions. These processes then create the financial resources and capabilities. The feedback loops from financial resources and capabilities to the paths and positions represent the financial resources feeding back into the firms' financial paths and positions;

i.e. the firms further developed their capabilities in raising capital, and the additional capital increases their financial positions.

The R&D and financial resources and capabilities in turn feed into each other. As the firm increases its financial resources and capabilities, it feeds these into the paths and positions of the R&D resources and capabilities. The capital gives the firm positions to further develop R&D, and it also gives the firm the capital needed to open up new R&D paths, such as developing a new product. Similarly, R&D feeds into the financial resources and capabilities of the firm. An increase in R&D gives the firm additional positions from which to raise capital; i.e. the innovation is more developed and shows even more market promise. This opens up new financing paths for the firm; i.e. the firm has more options for raising future capital because of the R&D resources and capabilities of the firm.

The feedback loops from the R&D and financial resources and capabilities represent the R&D and resources and capabilities' contributions to progressing the technology. Because of the developments in the firms' finances and R&D, it is able to get the core technology closer and closer to a point of commercialisation, which ultimately perpetuates the firm's growth.

Figure 6-1: Model of technology, R&D and financial interdependence



Source: Author

6.7 Analysis conclusions

It is clear from this analysis that R&D and financial resources and capabilities are paramount to the growth of innovative life science ventures. R&D and finance build on one another and then feed into the development of the firm's innovation throughout the growth process. The R&D and financial resources and capabilities develop from a unique set of paths, positions and processes. Especially important to R&D is the core technology that the firm sets out to develop. This establishes the R&D needs and ultimately the strategic direction of the firm. Unique resources, especially scientific human capital, allow the firm to develop processes to seize R&D paths. Financial resources and capabilities also develop along the path of the core technology. Developing novel life science innovations is costly and requires specialised financing. The firms use their technological positions, scientific human capital and founders' backgrounds as the positions to create the capabilities to secure the capital.

Variation existed amongst the firms in terms of the development of their R&D and financial resources and capabilities and the impact these resources and capabilities had on growth. For example, the relative importance of industry partners, the firm's board of directors, networking and raising capital differed substantially. For some of these firms, these paths, positions and processes proved important, whilst for others they did not. Moreover, the exact set of paths, positions and processes varied amongst the firms. However, what was consistent was that the core technology, scientific human capital, experienced founders and alliances were drivers to the development of R&D and financial resources and capabilities. The next chapter discusses the importance of these findings in relationship to the literature.

Chapter 7 – Conclusions

Chapter objectives

- To discuss the findings in relation to the research objectives presented in chapter 4.
- To discuss the theoretical contributions this study made.
- To identify implications for practitioners and policy makers.

7.1 Introduction

This thesis examined the resource and capability development of life science ventures. It focused on R&D and financial resources and capabilities, what they are and how they are determined and deployed by firms' towards growth. Previous work has examined the R&D and financial resources and capabilities of life science firms, but only a few studies examine these for new life science ventures. The few related R&D studies mostly focus on the role of academic and institutional partners' research inputs (Calabrese & Silverman, 2000; Coombs & Deeds, 2000). As such, they fail to take a holistic view of how early R&D resources and capabilities are formulated. In a similar vein, only a few studies look at the development of financial resources and capabilities of life science ventures. The few previous studies on the topic mainly focus on finance from a ROI standpoint (Lerner, 1995; Powell et al., 2002). There is a surprising shortage of studies that investigate how life science ventures develop capabilities to build or acquire financial resources. Similarly, there are only a handful of studies that probe the role of financial resources and capabilities on the development of a firm from a management standpoint; i.e. how financial resources and capabilities influence the early growth of a firm.

This chapter presents the findings from this study that are related to the knowledge gaps discussed above. Implications for the literature are first presented followed by the implications for practitioners and policy makers. The chapter is structured as follows:

7.2 Development of R&D and financial resources and capabilities
7.3 Effect of R&D and financial assets and capabilities
7.4 R&D and financial interdependence
7.5 Dynamic capabilities
7.6 VC and grants
7.7 Implications for practitioners and policy makers
7.8 Shortcomings
7.9 Recommendations for future research
7.10 Summary and final conclusions

7.2 Development of R&D and financial resources and capabilities

The first research objective of this study was to explore and examine how life science ventures develop R&D and financial resources and capabilities. This study used an RBV influenced dynamic capabilities perspective to examine this objective. The dynamic capabilities literature emphasises that paths, positions and processes are important to the development of key resources and capabilities (Teece et. al., 1997; Teece, 2007). Work has looked at important resources and capabilities (Arora & Ceccagnoli, 2006; Arthurs & Busenitz, 2006; Freear & Wetzel, 1990), but little work examines the paths, positions and processes that lead to the development of key resources and capabilities. Trispas (1997) is one of the few studies of note to look at the paths, positions and processes that lead to the development of key resources. However, this study focuses mainly on how changing technology influences the paths of developing key resources. It does not provide great depth on the positions and processes and how paths, positions and processes interact to create the capacities to develop resources. The present study examined this. Specifically the study looked at the paths, positions and processes that lead to the development of R&D and financial resources and capabilities. The development of R&D and financial resources and capabilities are divided into sections: 7.2.1 and 7.2.2.

7.2.1 R&D Paths, positions and processes

The results from this study indicate that life science firms develop R&D resources and capabilities along a unique set of paths, positions and processes. This section details the main findings of the study related to this.

R&D paths

The first question related to R&D paths that this study explored is '*How does an innovation affect the development of a firm?'* This question also aimed to explore how the source and type of innovation affects the development of a firm's R&D.

One of the most prevalent themes presented throughout the analysis is that the innovation that a firm pursues dictates the firm's R&D trajectories. The firms developed their R&D resources and capabilities based on the demands of their core innovation. These demands emanated from the type of innovation. Although the case firms are all in the life science industry, the number, type and focus of the firms' innovation(s) dictated the R&D

resources and capabilities needed by each. For example, the drug development firms' technologies called for R&D knowledge and capabilities revolving around biochemistry research capabilities; whereas BA1 and MD1's core innovations called for advanced engineering capabilities. This is consistent with the new technology-based firm (NBTF) literature, which suggests that firms' inception and growth is often based on a core technology (Lynskey, 2009; Onetti, Zucchella, Jones, & McDougall-Covin, 2010). It was also evident from the findings that firms that have a more focused innovation are more successful in developing their innovation. BA1, BA2 and MD2 focused on mainly one innovation in the first five years, and they were able to successfully develop their innovations; whereas MD1, DD1 and DD2 pursued a platform technology that took a lot longer to develop, which was largely attributable to the resource shortages that the pursuit of several innovations caused. It is evident from the study that a more concentrated R&D focus is better for life science ventures, and it is the first proposition the study puts forth:

> P1) Firms that have a narrower scope of R&D focus are more successful in commercialising their innovations because they are better able to attain the core resources and capabilities needed to develop their innovations.

This is an important proposition as it could help life science ventures to understand that it is better to focus their R&D. The results of this study indicate that a narrower scope of focus allows firms to fully develop an innovation, whereas the pursuit of multiple innovations stretches resources and puts firms in great a danger of exhausting resources before they have advanced their innovations.

The second R&D path-related question that this study looked at is '*Do partnerships have a major bearing on the development of R&D and financial resources and capabilities?'* This question also looked to see how firms know what they have to offer and how firms know what potential partners have to offer.

The analysis clearly indicated that partnerships have a major bearing in the development of a firm's R&D. This confirms the bulk of the existing literature; however, little work examines this through a dynamic capabilities or CAs lens. Rothaermel (2001a, 2001b, 2005) are major exceptions, as these studies specifically examine alliances and CAs. These studies provide much insight on the importance of alliances to developing CAs, but these studies did not factor in how partnerships influence the overall R&D paths. The present

study extends Rothaermel's work by providing depth on how partnerships cause life science firms to rearrange their scientific base to accommodate their partners' R&D inputs. For example, BA1 entered into a research partnership with the US government, which then dictated the early strategic direction of the firm's R&D resources. The firm refocused almost all of its R&D resources to focus on the co-development project with the Army. Not all of the firms were this significantly influenced by partners, but all of the firms had partners that impacted the strategic makeup of their R&D.

The study's results also indicate that firms identify potential partners from their founders' networks and the scholarly scientific community. All of the firms had at least one major partner who emanated because of the founder's background. The founders knew what partners had to offer because of their unique scientific and management experiences. Similarly, potential partners know what the firms had to offer because of the backgrounds of their founders. For example, BA1's founder had previously worked with one of the US Army's chief scientists, and because of this, the chief scientist knew what BA1's founder was working on and what its potential was. Similarly, DD1's founder had worked with their VCF in the past, and because of this the VCF knew what the potential of DD1's technology was; and DD1 knew what the VCF had to offer. This is supportive of the literature, which has also indicated that the founders are important in the development of partnerships (Witt, 2004).

In a similar fashion, this study found that scholarly journals and conferences are facilitators of partnership. Five of the firms used the scholarly community to help them facilitate R&D partnerships. For example, DD1 identified independent researchers doing work on areas related to their technology through scientific journals. Likewise, MD2 found two universities doing research related to their technology from scientific journals. The journals allowed the firms to identify what these organisations were doing and what they could possibly offer in a partnership. Staying active in the scientific journals and conference also helped five of the firms in this study gain credibility. Their publications and conference presentations let other firms know what they had to offer, and the scholarly process they underwent certified their credibility. This is supportive of Zucker and Darby (1996) who suggest that biotech firms publish to help them market their products. However, the present study extends this finding by showing how scholarship helps firms develop credibility. The discussion in this paragraph leads to the second proposition:

P2) Life Science ventures that publish in scholarly journals and attend conferences are better able to identify complementary technologies and assess the capabilities of potential partners.

This is an important proposition, as the literature has not paid much attention to the role of scholarly activity in the development of life science firms. Prior research has noted that it is corrleated with higher rates of commercialisation (Zucker and Darby, 1996), but it has not shown how this can be an important facilitator of partnerships. Thus this proposition has the potential to help life science ventures identify and vet potential partners.

In examining the R&D paths of the firm, an important influence that emerged from this study is the importance of government approvals. Directly or indirectly, government approval procedures and regulations influenced the R&D paths of the firms in this study. FDA approval proved as one of the largest influences. Most of the firms in this study developed products that required FDA approval, and in order to obtain it, the firms had to meet compliance and testing standards. This forced the firms to design their R&D around gaining these approvals, and it forced the firms to devote substantial resources to it. Studies have noted that the FDA is a major hurdle to life science firms (Grabowski, 2002; Olson, 1997), but they have not specifically looked at how these approvals affect a firm's R&D's strategic paths. The present study adds to these by providing insight on how government approvals affect the R&D paths of life science ventures.

Interestingly, FDA approval procedures forced three of the firms from this study down an internationalisation path. The firms sought approval for their products first in European markets because they felt they could get their products approved for market more efficiently there than they could in the US, an interesting finding because the literature on life science ventures does not provide great insight on how government approval procedures can force life science ventures down an internationalisation path. The internationalisation literature puts forth that government approval can influence internationalisation (Brewer, 1993), but there is little work that explicitly applies this to life science ventures. Thus the third proposition of this study puts forth:

P3) Life Science ventures that internationalise are motivated to do so to avoid FDA regulatory bureaucracy, and this is forcing firms to develop resources and capabilities for operating in international markets.

This proposition is notable because applying for foreign government approvals instead of US FDA has a major bearing on a firm's development. The literature and industry reports have noted that the propensity to outsource functions such as testing has increased dramatically in recent years (Giovannetti, 2010); however, it has not shown that firms are starting to look first at foreign market government approval instead of US FDA approval. Evidence from the present study indicates that firms are now in some cases looking to gain foreign market approvals first because these are more streamlined, allowing them to get their product to market quicker. It is also forcing the firms to develop resources andcompetencies in operating in international markets.

R&D Positions

This study found that a number of positions are important to the development of a firm's R&D. One particular position that this study is interested in is key individuals. More specifically, the fourth research question of the study looked at '*Are highly trained, skilled and experienced individuals driving the development of R&D and financial resources and capabilities?'* This question also aimed to examine whether star scientists are vital to the development of life science ventures' R&D.

All of the firms in this study's R&D revolved around the knowledge and capabilities of an individual or small group of individuals. Five of the firms noted the particular importance of standout scientists. This is supportive of the life science literature, which suggests that star scientists are often the impetus of new life science innovations (Rothaermel & Hess, 2007; Zucker & Darby, 1996, 2001). However, none of the individuals involved with a case firm in this study were in the Science and Technology Agents of Revolution (STAR) database. Indexing of individuals in this database is based on a complex set of criteria that traces the publishing, patenting and commercial activity of a researcher. This database originated from Zucker and Darby (1992) where they identified the top 327 biotechnology researchers and found that firms who collaborate with these individuals have a much higher rate of commercialising innovation. Whilst their findings were profound and have been well supported (Zucker & Darby, 2001; Zucker et al., 2002; Zucker et al., 1998), and star scientists do account for a statistically significant amount of innovation, overall they only account for a small percentage of life science innovation (Higgins, Stephan, & Thursby, 2011).

