Elucidating the Relationship between Chinese Medicine and Systems Biology: A Multi-Sited Ethnography

Glatz, S.

A PhD thesis awarded by the University of Westminster.

Elucidating the Relationship between Chinese Medicine and Systems Biology

A Multi-Sited Ethnography

SABINE MARTHA GLATZ

A thesis submitted in partial fulfilment of the requirements of the University of Westminster for the degree of Doctor of Philosophy

May 2019

ABSTRACT

Ever since Chinese medicine encountered modern science in the late nineteenth century, the relationship between the two traditions has been extremely one-sided. At best, scientists perceived Chinese medicine as an archive of primitive knowledge from which potentially useful drugs could be extracted. Chinese medicine practitioners themselves, meanwhile, began a long struggle throughout the twentieth century to modernise their medicine with the help of Western theories and technology. At the turn of the twenty-first century, the involvement of systems biologists in Chinese medicine research created a new encounter, however, that, at least in the rhetoric of its actors, promised a very different kind of relationship: a match of two systems brought together by a shared interest in understanding life, health, illness and medicine as intrinsically complex and not amenable to the reductionist approaches of mainstream science. This research empirically investigates the nature of this relationship and how it emerged. It aims to contribute to the contemporary history of Chinese medicine by exploring the relationship between Chinese medicine and systems biology. This thesis argues that a heterogeneous network evolved, which is composed of human and nonhuman actors and their interactions created globally distributed research projects on Chinese medicine and systems biology.

For the purpose of this research, a multi-sited ethnography was conducted over a period of eleven months and a literature survey was employed to trace the start and the development of this heterogeneous network. Ethnographic data reveals in four chapters on the rhetoric and perceptions of the actors, their involvement in Chinese medicine research, their laboratory practice, and the networks and political ties, which developed into a heterogeneous network of Chinese medicine and systems biology research. This research concludes that in the 2000s, a heterogeneous network emerged through the shared ideologies of systems thinking and holism. The shared ideologies set the groundwork for systems biologists to engage with Chinese medicine on its own terms, and created scientific practices, co-operation and funding opportunities between Europe and China.

LIST OF CONTENTS

List of Tables

List of Figures

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my supervisor Prof Volker Scheid for his patient guidance and his valuable, constructive and challenging comments during the development of this thesis. His willingness to give his time has been very much appreciated. I would also like to thank Prof Gerda Wielander for her advice and assistance in keeping my thesis on schedule. My grateful thanks are also extended to Dr Lena Springer for her supervision and support in the initial stage of this project.

I would like to express my great appreciation to the EastAsian Medicine Research team for setting up the Beyond Tradition project and making this PhD project a part of it. I want to thank the staff in the Chinese and Western Herbal Medicine Department and Biomedical Sciences at the University of Westminster for their support in carrying out this thesis. Dr Sigrun Lange, Marija Kovandžić and Dr Francois Roupert gave me the fruitful and cheering conversations.

Special thanks go to all of my informants in China and in Europe. This dissertation would not have been possible without their participation and invaluable support, their considerable time and care. Their perspectives and the access they gave me to their laboratories and working places provided data for this thesis. I am also grateful to all the people in the administration who helped me organize my stay and fieldwork in China.

My heartfelt thanks go to the people who supported and shared this experience of making my PhD possible throughout the past four years. I am lucky to have met Dima Issa, Ana Janeiro, Alexa Raisbeck and Wareed Alenaini on enrolment day and since then, we have shared, motivated, encouraged and supported each other. I also would like to thank all my friends and peers at the University of Westminster.

Many thanks go also to those dedicated and engaged people who supported me with the drafts of this dissertation and their helpful comments and discussions including Katie Mansfield, Guy Waddell and Carina Pamminger.

My infinite gratefulness is dedicated to my boyfriend Josef who has supported me throughout the past four years. I will never be able to return your support. Thank you so much. I am also grateful to my family and friends.

I remain indebted to the innumerable people who have contributed to this dissertation.

AUTHOR'S DECLARATION

I declare that all the material contained in this thesis is my own work.