The findings from the present study extend the work done by Zucker and Darby (1992) by suggesting that standout scientists, not necessarily star scientists, play a key role in the development of life science firms. The present study identifies standout scientists as individuals who have scientific achievements in the top five percent of all scientists, but are not in the elite .005% of the scientists in the world as defined by the Zucker and Darby (2011) STAR database. Four of the firms in this study had founders or employed scientists who were highly noted in the field but were not in the STAR database. For example, BA2's co-founder was named by The American Chemistry Society in 2010 as one of the top fifty researchers in chemistry. Similarly, DD2's founder holds seven patents and is noted in several publications as one of the leading experts in snake venom. These individuals drove the R&D capabilities of these firms. The last two paragraphs discussion leads to proposition four:

> P4) Firms that employ one or more standout scientist are better able to develop R&D resources because of the standout scientist(s) R&D capabilities and scientific contributions.

This proposition is significant, as it has already been noted that star scientists are driving innovation. However, star scientists still only account for a small percentage of life science innovation. Evidence from the present study suggests that standout scientists are having a profound impact on the R&D of life science ventures, and could possibly account for a large portion of innovation in the industry. For this reason, a more inclusive ranking system needs to be constructed to capture the impact of standout researchers – not just the elite star scientists that represent less than .005% of the scientists in the field (Higgins et al., 2011). Such a scale could help firms understand what is driving the development of new innovation; it could help firms in identifying standout researchers; and it could also help investors in the evaluation of life science firms.

Another interesting finding of this study is the importance of foreign-born and trained scientists. Four of the firms employed foreign-born and foreign-trained scientists who played key roles in the development of their technology, and it is evident that these scientists also made key contributions to the R&D positions of the firm. These scientists provided insights based on their overseas training and research that were invaluable to the development of their firms' technologies. This finding is consistent with the internationalisation and NBTF literatures, which suggest that foreign-born employees are

often a central asset to a firm's growth and internationalisation (Portes, Guarnizo, & Haller, 2002; Saxenian, 2002). Whilst this finding is more supportive than novel, it is novel in its extension to a dynamic capabilities framework; i.e. foreign-born employees can be an important position to the development of a firm's R&D resources and capabilities.

R&D Processes

The fifth research question of this study looked at '*What processes are vital to creating R&D resources and capabilities?'*

The dynamic capabilities literature underscores several processes that lead to the development of capabilities. Sensing opportunities is a higher-level process identified in the literature (Teece, 2007). In an in-depth study on the IBM Corporation, Harreld and Tushman (2007) found that sensing opportunities is a dynamic capability that IBM has developed, and it has been one of the firm's main sources of competitive advantage. Similarly, Trispas and Gavetti (2000) in an in-depth study of the Polaroid corporation found that sensing new technological opportunities was an important dynamic capability that the firm developed, and this has been one of the firm's main competitive advantages. In a similar vein, Kaplan, Murray and Henderson (2003) take an in-depth statistical look at fifteen pharmaceutical firms' TMTs' ability to recognise scientific opportunities. Their findings suggest that sensing is clearly an important routine. The present study's results support these studies and extend these findings to life science ventures. Specifically, the results indicate that the ability to sense and seize scientific opportunities is important to the development of R&D resources and capabilities of a life science venture. All of the firms identified a core innovation to develop, and the ability to identify a technology that presented both scientific and market potential provided an impetus to the firms' growth. The firms identified a technology and then assessed the development it needed and whether or not the technology could realistically be developed; i.e. did the firm have the capabilities and resources to accomplish this. The firms in this study excelled in this area, and this was an important driver to their growth.

Learning is perhaps the most cited dynamic capability in the literature. Numerous authors emphasise the importance of learning processes (Eisenhardt & Martin, 2000; Romme et al., 2010; Winter, 2000; Zollo & Winter, 2002). Accordingly, firms learn from their past paths and use this information to adapt their positions to pursue future paths that are available to

them. *The present study's findings suggest that learning from earlier research paths is vital to the development of R&D resources and capabilities.* All of the firms learned from their earlier paths and used this knowledge to further the development of their technologies. In particular, the firms learned how to use their research setbacks to advance their technology. For example, MD1 suffered several failed developments, but the firm established processes for dissecting the reason for the setbacks and then used this information to find ways to overcome them.

This study also finds that in small life science ventures learning processes transpire at the network, firm and individual levels. Most of the firms in this study had partners that they learned from on joint research projects. Moreover, all of the firms in this study practiced inter-organisational learning; i.e. employees from within the firm worked together to acquire new knowledge. Learning prevailed most evidently at the individual level for the firms in this study. All of the firms employed researchers who worked independently and acquired new scientific knowledge based on their individual work. Previous studies have indicated that key individuals are often the source of learning (Cohen, 1991; Rothaermel & Hess, 2007). The present study extends the importance of individuals to the learning process of life science ventures.

The third process this study found vital to the development of R&D resources and capabilities is partnering. This is supportive of earlier research that suggests that firms secure important inputs through alliances and partnerships (Das & Teng, 2000; Eisenhardt & Schoonhoven, 1996; Haeussler et al., 2010). Furthermore, networking is a dynamic capability that firms can derive competitive advantages from (Blyler & Coff, 2003; Mort & Weerawardena, 2006). *The present study's results confirm this and extend it to innovative life science ventures.* This study's findings also support the idea that partnerships can stem from many different places such as past business dealings, personal friendships and scholarly journals (Harris andWheeler, 2005; Hite and Hesterly, 2001; Hsu, 2007).

A fourth important set of processes that surfaced as important to the development of R&D resources and capabilities revolved around integrating new knowledge. All of the firms took in new knowledge into their operations that they synthesised into their research. Their capabilities to use this knowledge underpinned their ability to progress their technology. This finding supports absorptive capacity as a dynamic capability that firms derive competitive advantages from (Deeds et al., 2000; Zahra & George, 2002). This is an

important finding as it provides needed empirical support to absorptive capacity as a dynamic capability. Previous studies have established this a source of competitive advantage (Cockburn & Henderson, 1998; Lane & Lubatkin, 1998) and have alluded that absorptive capacity can be viewed as a dynamic capability, but few studies have directly offered support to absorptive capacity in a dynamic capabilities framework; the present study does so.

As the discussion above indicates, the results suggest that firms rely on a combination of processes to create their R&D resources and capabilities. Processes relating to sensing, learning, partnering and integrating proved important to all of the firms.

7.2.2 Financial paths, positions and processes

For the most part, generic financing has not been available to the firms in this study, which is no surprise as start-up life science firms are limited in their funding sources because of their risky nature (P. Gompers & Lerner, 2001). In order to develop the needed financial resources, the firms leveraged a unique set of paths, positions and processes.

Financial paths

The first research question looked at '*How does an innovation affect the development of firms' resources and capabilities?'* This question also looked at how the source and type of innovation affects the financial demands of firms.

Financing is an important path to the growth of life science ventures. Often these firms develop an innovative technology that is costly to develop (Colombo & Grilli, 2009). Furthermore, technology takes extensive time to develop, and firms go years without revenues whilst the technology is being developed (Zucker et al., 2002). This makes specialised high-risk capital germane to the development of life science ventures (Baum & Silverman, 2004). All but one of the firms in this study used a form of specialised financing, and the decision to use specialised financing stemmed from the large amount of capital that was needed to pursue the development and commercialisation of a novel life science innovation. Thus this study supports other research which shows that the novel innovation that life science firms pursue is costly to develop (Chakma & Sammut, 2011). Evidence from the study also suggests that the type of innovation has a profound effect on a firm's financial demands. Furthermore, the study suggests that firms looking to pursue

larger scale innovation have more financial difficulties. The three firms (DD1, DD2 and MD2) that pursued several innovations had to devote substantial time and resources to developing the financial resources needed to fund several different projects. This distracted from the scientific activities of the firms. Moreover, it also stretched the financial resources of the firms and made all three of the three firms terminate at least one of the innovations they were developing. In contrast, MD1, BA1 and BA3 narrowly focused on one type of innovation and were able to successfully develop their product largely because their financial resources were not stretched across several major projects. From this discussion proposition five is put forth:

> P5) Life science ventures that attempt to develop several innovations simultaneously develop slowly and risk failure as they create large financial requirements.

The third research question looked at '*How does the pursuit of financing impact the development of life science ventures?'* It was specifically interested in how the financial strategies of firms affect their financial trajectories.

The results indicate the financial strategies of the firms have a major bearing on the financial trajectories of a firm. All of the firms followed a unique financial strategy. Two of the firms (BA2 and MD1) made the choice to self-finance their early growth, which influenced the investments that could be made; i.e. it limited the funds that the firms had available to invest in the development of their technology. On the other hand, this choice freed them from having to devote resources to prospecting for capital and dealing with investors. In comparison, three of the firms relied heavily on outside investors for capital. These investors supplied large sums of capital, but raising this capital and dealing with the investors significantly affected the firm's operations. Studies have examined the financial strategies of new ventures (Freear & Wetzel, 1990; Van Auken, 2001; Willoughby, 2008). However, these studies have not provided deep insights on the long term effects of a firm's early financial strategies. Based on the findings from the present study the following proposition is put forth:

> P6) Firms that self-finance their growth will have significantly different financial trajectories than firms that pursue equity investors, as they will have less capital available, but will maintain greater organisational flexibility.

This is a notable proposition because rigidities are created from the early financial strategies, and these limit the financial choices available to firms in the future. For example, DD1 and DD2's public stock offering committed them to substantial government regulations, which consumed significant time from the firms' TMTs. In hindsight, both firms would have liked to have reversed their decisions to go public, but it was a decision that they could not change. Conversely, BA1 pursued government grants that did not commit the firm to a stratified financial path. This allowed the firm more flexibility in its future financial options.

Financial positions

The second research question explored '*Are highly trained, skilled and experienced individuals driving the development of resources and capabilities?'*

The results clearly indicate that founders provide important resources that feed into the development of the firm's financial resources and capabilities. All of the firms relied heavily on their founders' background to develop their financial resources and capabilities. For example, DD2's founders' network provided access to important financing opportunities. The firm's founder had previously worked with VCs, and these past experiences aided them in securing financing. DD1, MD2 and BA1's founders also provided an important position that the firms used to 'sell' the financiers on investing in the firm. The most extreme examples of this from this study are DD2 and MD2. Both of these firms' founders were famous in their respective fields, and because of this name recognition, the firms attracted significant investor interest. Put differently, investors wanted to invest in these firms because of the founders' successful track records. This finding is supportive rather than unique as several studies note the importance of the founder's background to raising capital (Colombo et al., 2004; Sengupta, 2011; Storey & Tether, 1998). The findings also show that founders do not have to have experience in running a life science firm to successfully raise capital. BA2 and MD2 founders had no business experience but were still able to develop the financial resources needed to progress their innovation towards a state of commercialisation.

It is evident from this study that the background and experience level of the founder(s) impacts the financial strategies of a firm. The two firms with inexperienced founders, BA2 and MD2, initiated the venture on a self-financing path mainly because they did not have

knowledge or contacts to pursue other financing routes. In comparison, BA1's founder was highly experienced in using government grants to finance new life science ventures, and thus he pursued this route for financing BA1's growth; whereas, DD1, DD2 and MD2's founders were experienced in attracting and working with equity investors and for this reason used VCs and private investors to incubate their new ventures. The discussion in this section leads to proposition seven:

> P7) Inexperienced founders are more likely to self-finance their venture's early growth, as opposed to experienced founders who use their background to secure financial resources from outside sources.

Another resource that this study found important to financial resources is the firms' technology. The firms leveraged their technical assets and capabilities to develop their financial resources and capabilities. Almost all of the firms displayed advanced technological knowledge and skills that helped attract specialised finance. Previous research on early stage financing indicates technological capabilities are important to raising capital (Gompers & Lerner, 2001; Kollmann & Kuckertz, 2009), so this is more supportive than novel. *However, the findings from the present study add fresh insights to this by showing that technological knowledge in some cases helps firms attract alternative forms of investment.* BA1 and BA2 used their technology to win government grants. The reason the government awarded the firms the grants is because the firms' technologies showed promise to help solve a problem that the government wanted to address.

Financial processes

The fifth research question this study explored is '*What processes are vital to creating R&D and financial resources and capabilities?'*

The R&D of life science firms is costly. This makes raising capital a vital process for new technology-based firms (Colombo & Grilli, 2009). *The results from the present study indicate that sensing and seizing funding opportunities are important processes.* Several of the firms in this study relied on routines related to identifying, meeting and negotiating with investors. These routines allowed these firms to raise the capital they needed to pursue the development of their innovation. For DD1, DD2 and MD2 these routines consistently proved important, but all of the firms in this study, except MD1, developed routines related to sensing and seizing capital investment. The firms identified capital from

a number of sources; VCs, private investors, public stock markets and government grants. This study also supports that these processes are driven by one or two individuals from a firm. In all but one of the cases in this study the founder or founders drove this process and provided the primary inputs into sensing and seizing funding opportunities.

A second suggestion from this study is that processes related to integrating and conserving financial resources are vital processes to life science ventures. Almost all of the firms ran into troubles forecasting the development costs of their R&D. DD1, for example, started to develop a new application for its technology, and it ended up costing much more than the firm originally budgeted for. Consequently, the firm went through its initial capital quicker than expected. Similarly, MD2 spent three times the anticipated amount on the development of their technology. At one point or another all of the firms ran into budgeting issues. For this reason it proved important for all of the firms to create routines for closely monitoring their spending. Whilst this is not a fresh finding, it is supportive of previous work that indicates budgeting is an important process for new ventures (Braden, 1993; Freear & Wetzel, 1990).

Closely related, this study finds that routines for conserving capital are vital to the financial endowments of the firms. The firms in this study were financially restrained, and for this reason all but one of the firms developed advanced systems for cutting costs. Some examples of these routines included finding the lowest cost inputs, developing partnerships to obtain low cost or free inputs and cutting out operations that were not essential. It is evident from this study that strategic cost cutting is a capability that is vital to the financial picture of young life science firms. This finding is in line with previous work that has shown how cost cutting is essential to the financial strategies of young ventures (Auken, 2005; Winborg & Landstrom, 2001).

A third set of processes the present study found important relate to IPOs. DD1 and DD2 went public on a US stock exchange. This was primarily motivated by a need for a substantial sum of capital that was the result of the development of costly innovations. In order to go public, the firms engaged in a number of processes. First, the firms completed substantial amounts of legal paperwork with the SEC. The TMTs of these firms spent hundreds of hours working with their teams of lawyers to ensure everything was properly documented as well as meeting with publicists to promote the stock offering. This included meeting with reporters and attending SEC events. The firms also developed systems for

reporting their financial and operational issues to the SEC, which was a significant burden on the firms as it consumed a substantial amount of the TMTs' time. It also forced the firms to develop a compliance team to gather the information needed for the SEC.

The findings related to the processes involved with the public stock offering are not new. Studies indicate that processes related to public offerings consume vast amounts of resources (Dona & David, 1997; Ibbotson, Sindelar, & Ritter, 1988; Poulsen & Stegemoller, 2008). In particular, firms invest massive amounts of time and resources in the filing and marketing of their stock offering. Research also suggests that the capital raised is often not worth the resources exerted (Aggarwal & Rivoli, 1991; Poulsen & Stegemoller, 2008). However, this research has not gone into great depth on this. The present study's findings extend this work by showing that the public offering is a resource drain that detracts from a firm's operations because of the tremendous amount of the TMTs' time that is consumed. From this the eighth proposition of the study is put forth:

> P8) IPOs consume valuable time from top management teams, and managers that spend less time on IPOs are better able to help their firms develop operational resources.

As the discussion in this section indicates, the results widely support that firms rely on a combination of processes to create their financial resources and capabilities. Processes relating to sensing, seizing, integrating and conserving capital proved important to all of the firms.

7.3 The effect of R&D and financial assets and capabilities

The second objective of this research is to examine the effect of R&D and financial resources and capabilities on the early growth of life science ventures. This study carefully investigated how these resources and capabilities formulate, and how these help firms in early growth. This section overviews the importance of R&D and financial resources and capabilities to early growth.

7.3.1 Effect of R&D resources and capabilities

The sixth research question of this study from an R&D perspective looked at '*How are R&D resources integral to life science ventures?'*

Results from this study strongly indicate that R&D resources and capabilities are vital to the early growth of innovative life science ventures. These resources and capabilities provided a leverage point from which to attract and develop other resources. The R&D resources consisted of the firms' research facilities, patents, employees and networks. Whilst the firms' R&D capabilities consisted of their abilities to sense and seize opportunities, learn from previous research paths, network, integrate new resources into their research, and the capabilities of transforming their R&D resources. In sum, these resources and capabilities provided important competitive positions that allowed the young resource constrained firms examined in this study to compete in a high velocity industry; these can be viewed through the VRIN framework.

First, R&D resources and capabilities are valuable. The results of this study definitively indicate that R&D resources and capabilities are of high worth. The R&D resources and capabilities of the firms in this study allowed the firms to develop products with high market values. This finding is supportive of the R&D literature, which indicates that most valuable new products and services are the result of R&D (Cassiman & Veugelers, 2006; Cohen & Levinthal, 1989; Sampson, 2007). Second, R&D resources and capabilities are rare. The R&D resources and capabilities of the firms in the present study are not readily available as they are closely linked to the particular skills and knowledge of individuals. Each of the firms possessed resources and competencies which few firms in the world possess. This is supportive of the R&D literature, which shows that advanced research abilities are rare (Liao, Wang, Chuang, Shih, & Liu, 2010; Pisano, 1990).

Third, the R&D resources and capabilities of the firms in this study were imperfectly imitable. This is most apparent in the fact that all of the firms held multiple patents, and legally patents cannot be perfectly imitated (Markman, Espina, & Phan, 2004). Moreover, all of the firms held tacit research knowledge and processes that could not be imitated. Fourth, R&D resources and capabilities are non-substitutable. The firms in this study could not substitute their R&D resources and capabilities. The progression of the firms' technologies depended on their R&D resources and capabilities; there was nothing else

that the firms could use in place of these to develop the state of the art technologies that they were pursuing.

It is apparent from the discussion in this section that R&D resources and capabilities are vital to the early development of life science ventures.

Complementary assets

The seventh and eighth questions of this study pertained to CAs: *7) Can R&D resources and capabilities serve as a CA? And 8) Can R&D resources and capabilities serve as SCAs?*

This study offers support of R&D resources as a category of CAs for life science ventures. Teece (1986) suggests that complementary technology is a category of CAs; i.e. technologies that go along with the core technology that a firm is attempting to commercialise. Similarly, Gans et al. (2002) suggest that the research resources needed to get through government approval is a category of CA. Moorman and Slotegraaf (1999) discuss product development capabilities and allude to R&D as a potential category of CA. Similarly, Lowe and Taylor (1998) allude to R&D as a CA, but do not explicitly call R&D a CA. *The results from the present study support R&D as a unique category of CA.* R&D is an auxiliary set of resources and capabilities that allows a firm to progress an innovation towards a state of commercialisation.

The present study also found that R&D resources and capabilities can be viewed through a SCAs lens. SCAs are specialised auxiliary resources and capabilities that are needed to commercialise an innovation (Teece, 1986). An example of an SCA is service capabilities of a medical device firm. In many cases medical devices require specialised service capabilities to maintain the product, and if a firm is unable to service the device, then the device cannot be commercialised. These capabilities are such that they require sophisticated and often tacit knowledge that cannot easily be replicated. Several studies have noted R&D as a CA, but few of studies have explored whether R&D is an SCA. The present study extends this by examining whether R&D resources and capabilities can serve as SCAs. In general, the firms in the present study required auxiliary R&D resources and capabilities that were highly specialised. These were capabilities that few firms in the world possessed, and they were needed to get the firms' innovations to a point of commercialisation.

The discussion in this section indicates that R&D resources and capabilities can serve as a CA and SCA, and that these are important resources to the development of life science ventures. Thus proposition nine puts forth:

> P9) Life science ventures with advanced R&D complementary assets are more successful in brining their innvotations to market, as the R&D complementary assets allow them to progress their innovations to a point of commercialisation.

This proposition is significant as R&D has been alluded to as a CA, but it has not been directly offered. Furthermore, R&D has not been viewed through an SCA's lens. The CA's model emerged to explain the auxiliary assets and capabilities needed in the commercialisation of an innovation (Taylor & Helfat, 2009; Teece, 1986). Thus this finding is significant, as it supports this model and extends it by fortifying R&D as a CA and it extending R&D as an SCA.

7.3.2 Effect of financial resources and capabilities

The sixth research question of this study from a financial prospective looked at '*How are financial resources integral to life science ventures?'*

Results from this study indicate that financial resources and capabilities are vital to life science ventures. The firms' financial resources consisted mainly of their capital reserves and access to financial networks, whilst the firms' financial capabilities consisted of their abilities to sense and seize funding opportunities, network with financiers, conserve capital and work with financiers. These capabilities led to specialised financing in the forms of VC investment, IPO, unique investment funds and government grants. This specialised financing provides important competitive positions that can be viewed through the VRIN framework (Barney, 1991).

First, specialised finance is valuable. This study clearly indicated that specialised financing is a precious commodity that is paramount to a life science venture's early growth. Second, specialised financing is rare. Financing for life science ventures is hyper-competitive. There are three thousand young life-science firms in the U.S, and yet there are only a handful of VCs that specialise in life science investments (BIO, 2010). Furthermore, the

firms in this study are so specialised that there were only a handful of financiers that would consider investing in their technologies.

Third, specialised finance is imperfectly imitable. Whilst, most of the firms in this study could have received the needed capital from other sources, the paths, positions and processes that the firms leveraged to develop the capabilities to get the financing are in-imitable. Fourth, specialised financing is non-substitutable. Specialised financing proved absolutely critical to the growth of all of the firms. A couple of the firms reduced the amount of specialised financing they needed. For example, BA1 limited the capital needed because their abilities to outsource important functions to partners for a minimal capital outlay. However, BA1, as well as the other firms in this study, could not completely find a substitute for the specialised financing their technology demanded.

It is apparent from the discussion in this section that financial resources and capabilities are vital to the early development of life science ventures. Financial capabilities create competencies that allowed the firms to secure the needed capital for the firms' development. In general, these competencies were a source of competitive advantage, as the case firms out competed scores of other firms for capital. Moreover, in some cases the financiers contributed more than just capital, which also fed into the competency base of the firms. These contributions are discussed in further detail in section 7.6.

Complementary assets

The seventh and eighth questions of this study pertained to CAs, (7) *'Can financial resources and capabilities serve as a CA and (8) can financial resources and capabilities serve as a SCA?'*

Early stage financing of high technology firms is well-researched (Colombo & Grilli, 2009; Davila, Foster, & Gupta, 2003). However, no research of note looks at financial resources and capabilities through a CA's lens. Most of the research focuses on the processes of raising VC (Dimov & Milanov, 2010; Kollmann & Kuckertz, 2009) and the management contributions of the VCs (Gompers & Lerner, 2001; Gorman & Sahlman, 1989). Although the extant research does not explicitly look at finance through a CA's lens, financing lends itself to being a CA. From a definitional standpoint, it is an auxiliary asset needed for the commercialisation of an innovation (Rothaermel, 2007; Teece, 1986; Trispas, 1997). Results from the present study support this idea by showing that financial

resources and capabilities are auxiliary resources and capabilities that complement other important assets. Some scholars may argue that finance is a core function, and therefore it is not a CA. But under this logic any category of CA offered in the literature could be considered as such. Furthermore, results from the present study suggest that financing for life science ventures is much more entailed than just being a source of capital. Certainly the capital is needed, but financing is much more encompassing than just being a proxy or a transactional tool. The capital is a generic asset, but capabilities in raising capital, working with specialised financiers and conserving capital was displayed by all of the firms in this study.

In certain cases these financial capabilities are an SCA; they are specialised auxiliary resources and capabilities needed in the commercialisation of an innovation that cannot be easily developed or contracted for (Teece, 1986). For example, DD2 and MD2 developed an innovation and successfully brought it to market largely because of their specialised financial capabilities. Another example of specialised financial capabilities are BA1's capabilities to conserve capital and to operate on a lean budget. All of the firms displayed specialised financial capabilities that proved instrumental to advancing their innovations towards a state of commercialisation.

The discussion in this section indicates that financial capabilities can serve as CAs and SCAs, which leads to the tenth proposition:

> P10) Firms that recognise the complementary and potentially specialised nature of finance and proactively manage these assets in relation to their R&D are more successful in brining their innovations to a point of commercialisation.

This proposition is significant, as financial capabilities have not been viewed through a CA's lens. Thus this finding extends the CAs model by offering a new category. The purpose of the CAs model is to offer an analytical tool for examining the auxiliary assets and capabilities needed in the commercialisation of an innovation (Teece, 1986). Findings from this study indicate that by ignoring financial capabilities, the CA model is missing an important set of auxiliary capabilities that are important to the commercialisation of innovation.