1. INTRODUCTION

Since the moment Chinese medicine encountered modern science in the late nineteenth century, the relationship between the two traditions has been rather one-sided. At best, pharmaceutical scientists perceive Chinese medicine as an archive of primitive knowledge from which potentially useful drugs can be extracted (Hsu, 2009; Jia, 2005). At worst, they dismiss Chinese medicine as a non-biomedical treatment, quack medicine[1], or a pseudoscience (Colquhoun, 2012; Van Hollen, 2005; Hsu, 2008; Xu, 1999; Scheid, 2014). In the twentieth century, Chinese medicine practitioners began a long struggle to modernise their medicine with the help of modern science (see for example, Lei, 2014; Scheid, 2002a; Taylor, 2005; Zhan, 2009; Andrews, 2014). At the turn of the twenty-first century, the phenomenon of an "interface" between systems biology, which is a multidisciplinary field that aims for a system-level understanding of a living organism[2], and Chinese medicine emerged (see Scheid, 2014). The term "interface" was first coined by Scheid (2014) to describe the translation between Chinese medicine and Western medicine through the Chinese medicine concept of *zheng* 证. *Zheng* describes patterns or symptoms in Chinese medicine diagnosis (Farquhar, 1994; Scheid, 2002a). In contrast, systems biologists and Chinese medicine researchers involved in this "interface", speak of a match of two systems brought together by a shared interest in understanding life, health, illness and medicine, as intrinsically complex and not as something that is amenable to the reductionist approach of mainstream science (see, for example, van der Greef, 2005; van der Greef

---

[1] The Cambridge Dictionary defines quack as "a person who dishonestly pretends to have medical skills or knowledge" (see Cambridge Dictionary, no date). Thus, quack medicine is not a (bio-)medical practice. Colquhoun (2012, p. 2) refers to complementary medicine and describes this as a "non-evidence based medicine".

[2] The definition of systems biology varies in the literature due to the multi-disciplinary background of systems biologists from biology, chemistry, biochemistry, engineering, bioinformatics and physics (see Nersessian, 2017). Most systems biologists define systems biology as a system-level understanding, which includes the networks of gene interactions, biochemical pathways, the underlying mechanisms and the behaviour of the system (Kitano, 2002; Ideker, Galitski and Hood, 2001). Others add to this definition that systems biology studies protein, metabolic and cellular pathways, which interact and are interdependent (see van der Greef, Stroobant and van der Heijden, 2004).

et al., 2010; Wang et al., 2005; van Wietmarschen et al., 2009, 2011; Zhang et al., 2012). According to their description, the new "interface" or match transforms the interpretation of encounters as a confrontation between the two opposites of modern science and Chinese medicine to a relationship between them, which is based on shared perspectives, and is not always guided by the same aims.

Since the 2000s, scientists have published articles about how systems biology has been used to examine Chinese medicine. These publications have taken the form of review articles and reports on Chinese medicine and systems biology research (see for example Wang et al., 2005; van der Greef, Hankemeier and Mcburney, 2006; van der Greef et al., 2010; Barlow et al., 2012; Uzuner et al., 2012; Buriani et al., 2012; Flower et al., 2012; Li, Yang and Gong, 2009), clinical studies (see, for example, Lu et al., 2006; van Wietmarschen et al., 2012; Huang et al., 2011; Litscher 2012), and research articles (see Scheid, 2014). These publications have primarily focused on the scientific evaluation of good practices in Chinese medicine research, the efficacy of Chinese medicine practice and therapies, and the historical investigation of the use of the Chinese medicine concept of *zheng*. The numerous studies on systems biology and Chinese medicine indicate that a scientific relationship is present between the two fields, and that other concepts and materials, such as omics technology or Chinese medicine drugs and practices are vital for their investigations. However, the existence of an "interface" or relationship and the nature of this relationship between Chinese medicine and systems biology, as well as, the development and defining features have yet to be unravelled.

Recent work by historians and STS scholars has investigated how modern science is integrated into Chinese medicine and has had a direct impact on it (see Lei, 2014; Scheid and Lei, 2014). Whilst ethnographers have provided empirical studies with STS approaches on the influence of science in traditional medicines (see, for example, Adams, Dhondup and Phuoc, 2010; Pordié and Gaudilliere, 2014; Kloos, 2017), little if any empirical work has been done to investigate the perspective of Western scientists on the integration of modern science in traditional medicine. It is still not known how systems biologists and technology participate and perform in current interaction processes between science, technology and Chinese medicine. It is also not known how Chinese medicine researchers consider the new approach of systems biology and technology. This thesis aims to investigate the involvement of systems biologists in Chinese medicine studies and Chinese medicine researchers in systems biology to understand how this latest relationship between Chinese medicine and systems biology emerged, what it was influenced by and how it changed from its emergence to the mid 2010s.