7.4 R&D and financial interdependence

This study was particularly interested the bilateral dependence of R&D and financial resources and capabilities. Questions 6a and 6b addressed this: *6a) How closely linked are R&D and financial resources and capabilities and 6b) Do R&D and financial resources co-evolve?*

The literature notes the interdependence of R&D and finance to the growth of NTBFs (Chakma & Sammut, 2011; Colombo & Grilli, 2009). However, it does not emphasize the interdependence of these in the development of life science ventures. From this study it emerged that there is a bilateral dependence between R&D and finance. This is supportive of the growth literature, which suggests that at or near inception developing a product and securing financing are the two main focuses of start-up technology firms (Delmar et al., 2003; Kazanjian & Drazin, 1990).

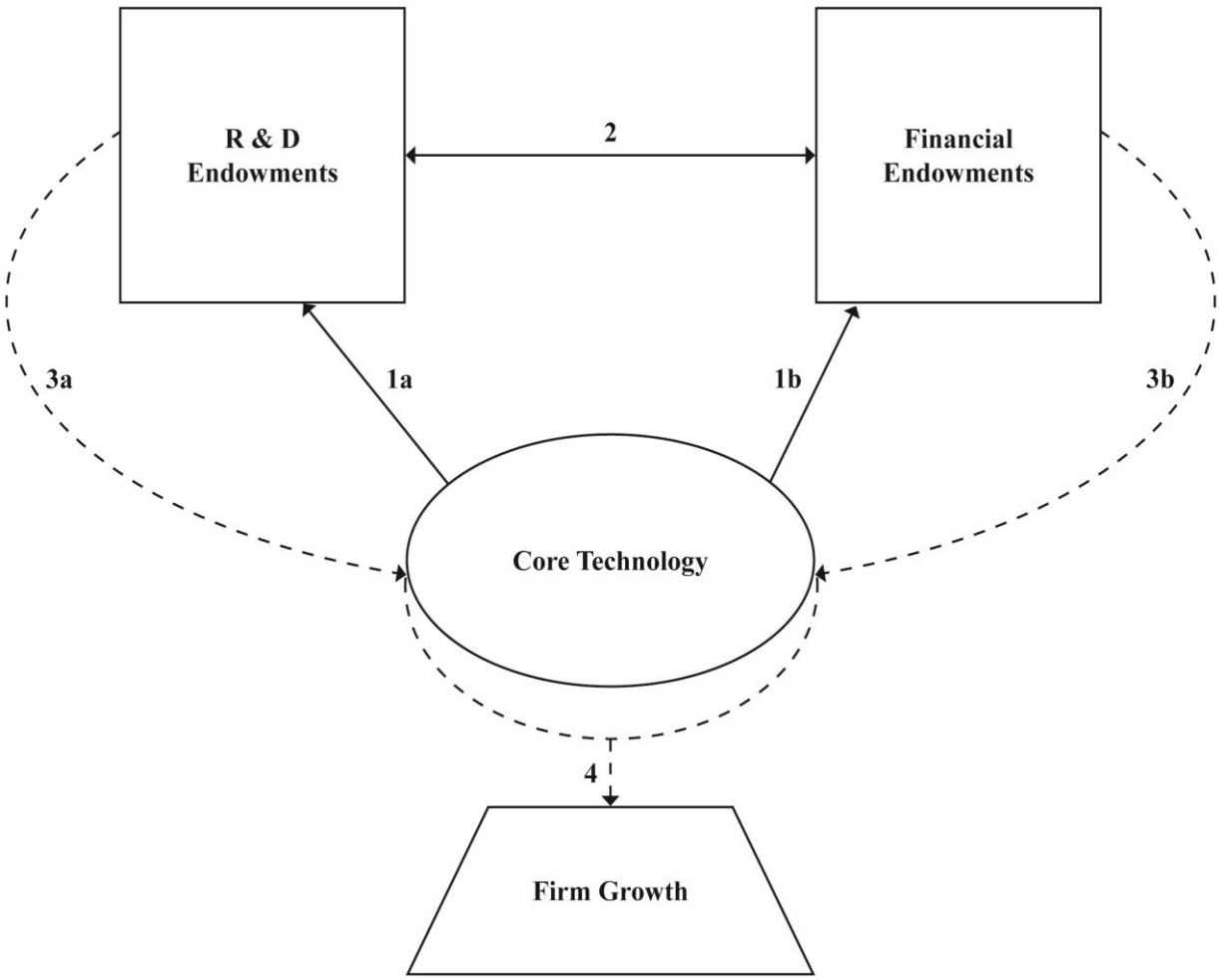
Results from the present study suggest that the core technology and R&D potential of the firm are instrumental in attracting specialised investment which comes primarily from specialised sources such as VC or grants; which concurs with other studies (Baum & Silverman, 2004; Colombo & Grilli, 2009; Timmons & Bygrave, 1986). The present study's findings underscore the fact that specialised investment is not easily raised and that unique capabilities lead to the acquisition of specialised investment. The specialised funding is paramount to developing a research infrastructure. Firms use the capital to hire a research staff, build research facilities, pay for testing and buy complementary technologies. In turn, these R&D resources and capabilities help develop a product which helps attract additional investment.

The results from this study indicate that R&D and financial resources and capabilities are interconnected; i.e. financial paths and positions influence R&D paths and positions and vice versa. This is not a surprise as previous work has shown that finance is critical to the start-up of life science firms (Davila et al., 2003; Hellman & Puri, 2000), and work has also shown that R&D is the impetus to new technology-based firm growth (Autio, 1997; Gubeli & Doloreux, 2005). However, these studies have merely noted that financial resources and capabilities pay for R&D. *The present study's results indicate that R&D and financial resources and capabilities have paths, positions and processes that influence one*

another and are inextricably linked. More specifically, the present study shows that financial resources are largely dependent R&D resources and vice versa.

A detailed overview of this was discussed in chapter six, and Figure 7-2 below presents a simplified model of this. The model depicts that the core innovation that a firm pursues feeds into the R&D (1a) and financial (1b) resources and capabilities of the firm. The core innovation dictates how much development the innovation needs and how much capital is needed. In turn, the R&D and financial resources and capabilities feed into each other (2). The financial resources and capabilities fund the development of R&D, and developments in R&D attract additional funding. In turn, progressions in finance and R&D perpetuate the innovation towards a state of commercialisation (3a and 3b), and ultimately the progressions in the technology perpetuates the firm's growth (4).

Figure 7-1: Model of R&D and financial interdependence



Source: Author

As the discussion above indicates, this study found clear evidence that there is a strong bi-lateral dependence between R&D and finance in life science ventures, and the co-development of R&D and financial resources are critical to the early growth of life science ventures. From this proposition eleven is put forth:

> P11) There is a co-specialised relationship between R&D and financial resources and these co-evolve throughout the growth process of life science ventures, and firms that are adept at co-developing these resources are more successful in commercialising their innovations.

7.5 Dynamic capabilities and RBV

This study took a RBV influenced dynamic capabilities framework to look at the research questions, and in doing so the study made some important contributions to dynamic capabilities and the RBV. Most notably, it contributes to Helfat's (2009a) call for deep empirical work on dynamic capabilities. Accordingly, the theory is still in its nascent phase of development and needs deep work to extend it. *One of the major contributions of the present study is showing an output of dynamic capabilities – R&D and financial resources and capabilities.* Results from the study indicate that a life science firm's ability to reconfigure its resources and capabilities leads to the development of R&D and financial resources and capabilities. All of the firms in this study faced large resource constraints and competed against large established competitors, yet all these firms successfully developed and brought their innovations to a point of commercialisation. The analysis in chapter five underscored several dynamic capabilities that allowed the firms to develop the key resources needed to compete in such a competitive environment.

All of the firms leveraged a unique set of paths, positions and processes to develop capabilities that resulted in the development of key resources. To represent this, Figure 7-2 presents a dynamic capabilities framework of how the case firm BA1 developed its key R&D and financial resources.

The firm was presented an opportunity to develop a novel device for analysing biological materials, which established the main course of the firm. A second path that profoundly affected the firm was the establishment of a key partnership with the U.S Army. This

relationship provided critical R&D and financial inputs that that influenced the development of the firm's key resources. The third major path that influenced the firm's strategic course was the decision not to take in equity invesement. This limited the scope and speed of the development of the firm's key resources, but it also allowed the firm to maintain flexibility, which allowed the firm to stay dynamic.

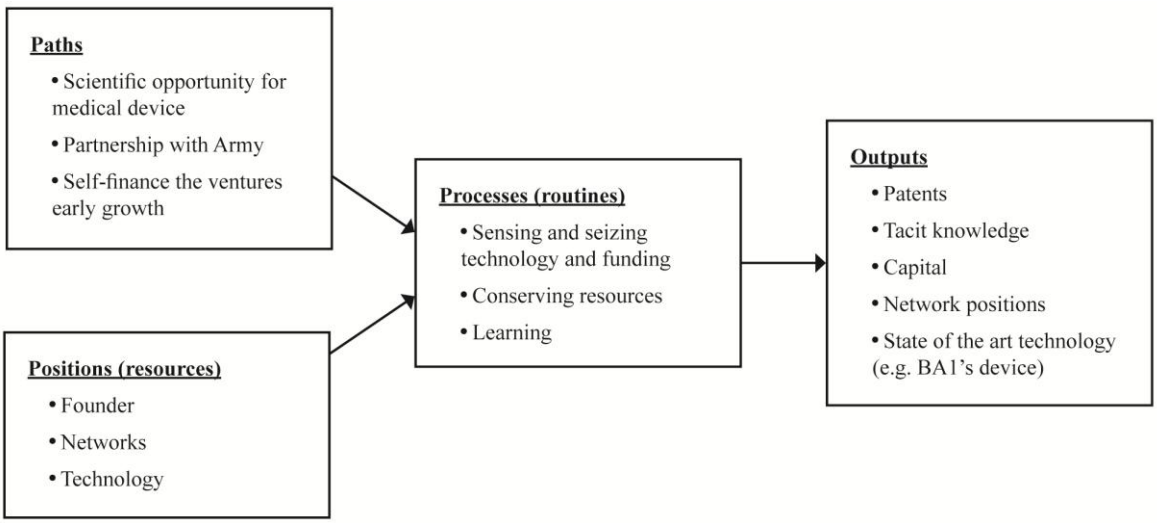
The second box in Figure 7-2 depicts the three most important positions (resources) that BA1 leveraged in order to pursue its paths. The most prominent position was the founder. He directly contributed to the R&D and financial resources of the firm. From a financial standpoint, he invested his own capital in the firm, and from an R&D standpoint, his scientific knowledge and capabilities allowed the firm to progress their technology. He also indirectly contributed resources, in that his background helped attract inputs from other organisations. For example, the U.S Army contributed substantial scientific knowledge to BA1, and the reason the Army worked with BA1 is because of the longstanding relationship BA1's founder had with the Army's chief scientist. The second position that the firm leveraged was their network position. The firm was well networked and used this to obtain key inputs. The third position that the firm relied heavily on was their technology. Their unique device was of interest to several prominent organisations, and the firm leveraged this to obtain key inputs.

The third box in Figure 7-2 shows that the firm developed and practiced several processes (routines) in order to maximise its paths and positions. One of the most important routines to BA1 was sensing and seizing opportunities. The central reason the firm successfully developed their device stemmed from their abilities to discover scientific opportunities. The founder established the firm based on three different sciences that he sensed out. Then on an ongoing basis the firm constantly sensed and seized science that helped in the development of their device. A second process that the firm relied on related to conserving resources. The financial and scientific capital available to BA1 was limited. For this reason, strategically using and conserving these resources was critical to the firm's development. Learning is a third process that proved important to BA1's ability to develop key resources. For example, the firm constantly learned from its earlier research. It also learned from its earlier financial decisions and interactions with partners. In turn, this learning greatly aided in the development of the firm's key resources.

The last box in Figure 7-2 shows the output of the firm's dynamic capabilities. From leveraging its paths and positions the firm created processes that led to important capabilities. In turn, these capabilities led to the development of advanced R&D and financial resources, which proved critical to the firm's ability to compete in an ultra competitive industry. More specifically, the firm developed patents, tacit and unique scientific knowledge, financial endowments, partnerships and a unique technology that allowed the firm to carve out a position in the market.

Although the firms differed in their development, the case of BA1 described above is representative of how all of the firms in this study leveraged their dynamic capabilities to create the resources on which they competed. One of the biggest criticisms of dynamic capabilities is that it does not show what the outputs of dynamic capabilities are (Helfat, 2009a). Thus one of the largest contributions of this study is showing that dynamic capabilities lead to the development of key resources. Furthermore, this study contributes to the dynamic capabilities literature by showing how firms develop and use their dynamic capabilities. This is also a significant contribution as few studies have holistically examined how firms do this (Arend and Bromiley, 2009).

Figure 7-2: BA1's dynamic capabilities outputs



Source: Author

The findings from this study also weigh in on the on-going debate as to whether resources are still relevant to dynamic capabilities. Some scholars believe that there is little use for the RBV in dynamic capabilities (Arend & Bromiley, 2009), whilst others see resources as what firms use their dynamic capabilities to reconfigure (Helfat & Peteraf, 2003; Makadok, 2001; Teece, 2007). Makadok (2001) goes one step further by suggesting that

firms build competitive advantages from both their resource picking abilities and their capabilities to reconfigure their resources. *Findings from the present study are supportive of this notion.* All of the case firms displayed competencies in choosing innovations to commercialise and picking important complementary resources to further develop their innovations. Moreover, resources are clearly an important part of how the firms developed and used their dynamic capabilities. Chapter five presents strong evidence on numerous resources that proved vital to the development of the firms' R&D, but these resources only provided value because the firms used their capabilities to maximise the value of these resources. For example, specialised R&D facilities provided important resources to BA1 and DD2, but these facilities only proved valuable to them because they were able to use their capabilities to integrate these resources into their R&D.

Emprical support for dynamic capabilities

In addition to the unique contributions related to dynamic capabilities, the results from this study reaffirm several dynamic capabilities that are offered in the literature. For example the study supports that learning is an important dynamic capability (Eisenhardt & Martin, 2000; Winter, 2000; Zollo & Winter, 2002). The within-group analysis in chapter five presented ample evidence of the importance of learning to both R&D and finance and is substantiated as well by Tables 6-25 and 6-28 in chapter six. *This study shows that learning allows firms to use their earlier R&D results to further the progress of their research. From a financial standpoint, findings from this study suggest that firms learn from their previous financing paths.* These findings are consistent with earlier studies which suggest that learning is a higher level dynamic capability that allows firms adapt to rapidly changing environments (Easterby Smith & Prieto, 2008; Verona & Ravasi, 2003; Zollo & Winter, 2002).

This study also offers support to sensing and seizing as a dynamic capability. Accordingly, all of the firms in this study were heavily reliant on their ability to find and take advantage of research and financing opportunities. The firms' processes for sensing and taking advantage of these opportunities were paramount to the firms' growth. These findings reaffirm work done by Herreld et al. (1997), which shows sensing and seizing are key capabilities in rapidly changing environments. *The third dynamic capability that the present study's findings embrace is R&D.* Based on case studies of petroleum firms, Helfat (1997) suggests that R&D is a dynamic capability that firms use to change their product or operations to make to enhance their competitive positions. Findings from the present study

unequivocally support this, as all of the case firms used advanced R&D capabilities to create new products and/or to advance existing products –ultimately improving the firms' competitive positions. Table 6-26 and 5-27 from chapter five highlight the unique R&D resources and capabilities that allowed the firms to develop a novel life science innovation.

A fourth dynamic capability that this study supports is transformational capabilities. All of the firms in this study displayed transformational capabilities. Almost all of the firms had situations influenced by outside events or internal breakthroughs that forced the firms to transform their operations. For example, DD1's drug did not progress quickly, which forced the firm to transform its R&D to focus on the development of a diagnostic device. Several of the firms also encountered events that forced them to reconfigure their financial resources. For example, BA2 won a large grant that changed their financial trajectory. This grant forced the firm to reorganise its financial resources and priorities. The support of transformational capabilities is a notable contribution as the theory of dynamic capabilities is based on the central tenet that firms that rearrange their resources and capabilities in response to changing conditions perform better (Rindova & Kotha, 2001; Teece et al., 1997; Winter, 2003). However, little empirical work directly supports this; the results from the present study give insights into how and why young life science ventures reconfigure their R&D and financial resources. These results also support the idea that strategic decisions are triggered by events, and that firms must be able to alter their strategies to respond to these events (Canales and Villa, 2005).

7.6 VC and government grants

This study also produced findings related to VC and government grants. VC is highly influential on life science firms (Baum & Silverman, 2004). For this reason, and also because of the researcher's interest in VC, this study incorporated the influence of VC on the development of capabilities and resources in life science ventures. In a similar fashion, findings relating to grant-backed firms also emerged as three of the case firms received sizable government grants. Although VC and grants are not the central focus of this study, some important findings from the study related to these areas surfaced. This section details these findings.

For all of the firms in this study that received VC, it provided essential capital, and in most of the cases important management inputs. However, all of the VC backed firms,

unsolicited, offered an in-depth description of their desire to avoid VC in the future. This is mainly because of the founders' dilution of equity that happens when VCs invest in a company. It is not just the dilution in equity that causes concern, but also the loss of control. Once the firms dilute beyond a certain point, they lose control of their overall operations. MD2 ran into this problem, and because of it, one of the research projects that the founders thought had great potential was discontinued because the VCs wanted to stop it, and the VCs had gained enough control to do so. These findings are consistent with previous studies, which show that VCs often take large amounts of equity (Hsu, 2004; Sahlman, 1990) and that conflicts often arise because of the founders' dilution (Berglof, 1994; Hellmann & Puri, 2002).

Interestingly, BA1, DD1 and MD2's CEOs –-without prompting– referred to VC as '*a necessary evil*'. Similarly, four executives from four different firms (BA1, DD1, MD1 and MD2) discussed in detail how the VC model is '*broken*'. They specifically pointed to the dilution of equity and the amount of resources consumed in attracting VC and dealing with the VCs.

Another interesting finding relating to VC that this study gleaned is the impact the recession that started in 2008 had on the funding for life science ventures. The recession caused clear funding obstacles for the firms in this study. Four of the firms without prompting went into detail on how VC for life science ventures 'dried up'. Furthermore, the same firms discussed how the recession has fundamentally changed the funding model of VCs. They suggested that VCs are no longer interested in financing early stage ventures, and VCs would only invest in later stage firms. The impact of this did have a bearing on this research as it affected the financial paths of the firms in this study. The research did not go into great depth on how the VC model has changed, but the findings are worth noting and may be used for future studies examining the impact of the recession on the funding of life science ventures.

In order to avoid the drawbacks of the traditional VC funding model, two of the firms followed alternative financing paths. BA1 and BA2 financed their early growth through personal funds and then received a considerable amount of financing from small business innovation research (SBIR) grants. They both received close to a million dollars through these grants, which provided the bulk of the financing needed to get the firms to a point of

commercialisation. These grants required no equity from the firms and allowed the founders to keep the decision-making powers in the firm.

Overall the strategy of avoiding VC worked well for BA1 and BA2. This is consistent with the previous research, which suggests that grant-funded firms display superior performance in comparison to VC backed firms (Gans & Stern, 2003; Lerner, 1996). What the literature does not show is why SBIR firms demonstrate superior performance. Lerner (1996) conjectures this may because of the intense competition for the grants, which results in only the very best firms getting them. The results from the present study suggest that grant-backed firms acquire the capital they need, but do not have to contend with the inefficiencies created by outside investors.

This section underscores the study's finding relating to the recent changes and challenges that life science ventures face in financing their development. From this discussion the following propositions is set forth:

> P12) Grant-backed firms' superior performance compared to VC backed firms is a result of the grant backed firms not having outside investors creating inefficiencies that stifle development.

7.7 Implications for practitioners and policy makers

The discussions above underscore the findings in relation to the context of life science ventures and the key theories that this study draws on. This section goes into more depth on the findings from a practical standpoint; more specifically, it provides insights that managers of life science ventures can use in their quest to develop R&D and financial resources and capabilities. Following Starkey and Madan's (2001) argument that academic research in management needs to have a connection with the practice of it, the present study was designed to have implications for scholars, practitioners and policy makers. This study makes several unique contributions to the practical base of knowledge.

First, the findings underscore the importance of examining the paths, positions and processes available to develop key resources and capabilities. From this strategies can be set forth to position a firm. Closely related, this study also supports the valuable, rare, imperfectly-imitable and non-substitutable (VRIN) framework as an analytical tool for life

science managers to use when evaluating resources. Managers must analyse the resources required for their firms and gauge whether or not the resources can serve as a source of competitive advantage. Analysing whether or not each resource is valuable, rare, and imperfectly imitable and non-substitutable will determine it. Once key resources and capabilities are identified, it is then important for firms to examine the options for developing the resources they need: what paths are available to the firm? What positions does the firm have to leverage in these paths? What processes is the firm skilled in and what processes could they create? For example, MD1 identified several unique options for developing their spinal technology and carefully evaluated the possible outcomes of the paths available to the firm. From this analysis the firm made the strategic choice to self-finance and self-develop their device, and these choices has allowed the firm to maintain organisational flexibility whilst still developing a state of the art device.

Second, findings from the present study emphasise the importance of partnerships in life science ventures. The R&D literature underscores the importance of partnerships in the development of novel innovations (Blumenthal et al., 1986; Calabrese & Silverman, 2000; Coombs & Deeds, 2000). However, it has largely been neglected from a start-up firm point of view and has failed to offer prescriptive insights for practitioners. The present study isolates the importance of partners from a life science venture's perspective. The results indicate that managers must become proficient in sensing partners and developing routines to work with their partners. A major catalyst to the development of the firms in this study was their ability to find partners that were a good strategic fit; i.e. partners that offered needed inputs and were amicable to work with. For example, BA1's partnership with the US government is the central reason that the firm successfully developed a leading edge instrument for identifying diseases. Another prime example of the importance of partners is the importance of BA2's partnership with a top university. This university provided scientific inputs that proved vital to the development of their chiral drug technology. The findings from this study also suggest that that scholarly journals and conferences provide a means to find and vet potential partners. In addition, this study also indicates that partners are often inhibitive to growth. In short, this study reinforces the alliance literature, which shows there are both positives and negatives with partnerships (Cassiman & Veugelers, 2006; Sampson, 2007). Consequently, it is important for managers to carefully sense and evaluate potential partners.

Third, firms should analyse at what point in development specific resources and capabilities will become critical. Several of the firms from this study did not properly estimate the timing and the amount of financing they would need. This delayed their entrance into the commercialisation phase and caused a bottleneck in the firms' growth. For example, MD2 did not properly time its funding rounds, which forced the firm to abruptly stop three important projects that they had started because they had not brought in enough capital. In general, the study shows that the proper timing of the development or acquisition of resources allows firms to avoid many troubles.

Fourth, this thesis underscores the importance of international paths. DD1 and MD2 greatly expedited the commercialisation of their products because they first put them through European approvals. This proved much more efficient and cost effective then FDA approval. BA1, BA2 and MD1 also greatly aided their early growth by actively marketing their products overseas. The overseas revenues greatly helped the firms finance their growth.

Fifth, this study's findings suggest new ventures should explore all financing options before committing to a VC path. Although the results of this study are supportive of the literature that indicates VC is often needed for life science ventures because of the high degree of risk (Baum & Silverman, 2004; Colombo & Grilli, 2009), the results also suggest that alternative routes of financing are available. As discussed in the literature implications, two of the case firms acquired financing from alternative sources; whereas, the other four firms did not even consider alternative paths. There might not have been any other paths available for the firms that did not pursue alternative financial paths, but the results of the study imply that it is not difficult or time consuming to look for them. For example, one particular source that many firms often do not consider is government grants.

Policy implications

On top of the management implications, this study also provides insights for policy makers. For starters, it adds to Lerner's (1996) findings that SBIR grants are effective in developing innovative firms. The present study adds to this by showing not only do these grants offer the needed capital for firms to develop, but these grants also offer an alternative to equity financing. This helps firms by affording them the capital they need, but without the drawbacks of equity financing. BA1 and BA2 were greatly aided by government grants, and for these firms the grants proved highly effective. The grants are

the central reason that BA1 commercialised its technology, resulting in the creation of jobs and the delivery of a technology that benefited society.

Another policy implication from this study is that governments from around the world need to better coordinate and standardise testing and development procedures for life science innovations. The literature notes this (Giovannetti, 2010; Martínez-Torres & Toral, 2010), but it does not provide prescriptive advice on how governments can work together to alleviate this problem. Moreover, Bio and several other large life science trade associations are lobbying for increased standardisation amongst governments across the world, but little movement has been made towards this (Bio, 2009). The present study suggests that the lack of standardisation is slowing the dissemination of innovation. This is hurting the firms that create innovations because these firms are required to expend extra resources in duplicating processes and procedures in order to obtain foreign market approvals. Moreover, this is greatly hurting the proclivity of internationalisation because often small life science firms do not have the resources to duplicate the entry procedures required in different foreign markets. Most of the case firms in this study focused mainly on one market because of the extra resources and time required to obtain approval for multiple markets. What is worse is people from all around the world are being barred from technologies that could help cure disease.