The aim of this study to investigate the emergence, interpretation and nature of this suspected "interface" between Chinese medicine and Western medicine in relationship to encounters that happened in the twentieth century. In this thesis, Rogaski's (2004, p.8) definition of encounters will be used. She claims that encounters are "moments of co-operation as well as coercion" between Chinese medicine and modern science or Western medicine that occurred before the twenty-first century. The term "interface" or relationship will be used to describe the contact or interactions between Chinese medicine and systems biology in the last two decades. This study will provide a historical and ethnographic account of various types of involvement of scientists and materials in this "interface" and multiple factors that have contributed to its emergence and development.

1.1 RESEARCH HYPOTHESIS AND QUESTIONS

The relationship between Chinese medicine and systems biology is defined in the secondary and scientific literature as an “interface” or a match. Thus, my research hypothesises that there is an “interface” or a relationship between Chinese medicine and systems biology. The actors involved might share perspectives and intentions which generated and shaped this interface from the beginning.

Based on this hypothesis this study investigates the following questions:

1. Is there an “interface” and if so, can this latest contact between Chinese medicine and systems biology be referred to as an “interface” and what is its nature?
2. How does this “interface” differ from previous encounters between Chinese medicine and modern science and Western medicine?
3. How did the actors become involved in Chinese medicine and systems biology research?
4. How did the participation of the human and nonhuman actors in Chinese medicine and systems biology research influence the development of the relationship between Chinese medicine and systems biology?

The objectives of this thesis are, first, to investigate the perceptions of this “interface” and how the “interface” arose and what its nature is. Secondly, to find out what makes it stable, detectable or describable and distinguished from past encounters between Chinese medicine and modern science. Thirdly, to discover how it emerged and developed over the past thirty years. To date, these issues are not addressed in the literature. While an extensive analysis of the existing literature is paramount, the scope of this study reaches beyond scientific literature about this phenomenon. The thesis not only aims to identify various academic and scientific components that underpin the emergence of the “interface”, but it also aims to provide an ethnographic account on the way this “interface” emerged and developed in multiple sites. I am going to focus specifically on the period from the 1990s to the 2010s.

In order to answer my research questions, I will employ methodological triangulation (Flick, 2014). With a triangulation approach, different data will be collected to expose the different interpretations and the development of this "interface" between Chinese medicine and systems biology. My methods will include: a literature survey, multi-sited ethnography and episodic interviews.

A literature survey of the secondary scientific literature published in Chinese medicine research and systems biology will be analysed to confirm scientific interest in Chinese medicine and systems biology. This analysis will enable me to identify the principal authors/actors and themes in this "interface" which will help me determine field research sites and topics of concern for both fields.

To investigate the emergence of this "interface" as an ongoing process, ethnographic methods will be used to document the process as it is happening. The ethnographic method used to investigate this "interface" aims to capture details about its emergence, involvements of actors, influences, perceptions, experiences and development while it is still emerging. Thus, multi-sited ethnography will be used to investigate how the "interface" occurred in globally distributed fields. This will be achieved through participant observations which yield rich primary data on this "interface" beyond the scientific publications.

Episodic interviews will be incorporated to collect episodes of biographic-narratives of the leading human actors. This method will help me obtain in-depth descriptions of their perspectives and experiences about their involvement and work in this "interface".

The meeting of two fields creates a multidisciplinary interaction between Chinese medicine and systems biology. Both fields themselves are multidisciplinary. For example, systems biology is a mix of biology, physics, chemistry, engineering and bioinformatics. Chinese medicine is a mongrel of traditional practices and theories mixed with biomedical disease categories and technology (see for example Lei, 2014; Taylor, 2005; Scheid, 2002a). In order to explore the scientific relationship between these two fields and to distinguish implemented structures from modern science into Chinese medicine, knowledge of Chinese medicine and the lenses of Science and Technology Studies (STS) are useful. Thus, an interdisciplinary research approach of ethnography, history and STS research can grasp the nature of this scientific relationship.

My research is the first to investigate the "interface" between Chinese medicine and systems biology with multi-sited ethnography. Multi-sited ethnographic descriptions and interview data will be provided through field research for eleven months from 2015 and 2016 in England (UK), in Graz (Austria), in Leiden and Zeist (the Netherlands), in Harbin, Dalian and Hangzhou (China) and Tokyo (Japan) (see Table 1 for the dates and observation details of my fieldwork). Data will be analysed to gain a "thick description", which are detailed accounts and explanations of social actions to produce conceptual structures for conveying the findings of the study to an audience or an outsider of the study (see Geertz, 1988). My study aims to present a thick description of the relationships between human and nonhuman actors which constitute to this "interface". The actors include students, professors, Chinese medicine practitioners, researchers, politicians, technology, and laboratory materials. The themes acquired from thematic coding will be refined into codes to provide rounded, detailed chapters of the emergent "interface" and its development. The themes and codes will uncover various aspects of this "interface" and inform the analysis of "modes of ordering" this "interface" as a heterogeneous network, vision and vocation, which will be presented in Chapter 8.

The first research question: "Is there an 'interface' and if so, can this latest contact between Chinese medicine and systems biology be referred to as an 'interface' and what is its nature?" will examine the term and the nature of this "interface". To answer the first question, results from a literature survey will be compared with interview data on the perception and interpretation of "interface" by actors in the field of Chinese medicine and systems biology studies. The second question: "How does this "interface" differ from previous encounters between Chinese medicine and modern science and Western medicine?" will be explored with the use of a literature survey on the development of concepts such as holism and systems thinking in systems biology and Chinese medicine. This analysis will provide an answer to why actors in this "interface" believe in a shared ground between Chinese medicine and systems biology.

The third research question: "How did the actors become involved in Chinese medicine and systems biology research?" will be answered by analysing interview material. The data will show the motivations and aims of the actors that influenced their decision to undertake Chinese medicine and systems biology research. The answer to this question will demonstrate the interest of the actors in Chinese medicine and demonstrate how this changed their approaches to medicine and their way of practising science following their involvement with Chinese medicine. Therefore, the involvement of the actors will show a conscious decision that was influenced by their vision, interest, needs and values.

The last research question will reflect on: "How did the participation of the human and nonhuman actors in Chinese medicine and systems biology research influence the development of the relationship between Chinese medicine and systems biology?" To answer this question, I will analyse ethnographic data and secondary and scientific literature to reveal how the actors were employed in various global research collaborations on Chinese medicine and systems biology between 2005 and 2012.

This thesis will demonstrate that the "interface" has emerged through different involvements of scientists in Chinese medicine and systems biology research. Thus, it makes an important contribution to the investigation of scientific and technological studies on how scientists approached and engaged with Chinese medicine. It aims to contribute to contemporary history of Chinese medicine and the concept of "modes of ordering" (Law, 1994) through the combined analysis of ethnographic data and scientific literature, which places this most recent "interface" in the historical context of previous encounters between Chinese and modern science.

1.2 THESIS ORGANISATION

This thesis is divided into nine chapters. Following the Introduction (Chapter 1), Chapter 2 will review the existing literature on the historical encounters between Chinese medicine and modern science. It will look at the works of Scheid (2002a, 2007), Taylor (2005), Zhan (2009), Lei (2014), Andrews (2014), to name a few. First, the literature will inform the approach of this thesis on the emergent "interface" between Chinese medicine and systems biology with perspectives from historical and ethnographic studies. The emergence of a relationship of scientific interactions between Chinese medicine and systems biology will be investigated and analysed. Secondly, previous encounters that occurred in the twentieth century will inform this study about changes that happened in Chinese medicine following the contact with modern science. This chapter will consider a variety of methodological and theoretical approaches taken by Chinese medicine historians, anthropologists and STS scholars (Scheid, 2002a, 2014; Lei, 2014; Andrews, 2014; Law, 1994; Latour, 1987, 2013). Chapter 2 thus sets the disciplinary framework for this thesis in Chinese medicine history, ethnography and STS study and aims to fill the gap in the recent history of Chinese medicine and scientific studies with the focus on involvement.

Chapter 3 will discuss the research methods used for this study. The methodological triangulation emanates from anthropology and STS studies and will combine a literature survey, participant observation and episodic interviews. The triangulation will provide critical methods to investigate the emergence of the current "interface" during the past three decades. A thematic coding of ethnographic and literature survey data will establish the main themes and codes which will be presented in four Chapters (4, 5, 6, and 7), and which are accounts of the relationships between Chinese medicine researchers and systems biologists.