In short, the negative effect of this on life science firms was evident in most of the case firms in this study, as most of them desired to more rapidly enter foreign markets, but refrained largely because of the extra regulatory steps needed to enter them. Biotech policy makers need to find ways to increase the globalisation of biotech innovations, whilst still protecting their citizens from harmful technologies. This is being worked on (BIO, 2009), and is a tall order, but one that should receive even further attention.

7.8 Shortcomings

Management is a complex topic made up of many actors and outside factors. It is nearly impossible to properly examine all of these in a single study (Easterby-Smith et al., 2002), and for this reason almost all studies in management are flawed to some extent – the present study is no exception. The most glaring shortcoming of this study is that it relied on a small subset of life science firms. The life science industry is fundamentally different than most other industries – even other technology based industries (Owen-Smith et al.,

2002b; Powell et al., 2002). Life science innovations take years to develop, and there is much more regulation in life science than there is for most other industries, which further slows the commercialisation of innovation (Murray and Wolfson, 2010). The fact that this study used life science firms raises questions on the generalisability of the findings. However, this was factored into the study design as the questions and analysis were carefully crafted to provide both practical and theoretical implications. Furthermore, even if future research finds that the present study's results are only applicable to life science firms, then the findings will still make an impact, as the industry is a major and important part of the global economy. Moreover, the author has a practical background working with life science firms and the main motivation of this study was to help managers of life science firms better understand the key resources and capabilities needed in early growth.

Properly planned and executed qualitative research is valid, needed and important (Yin, 2008). However, qualitative research is always scrutinized for validity, and many quantitative purists will fault qualitative work without cause (Johnson & Onwuegbuzie, 2004). Consequently, it is important to reiterate that the approach taken in the present study was appropriate and properly executed. First, the theoretical constructs of the relevant theories were clearly not well developed; therefore, these theories needed qualitative work to extend them (Edmondson & McManus, 2007). Second, the study was properly designed and executed to minimise the impact of researcher bias and to establish trustworthiness in the findings. The six firms used in this study is an ideal number for case research (Eisenhardt, 1989a). Furthermore, a substantial amount of data was collected and the study was triangulated through multiple techniques (Yin, 2008). One shortcoming that arose from the high volume of data that the study generated is that some of its richness was lost in the presentation. Another shortcoming that arose from the data is that there was only one researcher who analysed it. Subject experts reviewed several important sections of the data, but given the researcher's constraints, it was not possible to have another researcher analyse all of the data.

Another potential shortcoming of this study stems from the theoretical framework used. Even for qualitative work, dynamic capabilities presents many challenges because of its lack of theoretical development (Helfat & Peteraf, 2009). Potential problems arose with the present study because the study's framework is based on a relatively undeveloped theory. However, the multiple theoretical inputs used to design and analyse this research minimised this problem; i.e. the RBV provided a means of theoretical triangulation.

A third potential problem emanated from the study's holistic approach to examining the development of R&D and financial resources and capabilities. Developing resources and capabilities is a complex phenomenon that evolves over time, and it is difficult to capture in a single study. Notwithstanding, scholars contend that it is possible to isolate process-based phenomenon over time in a single study – if the study is properly executed and factors in the element of time (Pettigrew, 1992). The present study followed this advice and longitudinally examined the development of R&D and financial resources and capabilities.

7.9 Recommendations for future research

This study put forth a number of findings relating to the development of R&D and financial resources and capabilities. There are opportunities for future research to both qualitatively and quantitatively extend the present study's findings in several ways. For example, a study is already underway to develop measurable constructs on how to gauge the background of a standout scientist.

This research found that inward and outward international activity contributes to the development of R&D and financial resources and capabilities. Work is underway using the present study's findings to create measurable constructs to quantify the importance of international activity. The findings here provide a good basis for this, but there still opportunity to unearth deeper insights on these triggers.

Another major finding from this study is that the traditional VC financing model used by many life science firms is inherently flawed. VC is critical because it provides the capital needed for high risk ventures to grow (Chakma & Sammut, 2011; Gans & Stern, 2003; Timmons & Bygrave, 1986), and VCs in most instances offer non-financial value from their management inputs (Hsu, 2004; Unger et al., 2010), but VC financing also has its drawbacks (Kortum & Lerner, 2000). The present study unearthed the idea that the VC model is broken, which presents an opportunity to go into more depth as to if and why this is through qualitative interviews. Similarly, the findings suggest that there are funding models for high technology ventures that are superior to the traditional VC model. There is a developed literature on angel investors, but little research has looked at grants as a source for funding life science ventures. Lerner (1996) is one of the few noted studies on this topic, but this study simply compares performance of grant- backed firms against VC-backed firms. Findings from the present study suggest there are other reasons as to why grant-backed firms perform better, namely that grant-backed firms avoid the drawbacks of equity investors. There is ample room for future work to go into more depth on this, and also to look for other reasons for this difference.

7.10 Summary and final conclusions

The author is a partner in a life science-related venture, and this research was spurred by a desire to unearth deeper insights on the development of key resources and capabilities needed in their early growth. Initially the study looked at the effect of internationalisation and VC on the development of key assets in life science ventures. The exploratory interviews and initial literature revealed a more relevant question: *What influence do R&D and financial resources and capabilities have on the early growth of life science ventures?* A further look into the life science literature revealed several gaps related to this question; most notably, little investigates how R&D and financial resources and capabilities are formulated and how these resources and capabilities affect the early growth of life science ventures. This motivated the author to holistically examine the R&D and financial resources and capabilities needed in the early growth of life science firms.

This study unearthed several unique insights on the development of R&D and financial resources and capabilities. This study was especially interested in life science firms, which are firms that are in turbulent environments and are driven by innovation (Azzone & Dalla Pozza, 2003; Bergeron & Chan, 2004). Despite the fact these firms are in such dynamic environments, few studies have examined them through a dynamic capabilities lens. Life science firms are technology-based, highly dynamic and important to the global economy. For these reasons and because the researcher was interested in the industry, life science firms served as the focus.

The research influences and the fact that this study drew on a relatively undeveloped theory made a qualitative research approach appropriate (Edmondson & McManus, 2007). Case studies have gained credibility in the field of management (Eisenhardt, 1989a; Yin, 1981, 2008). For this reason and the flexibility that case studies offer, this study implored a case method. Six case firms were carefully selected, and the data for the firms came from multiple rounds of interviews with multiple key informants and a considerable amount of secondary data. The research started with a broad interest on resources and capabilities and honed down the resources and capabilities that emerged as important. The multiple rounds of interviews allowed more specific questions to be designed from the earlier round of interviews, which allowed the study to further hone down on the key themes. The analysis began with a multiple step process of abstracting themes. From this the categories of themes emerged that provided the structure for the analysis. The firms were categorised

into three groups and a within-case, cross-group and cross-case analysis was performed. Following Maitlis and Lawerence (2007), a systematic trail of evidence supported the findings. Although the methods are not highly unique, what is unique is the massive amounts of data that this study collected and analysed. The study yielded over 500 pages of transcripts and over 3000 pages of secondary data. What is also unique is the depth of analysis for the relatively large number of case firms and massive amount of data that the study drew on. Another interesting aspect of the research is the unique questionnaire that the study used to triangulate and validate the findings.

This thesis examined the resource and capability development of life science ventures. It was particularly interested in R&D and financial resources and capabilities; what they are, how they are determined and deployed by firms towards competitive advantage. Table 7-1 presents the unique contributions of this study. These are contributions that offer something materially different from what is already offered in the literature, and advance the body of knowledge on the research topics. Clearly the study produced significant insights on the research topics.

Table 7-1: Study's propositions

P1) Firms that have a narrower scope of R&D focus are more successful in commercialising their innovations because they are better able to attain the core resources and capabilities needed to develop their innovations.
P2) Life Science ventures that publish in scholarly journals and attend conferences are better able to identify complementary technologies and assess the capabilities of potential partners.
P3) Life Science ventures that internationalise are motivated to do so to avoid FDA regulatory bureaucracy, and this is forcing firms to develop resources and capabilities for operating in international markets.
P4) Firms that employ one or more standout scientist are better able to develop R&D resources because of the standout scientist(s) R&D capabilities and scientific contributions.
P5) Life science ventures that attempt to develop several innovations simultaneously develop slowly and risk failure as they create large financial requirements.
P6) Firms that self-finance their growth will have significantly different financial trajectories than firms that pursue equity investors, as they will have less capital available, but will maintain greater organisational flexibility.
P7) Inexperienced founders are more likely to self-finance their venture's early growth, as opposed to experienced founders who use their background to secure financial resources from outside sources.
P8) IPOs consume valuable time from top management teams, and managers that spend less time on IPOs are better able to help their firms develop operational resources.
P9) Life science ventures with advanced R&D complementary assets are more successful in bringing their innovations to market, as the R&D complementary assets allow them to progress their innovations to a point of commercialisation.
P10) Firms that recognise the complementary and potentially specialised nature of finance and proactively manage these assets in relation to their R&D are more successful in bringing their innovations to a point of commercialisation.
P11) There is a co-specialised relationship between R&D and financial resources and these co-evolve throughout the growth process of life science ventures, and firms that are adept at co-developing these resources are more successful in commercialising their innovations.
P12) Grant-backed firms' superior performance compared to VC backed firms is a result of the grant backed firms not having outside investors creating inefficiencies that stifle development.

Source: Author

In conclusion, this study makes a number of incremental but important contributions to the practice and scholarship of management. First, it unearths key paths, positions and processes that lead to the development of R&D and financial resources and capabilities. Second, it offers insights on the influence of R&D and financial resources and capabilities in the early growth of life science ventures. Third, it offers empirical support to the dynamic capabilities framework (i.e. the paths, positions and processes framework). This framework can serve as it did in this study to further the examination of the development of key resources, but it can also be adapted for more general uses for strategic management. Put differently, results from this study contribute to the resurgence of the dynamic capabilities framework and offer a base for other studies to use in the examination of dynamic capabilities. Fourth, this study at least partially answers Helfat's (2009) call for deep empirical research to examine what the outputs of dynamic capabilities are. The present study examined what Teece (2007) sees as one of the most important outputs of dynamic capabilities, the development of key assets. Specifically this study looked at the paths, positions and processes leading to the development of R&D and financial resources and capabilities. Fifth, this study gives rise to the idea that the VC funding model is flawed.

This thesis provides a platform for a research career. Two papers have already been published from this thesis: the first presents the results from exploratory interviews on the influences on the development of resources and capabilities, and the second is on the important resources that serve as the antecedents to dynamic capabilities. Another paper that stems from the present study reviews and reconceptualises dynamic capabilities based on the extant literature and the findings from the present study. Several top scholars have reviewed the paper, and it is under revision for one of the top journals in management. In addition, several other papers will soon be written based on this thesis. For example, one paper will present the empirical findings on the paths, positions and processes that lead to the development of R&D and financial resources and capabilities. These are the papers slated in the near-term. There are opportunities for many more papers to emanate from this thesis in the long-term.

The life science industry is an important part of the global economy. Innovations from the industry have been the main force that has increased the average life expectancy of a person living in the U.S from sixty-six in 1950 to seventy-eight in 2008 (Bio, 2009). Moreover, innovations in the industry produce over $80 billion in revenue per year. Small

firms are germane to this innovation, as it is estimated that forty per cent of innovation emanates from firms that employ fewer than 250 (Van Beuzekom and Arundel, 2009). Despite the importance of small firms, little is known on how small resource constrained firms develop the R&D and financial resources and capabilities to develop financially and scientifically capitally intensive innovations. This study makes considerable contributions to filling this gap.

In short, this is a rigorous, well planned and executed study that provides great depth on the R&D and financial resources and capabilities germane to the early growth of life sciences ventures. It makes several unique contributions to the scholarship and practice of management.

Appendix A: Data Reduction Tables

Table A1: Level 1 data summary

PRIORI THEMES
Founder's experience (Toole & Czarnitzki, 2009)
Founder's education (Toole & Czarnitzki, 2009)
Industry alliances (Audretsch, 2001; Rothaermel, 2001)
University alliances (Anselin, Varga, & Acs, 1997; Gubeli & Doloreux, 2005)
Government alliances (Giesecke, 2000)
VC monitoring activities (P. A. Gompers, 1995)
VC inputs (P. Gompers & Lerner, 2001)
International inputs (Athreye & Godley, 2009; Welch & Luostarinen, 1993)
International markets (Andersson & Wictor, 2003)
R&D capabilities (Tripsas & Gavetti, 2000)
Complementary technologies (A. Arora & Gambardella, 1990; Teece, 2007)
Sensing and seizing technological opportunities (Teece, 2007)
Distribution assets and capabilities (Trispas, 1997)
Service assets and capabilities (Teece, 1986)
Intellectual property (A. M. Arora & Ceccagnoli, 2006; Trajtenberg, 1990)
R&D facilities (Pisano, 1990)
Production assets (Schmenner, 2009)
INDUCTIVE THEMES
Unique technology
Industry developments
FDA approval
Pursuit of patents influences development
Failed R&D projects
Raising capital is necessary
Raising capital consumes time and resources
Core technology is vital to raising capital
Integrating resources is vital
Raising VC wastes time and energy
TMTs waste time with VC
The VC model is broken

Source: Author

Table A2: Level 2 data repackaging

R&D	• Founder's experience • Founder's education • Industry alliances • University alliances • Government alliances • International inputs • International markets • R&D capabilities • Complementary technologies • Sensing and seizing technological opportunities • Intellectual property resources • R&D facilities
Financial	• Founder's experience • Founder's education • Industry alliances • Government alliances • VC inputs • FDA approval • Raising capital is necessary • Raising capital consumes time and resources • Core technology is vital to raising capital • Integrating resources is vital
VC model is flawed	• VCs do not want to invest in early stage firms • TMTs waste time with VC • Raising VC wastes time and energy

Source: Author

Table A3: Level 3 data structure and framework

Metathemes	Emergent Themes
R&D paths	• Unique technology • Partnership opportunities • Gaining FDA approval • Complementary technologies • Scientific developments
R&D positions	• Core technology • Patents • Scientists • Star scientists • Founders • Networks • Research facilities
R&D processes	• Seizing scientific opportunities • Learning from earlier research • Navigating government approval • Developing scientific partnerships • Transforming R&D
Financial paths	• Core technology made specialised financing necessary • Obtaining capital is resource consuming • VC • IPO • Revenue generation
Financial positions	• The core technology • Scientific staff • Founders • TMTs • Government resources
Financial processes	• Sensing financing opportunities • Integrating financial resources • Budgeting financial resources • IPO related processes • Dealing with investors

Source: Author

Appendix B: Interview Schedule I

Preliminary Research on Resources, Dynamic Capabilities and the Role of Venture Capital in Life Science Firms

Professor Marian V Jones
Jon Carrick

Instructions to Interviewers
Fill in one booklet per firm (or per interviewee).
The interview should follow the format of *open* questions, answered in the respondent's own words; followed by *closed*, checklist questions.

1. Write the answers to the open questions as told by the respondent, use as much space as necessary.
2. Follow each section of open questions immediately with the corresponding closed questions in order to verify the respondent's story.
3. Ask the closed questions precisely and enter the answers in the spaces provided
4. Once the form is completed, ask the respondent to elaborate on any issues that have emerged during the interview that they think are of particular importance to the future development of their firm

Company Name:

Address:

Telephone: e-mail

Time:

Date:

Interviewer 1:

Interviewer 2:

Section A. Open Questions: The Firm's current position

Q. Please tell us about this firm. In your own words please describe your firm, the business it does, the nature of its products, its role within the industry and its competitiveness in domestic and any foreign markets.

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• Business, products and manufacturing or production processes • Firms' role in its industry (identify the industry). • Suppliers, buyers, new entrants, substitute products, concentration. Your position on the industry value chain • Customers / domestic market, who, where? • Competitive position, market share, unique niche, etc. source of competitive advantage in domestic market • Describe your firms overseas markets, where are they, how many are they, what do you sell there, what is your source of competitive advantage there?	

Continue on reverse if necessary

Section A. Closed Questions: The Firm's current position

(Please ask questions and record answers precisely in this section.)

A1. Business and Products

1.1 Would you classify your firm primarily as: **1.** a manufacturing firm _____ **2.** a firm producing services _____ **3.** an R&D laboratory_____ or **4.** other, please describe_____? (tick one)

1.2 What percentage of your firm's annual income comes from: 1. Sale of hardware products_____ %, 2. Sale of software products_____ %, 3. Sale of services_____ %, 4. Research grants_____ %, 5. Other _____% (check total = 100%)

1.3 What proportion of your firm's annual income comes from: 1. Business activities/ sources in the UK _____%, 2. Business activities / sources overseas _____ % ? (check total = 100%)

1.4 What is your major product?
_____
_____ ?

1.5 Is your major product sold to: 1. consumer markets _____ , 2. organisational markets _____ 3. both _____ ?

1.6 Would you describe your product as: (tick all that apply)

- Having a narrow range of applications within one or a few industries / markets_____
- Having a wide range of industry applications across a number of industries / markets_____
- Specific to a target group of customers with particular needs_____
- A niche product with local applicability (UK only)_____
- A niche product with global applicability (foreign markets) _____
- General to a wide range of industries / markets in UK and abroad _____

1.7 Would you describe your major product as: (tick one only)

- Innovative, leading edge technology _____
- An incremental innovation of relatively new technology_____
- Other, please describe
  _____
  _____
  _____
  _____

1.7 Do you have a portfolio of products? 1. Yes _____, 2. No _____? (tick one)

1.8 Could any of your products be described as a Cash Cow? 1. Yes ____ 2. No ____ 3. Might be in the future _____ ?

A2. Industry Structure

2.1 Approximately how many direct competitors do you have in the US _____ ?

2.2 Are your main competitors large firms _____, or small firms _____?

2.3 If you have few competitors, can you identify them by name? _____?

2.4 If you have few competitors, are these firms US owned _____, foreign owned _____, both _____ ?

2.5 How unique is your product or service _____ ?

2.6 How important is your product e.g. could customers use something else in its place _____? What _____ ?

A3. Competitive Advantage

3.1 Please describe the source of your firm's competitive advantage in the US?

_____
_____
_____
_____
_____
___

3.2 Please describe the source of your firm's competitive advantage in its overseas markets if any?

_____
_____
_____
_____
_____
_____
_____

Section B. Open Questions: The Firm's Foundation Process

Q. In your own words, please describe how your firm was founded, who was involved, how it was supported, why it was founded and the aspirations, aims and objectives of the founding members.

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• Was there a particular reason for its foundation eg to exploit a new technology or innovation, or other? • Is there any pre-foundation history that influenced the establishment of this firm eg spin-out or spin-off, MBO etc.? Reasons? Opportunities or threats? • Who were the founders, describe, them, what role did they play in founding, what role do they play now? • What international connections did the firm, or its founders have at foundation? What role/contribution have these made to the growth of the firm (in general internationally). • How was the firm resourced at foundation (financial, physical resources, human resources)? Where did the resources come from, how did the firm go about getting them? • Where there any important university connections? • Were there any important industry partnerships? • Did the firm use Venture Capital in the foundation process? What were the main motivations for using VC?	

Section B. Closed Questions: The Firm's Foundation Process

(Please ask questions and record answers precisely in this section.)

1. In what year was the firm founded? _____

2. a) Was the firm founded specifically to develop a scientific/technological innovation?

Yes_____(go to 2.1)

b) Since founding, has your firm developed a scientific / technological innovation?

Yes_____(go to 2.1)

(If no to both 2a and 2b, go to 3)

2.1 Please describe that innovation

_____

_____

_____

_____

_____

_____

2.2 What was the source of the firm's **first** scientific/ technological innovation?

Yes/No	**Source Country**
• In-house development	_____
• University	_____
• Other firm	_____
• Previous employer	_____
• Acquisition of patent rights from third party	_____
• Other_____	

2.3 Does the firm have intellectual property rights for that innovation here and/or abroad? (Note all countries and sequence in which IPRs were sought.)

_____

_____

_____

_____

2.4 Does the firm have FDA approval for the US Market?

2.5 Yes _____ Date _____

2.6 No _____ Pending_____

3. Why was the firm founded?

_____

_____

_____

4. How was the firm financed? (tick all that apply)
   - Research Grant _____
   - Enterprise / start-up funding from Government _____
   - Bank loan _____
   - Founder's personal sources _____
   - Other _____
5. Was the firm founded as an independent new firm with no corporate history? Yes_____(go to 7), No _____ (go to 6)
6. Was the firm founded as: (tick one only)
   a. A spin-off from another firm _____
   b. A spin-off from a university _____
   c. Merger/takeover _____
   d. Management worker buy-out_____
   e. Other _____
7. How many founders were there? _____.
8. What personal, social or business contacts and networks with individuals or organisations overseas, did the founding team have at start-up?

   _____

   _____

   _____

9. To what extent have those links and networks contributed to the development and growth of the firm?

   _____

   _____

   _____

   _____

10. The table below relates to the human and social capital of the firm at founding. Please record relevant details on each of the founders.

	Founder 1	**Founder 2**	**Founder 3**	**Founder 4**	**Founder 5**
Age					
Gender					
Nationality					
Current role/position?					
Previous entrepreneur? Yes/No					
Family history of entrepreneurship Yes/No					
Highest Level of education, e.g School Cert, College degree/diploma (CD), University 1st Degree (UD), Advanced degree(AD), Doctoral degree (Dr), Professional bodies,					
Overseas education? Where ? Country (ies)					
Overseas working experience Where? Country (ies) SME/MNE? Role Position?					
Working experience in a Domestic internationalising firm?					
Foreign language ability? Languages? Spoken/written/fluent?					

Section C. Open Questions: Critical Events and Milestones (Timeline)

Q. Please tell us about events in the history of the firm that you see as major milestones, or critical incidents in the development of the firm, or things that happened, internally or externally, that triggered change in the firm's development process?

Enter the foundation date of the firm at the left of the time-line.

1. Record the nature of each event
2. Write the date on the approximate place on the time-line
3. Write the story surrounding the event (continue over for space)

Section C. Open Questions: Prompts Relating to Events on the Firm's Timeline

Q. Please allow the respondent to discuss each event as fully as possible. The prompts relate to each relevant event

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• When did the firm get venture capital investment? • What triggered this event? • Were business networks and alliances important in any of these milestones? What role did VC play in aligning these networks? • What were the implications for the future growth and development of the firm? • What were the implications for the functional areas of the firm: R&D, manufacture, marketing, distribution, new product development, commercialisation, funding, etc. • What implications did the event have for internationalisation or international aspects of the firm's business? • What new processes or strategies were triggered? • What aspects of the firm's business were dropped? • What were the immediate effects on profitability, financing, sales, revenues, etc. • In retrospect, what were the long-term effects?	

Continue on reverse if necessary

Section D. Open Questions: The Internationalisation Process (Timeline)

Q. Please tell us about the firm's internationalisation process from its first international links and contacts, to its first international contracts and investments, to its current situation as regards involvement in international business.

Enter the foundation date of the firm at the left of the time-line.

1. Record the nature of each internationalisation event recounted, as far as possible as the respondent describes it, with countries.
2. Write the date on the approximate place on the time-line
3. Write the story surrounding the internationalisation event (continue over for space)

Section D.1. Open Questions: Prompts Relating to Events on the Firm's Internationalisation Timeline

Q. Please allow the respondent to discuss each event as fully as possible. The prompts relate to each relevant event

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• What role did the VC play in the internationalization of the firm? • How did your firm's involvement in international business evolve? • What was the nature of the cross-border arrangements you had? Export, import licensing in or out of technology, source of technological knowledge, raw materials etc. • What was the purpose of them? Increase knowledge, expand sales, exploit opportunities, avoid unfavourable conditions in home country? • Were there any investments involved (FDI), investment in technology etc.? • What were the implications of your international involvement for the functional areas of the firm: R&D, manufacture, marketing, distribution, new product development, commercialisation, funding etc. • How important is your international activity to firm growth and development in general? • What did the firm learn from its overseas involvement in relation to overseas markets, new product development, marketing techniques and processes, technological techniques and processes, R&D, technology transfer and the protection of intellectual property	

Section E. Open Questions: Boldness, Creativity and innovativeness of International Ventures

Q. Please tell us about anything in your firm's international activities that you would consider to be bold / innovative / venturesome / creative? (If the respondent feels that nothing they do is particularly bold / innovative / venturesome or creative, ask them to explain why and what makes them say so).

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• What particular international activities in which your firm is involved could be described in those terms? • Why would you describe them in that way? • Did the VCs have an influence an influence on these events? Did they encourage innovation? • Have the VC(s) helped increase your capabilities? • Have the VC(s) helped you become more dynamic and able to expand change your capabilities quickly to respond to the market? • How did these activities evolve, develop or come about? • What was it within the firm that led to these developments? • What stimuli/ events in the external environment? • Were there specific opportunities or threats that were responded to? (new markets, new production methods etc.). • To what extent did you actually search to find this stimulus? • Did anyone provide you information or a hint, or advice on that stimulus, and if yes, how did you use it? • How would your competitors see you in terms of: 1. Your optimism to achieve difficult /specific goals? 2. Your creativity in discovering attractive stimuli that others don't see?	

Section F. Open Questions: R&D and Product Portfolio Management

Q. Please describe the role of R&D in your firm, how it is organised, its relation to your portfolio of products, and to the development of new products for local and overseas markets.

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• How have the VC(s) affected the R&D of the firm? • Has the VC involvement adversely affected the R&D process? • Do you have an in-house R&D department and if so, how much importance is given to it in terms of numbers of employees, annual investment as a percentage of turnovers etc. • When was the R&D department established? • What role does it play? Research for internal purposes, research for other firms under contract? Research for strategic partners? • What international connections, contracts, and involvement does your firm have in relation to R&D? • What are the purposes of the international connections, and how does the firm benefit? • What R&D-based international connections has the firm had that have resulted in commercial business ventures?	

Section F. Closed Questions (Please ask questions and record answers precisely in this section.)

F.1 Strategy and Planning

1.1 Would you describe your firm's development as: (tick one only)

1. Organic (evolutionary process in response to events and triggers) _____
2. Strategic (develops according to our pre-determined plans)_____
3. A combination of 1. and 2. _____

1.2 Does your firm have a formal, written strategic plan? Yes / No.

1.3 If yes, does that plan make explicit reference aims and objectives relating to your firm's involvement or future involvement in international business activity? Yes / No.

1.4 If yes, does that plan contain explicit targets for Research and Development? Yes / No . For 1 year, 2 years, 3 years, 4 years, 5years, over 5 years?

1.5 If yes, does that plan make explicit reference to(Yes/No)

1. Product portfolio planning _____;
2. New product development_____;
3. Adaptation of products for foreign markets _____;
4. Entry into new foreign markets_____
5. Withdrawal from any current international business activities _____;
6. Cessation of R&D _____.

F.2 Firm Performance and Projections

2.1 How would you rate the performance of this firm in its first five years, on a scale of 1-10, with 1 being unsuccessful, 10 being successful?

Unsuccessful 1 2 3 4 5 6 7 8 9 10 Successful

2.2 Was the firm profitable in the each of the first five years?

Year 1 Y/N Year 2 Y/N Year 3 Y/N Year 4 Y/N Year 5 Y/N

2.3 What percentage of the firm's revenue was derived from overseas in each of the first five years?

Year 1 _____% Year 2 _____% Year 3 _____% Year 4 _____% Year 5 _____%

2.4 What is your firm's current percentage of profits is derived from foreign operations? _____% of total profits?

2.5 What is your firm's current percentage of sales is derived from foreign operations? _____% of total sales?

2.6 Would you mind telling us the approximate total sales of your firm in the last financial year £_____?

2.7 Would you mind telling us the profitability of your firm in the last financial year as a percentage of total sales_____ %

2.8 How many staff (FTEs), including working directors, does your firm currently employ_____?

Appendix C: Interview Schedule II

Research on R&D and financial assets and capabilities.

Jon Carrick

Instructions to Interviewers
Fill in one booklet per firm (or per interviewee).
The interview should follow the format of *open* questions, answered in the respondent's own words; followed by *closed*, checklist questions.

5. Write the answers to the open questions as told by the respondent, use as much space as necessary. Follow each section of open questions immediately with the corresponding closed questions in order to verify the respondent's story.
6. Ask the closed questions precisely and enter the answers in the spaces provided
7. Once the form is completed, ask the respondent to elaborate on any issues that have emerged during the interview that they think are of particular importance to the future development of their firm

Company Name: Address: Telephone: e-mail
Time: Date: Interviewer 1: Interviewer 2:

Section A. Open Questions: R&D and financial assets and capabilities

Q. In your own words please describe your firm's important R&D and financial assets and capabilities and how these were developed.

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• Key paths -Core technology -Scientific opportunities -Partnerships • Key positions -Core technology -Scientific staff -Founder • Key processes -Learning -Sensing -Integrating • R&D -VC Influence -Founders connections • Financing -VC Influence -Founders connections	

Continue on reverse if necessary

Section B. Open Questions: Critical Events and Milestones (Timeline)

Q. Please tell us about events in the history of the firm that you see as major alliance milestones important to the firm's development process?

Enter the foundation date of the firm at the left of the time-line.

4. Record the nature of each event
5. Write the date on the approximate place on the time-line
6. Write the story surrounding the event (continue over for space)

Section B. Open Questions: Effect of R&D and financial assets and capabilities on early growth (Timeline)

Q. In your own words please describe the effect of R&D assets on the early growth of the firm. Define early growth: from the time the firm started until the time that it started to generate a significant amount of revenue.

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• Key paths -Core technology -Scientific opportunities -Partnerships • Key positions -Core technology -Scientific staff -Founder • Key processes -Learning -Sensing -Integrating • R&D Alliances -VC Influence -Founders connections • Financing alliances -VC Influence -Founders connections	

Section C. Open Questions: The Value of Alliances

Q. In your own words, please describe how your firm's important alliances have affected your firm's early growth.(Define early growth for respondent)

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• Did any of the alliances help the firm obtain financing? • Did any of the alliances lead to development in R&D? • Did the alliances formed through the facilitation of the VCs result in more valuable alliances? • Did the alliances formed from **within** the VCs portfolio have more value than the other alliances? • How did the alliances help in the early growth of the firm? What involvement did the VC have in these?	

Section C. Closed Questions: Major Partners

	Alliance Partner 1	Alliance Partner 2	Alliance Partner 3	Alliance Partner 4	Alliance Partner 5
Firm Type/same industry					
Alliance Facilitated by					
Relationship duration					
Purpose of alliance					
Specialised Assets created from alliance					
Alliance was critical to firms early growth					
Alliance was critical to firms internationalisation					
Is partner international					
Did alliance help in the firms internationalisation					

Section C. Closed Questions: The Firm's Alliances

(Please ask questions and record answers precisely in this section)

C.1 Alliances and Types of Alliances

1.8 How many strong alliances does your firm have_____?

1.9 What was the primary way that these alliances were formed? 1. CEO contacts_____ 2. VC facilitating alliances with other firms within their portfolios_____ 3. VCs facilitating alliances with firms outside of their portfolios____ 4. Industry networking events____
5. Other, please describe_____.

1.10 How many products did R&D alliances help your firm develop or jointly develop_____?

1.11 How many of the R&D alliances were facilitated by your VC_____? How many of these were from firms within the VCs portfolio_____?

1.12 How important were the VCs in facilitating alliances ?
Unimportant 1 2 3 4 5 6 7 8 9 10 Very Important

C.2 Alliance Formation

2.1 Please describe how your major alliances were formed?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Section D. Open Questions: The VC Business Model

Q. Please tell us your opinion of the VCs business model? (Make sure to explain what is meant by the VC business model.)

Prompts (for guidance)	Please allow the respondent to answer in their own way, and record their responses in their own words
• What was the most detrimental part of the VCs business model? • In what ways was the VCs business model good for your firm? • Have the VC(s) helped you become more dynamic and able to expand change your capabilities quickly to respond to the market? • Did the firm's executives waste a lot of time meeting with the VCs and writing reports for them? • Is the VC business model broken? • • If you were to do it all over again would you pursue VC for the firm?	

Section D. Closed Questions (Please ask questions and record answers precisely in this section)

E.1 Strategy and Planning

1.6 Was it the intent of the firm from its inception to attract VC investment? Yes / No.

1.7 Did the strategic direction of the firm change once VC came on board? Yes / No.

1.8 Did the VC encourage the internationalisation of the firm? Yes/No.

1.9 Did the VCs encourage you to incorporate alliances into your strategy? Yes/No.

1.10Overall was the VC investment positive on your firm's early growth?
1.5a Why or Why not?

_____
_____
_____
_____
_____
_____
_____
_____
_____

Appendix D: Triangulation Survey

Questionnaire

R&D and financial resource development of small life science firms

Jon Carrick / University of Glasgow

Dear
Name: Given Name:
Position:
Company:
Responsible for the firms since:

In my research I am analysing the variables that impact the development of small life science firms. Your valuable feedback is very important to me, and I would greatly appreciate if you would complete this questionnaire and return it to me as soon as possible.

The questionnaire will need approximately 45 minutes.
I assure that all information will be kept strictly confidential and will only be used for the purpose of this project. Thank you very much for your support.
Contact address:

Jon Carrick
5720 Old Ocean BLVD 5W
Ocean Ridge, FL 33435
+1-561-214-3657
Email: carrickjon

Closed question on R&D and Financial Assets and Capabilities

1. R&D assets and capabilities

Focus: R&D paths (past decisions and future opportunities) that influenced the development of your firm's R&D assets and capabilities. Put differently, these pursuits influenced the strategic direction of the firm's R&D. To what extent did the following opportunities have on the development of your firms R&D?

1= to no extent 7 = to a very great extent

		1	2	3	4	5	6	7
1.	Your firm's core innovation(s)							
2.	Venture capital investment							
3.	Industry partnerships							
4.	University partnerships							
5.	Government partnerships							
6.	Scientific breakthroughs by your firm							
7.	Scientific breakthroughs in the industry							
8.	FDA, EU or other approvals							
9.	Patenting							
10.	Other:							
11.	Other:							

Focus: Resources influencing the development of your R&D assets and capabilities.
To what extent did the following resources have on the development of your firms R&D?

1= to no extent 7 = to a very great extent

		1	2	3	4	5	6	7
1.	Your firm's core technology							
2.	Your firm's knowledge and capabilities							
3.	Your firm'sscientific staff							
4.	Star scientists*							
5.	Founders							
6.	Executive staff and board of directors							
7.	University inputs							
8.	Industry partners' inputs							
9.	Government inputs							
10.	Patents							
11.	Specialized R&D facility***							
12.	Other:							
13.	Other:							

*Star scientists are individuals who are highly accomplished. These individuals hold a great number of patents, have scientific papers that are frequently cited, have been central to the development of notable products in the field or a combination thereof.

******* Specialized R&D facilities are those that could not readily be leased or built

Focus: Processes influencing the development of your firm's R&D assets and capabilities.
To what extent did the following processes have on the development of your firms R&D?

1= to no extent 7 = to a very great extent

		1	2	3	4	5	6	7
1.	Finding (sensing) the core technology							
2.	Finding (sensing) complementary technologies							
3.	Networking							
4.	Learning from previous research paths							
5.	Tracking and sharing information							
6.	Other:							
7.	Other:							

Focus: Effect of R&D on the firm's early growth; early growth is defined as the time from when the firm was incepted until the time it developed and commercialised its main product (s).

How important were your firm's R&D assets and capabilities to the following:

1= no importance 7= highly important

		1	2	3	4	5	6	7
1.	Developing the core technology							
2.	Refining the core technology							
3.	Developing a platform technology							
4.	Allowing firm to progress technology							
5.	Developing new applications							
6.	Aiding in the attraction of key employees							
7.	Aiding in the attraction of research partners							
8.	Aiding in the attraction of investment capital							
9.	Gaining FDA, EU, or other approvals							
10.	Helping in the firm's growth							
11.	Other:							
12.	Other:							

2. Financial assets and capabilities

Focus: Financial paths (past decisions and future opportunities) that influenced the development of your firm's financial assets and capabilities. Put differently, these pursuits influenced the strategic direction of the firm's financial assets and capabilities. To what extent did the following have on the development of your firm's financial assets and capabilities?

1= to no extent 7 = to a very great extent

		1	2	3	4	5	6	7
1.	Costly to develop innovation(s)							
2.	Raising capital							
3.	Dealing with investors							
4.	Initial public stock offering (IPO)							
5.	FDA, EU or other approvals							
5.	Other:							
6.	Other:							

Focus: Resources influencing the development of your financial assets and capabilities.
To what extent did the following resources have on the development of your firm's financial assets and capabilities:

1= to no extent 7 = to a very great extent

		1	2	3	4	5	6	7
1.	Founder(s)' experience							
2.	Founder(s)' networks within financial community							
3.	Executive staff's and board members' experience							
4.	Executive staff's and board members' networks							
5.	Networks within financial community							
6.	Venture capital investor(s)' networks							
7.	Venture capital investor(s)' management contributions							
8.	Core technology's value in attracting capital							
9.	Company's staff							
10.	Other:							
11.	Other:							

Focus: Processes influencing the development of your firm's financial assets and capabilities.
To what extent did the following processes have on the development of your firm's financial assets and capabilities?

1= to no extent 7 = to a very great extent

		1	2	3	4	5	6	7
1.	Prospecting for capital							
2.	Negotiating for capital							
3.	Dealing with financiers							
4.	Budgeting capital for operations							
5.	Learning from earlier financial paths							
6.	Filing for an initial public offering (IPO)							
7.	Other:							
8.	Other:							

Focus: Effect of financial resources on the firm's early growth; early growth is defined as the time from when the firm was incepted until the time it developed and commercialised its main product (s).

How important were financial assets and capabilities to the following?

1= no importance 7= highly important

		1	2	3	4	5	6	7
1.	Developing the core technology							
2.	Developing key R&D assets and capabilities							
3.	Allowing firm to progress its technology							
4.	Aiding in the attraction of key employees							
5.	Gaining FDA, EU or other approvals							
6.	Helping in the firm's growth							
7.	Other:							
8.	Other:							

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