In Chapter 4, I will analyse the findings of interviews and a literature survey on the three codes: rhetoric and coining the term "interface", perceptions and definition of this "interface" and Chinese medicine and systems biology are the same. A literature survey will present the historical traces of their sameness. The thematic coding from scientific literature will show the first instance of the term "interface" between Chinese medicine and systems biology and how systems biologists and Chinese medicine researchers (referred to as the actors in this thesis) described their relationship in research papers. The second section will examine interview data on the perceptions and descriptions of this "interface" and the work of the actors. The interview material will reveal the insights of this relationship in four codes: co-operation, molecules as a bridge, technology as a bridge, the sameness of Chinese medicine and systems biology. The last section will explore historical accounts of the belief that Chinese medicine and systems biology are the same. This chapter will analyse how systems thinking and holism became central concepts in Chinese medicine and systems biology studies. Hence, Chapter 4 will build the groundwork for the definitions and perceptions of the term "interface" and the ideological connections between systems biology and Chinese medicine.

Chapter 5 will identify the involvement of the actors with Chinese medicine or systems biology research. The analysis of interview material will disclose early involvement of the actors in Chinese medicine in the 1990s, which later developed into initial studies on Chinese medicine and systems biology. Thus, I will call those involved, the inner circle of the relationship between Chinese medicine and systems biology. The main theme of the inner circle will be "involvement" which can be divided into four different types: (a) technology and health, (b) complexity, (c) family and exploitation, and (d) the discontentment with reductionist representation of medicine and research practice.

Chapter 6 will examine ethnographic data that will elaborate on the theme "Laboratory practice and industrial ties". The codes in this chapter will be (a) co-operation projects, (b) laboratory practice and technology, and (c) funding and industrial ties. These codes will demonstrate academic and industrial structures, which facilitate this "interface" by employing students, researchers and omics technology in projects that examine systems biology concepts and various aspects of Chinese medicine. This chapter will be complemented with the opinion of systems biology experts on the study of Chinese medicine.

In Chapter 7, the last theme of “Networks and political ties” will be explained having analysed data from interviews and the literature survey. This analysis will present three codes: (a) political networking, (b) joining Chinese medicine studies, and (c) funding and regulations. These codes detect that actors were invited or employed in network organisations and an international consortium to participate in discussions on Chinese medicine research and regulations in a European healthcare setting.

Chapter 8 will analyse the various themes and codes of Chapters 4, 5, 6 and 7 with the adaption of “modes of ordering” (Law, 1994; Moser, 2005). Law’s (1994) “modes of ordering” define in STS an approach to study how interactions between human and nonhuman actors co-evolve in society and science. Moser’s (2005) application of “modes of ordering” is important for this study as Moser includes multi-sited ethnography and he patterns the life stories of interview materials. Moser (2005) uses this concept to understand the “ordering” of normality which disabled people regain through technology. With the concept of ordering, I aim to analyse how technology, as an actor, generates in co-operation with humans a new understanding of a phenomenon (i.e., this “interface”).

My thesis will analyse three “modes of ordering”, which are heterogeneous networks, vision and vocation. The first ordering of heterogenous networks, is a definition gained from my data of life stories. This mode will answer the research question of the existence and nature of the “interface”. The ordering of heterogeneous networks will reveal that projects and collaborations were built to challenge existing research paradigms and expensive healthcare systems. The second and third orderings are adopted from Law’s “modes of ordering vision and vocation”. I will analyse with the “ordering of vision” the emergence of this “interface” through the involvement of systems biologists in the study of and the learning from Chinese medicine. This mode will analyse how technology and concepts of systems thinking and holism facilitated systems biologists to engage with Chinese medicine. While the mode of vocation will investigate the employment of the actors and the development of their studies on Chinese medicine and systems biology from understanding Chinese medicine to examining the safety and regulation of this medicine. With these “modes of ordering”, I will show significant interactions between humans and nonhuman actors in generating and transforming the "interface" between systems biology and Chinese medicine.

The concluding chapter summarises the main findings of the thesis. It restates the research aim to contribute to the contemporary history of Chinese medicine by being the first ethnographic and historical exploration of this ongoing phenomenon. It also aims to contribute to STS studies with the theoretical analysis of different modes of a heterogeneous networks, vision and vocation of scientists and technology in the research of Chinese medicine and how various involvements transform the research approach to investigate Chinese medicine. Finally, it evaluates the limitations of the thesis through critical reflections and suggests directions for future work.

2. HISTORICAL AND METHODOLOGICAL ORIENTATIONS

The term "interface" was coined to describe the translation process between Chinese medicine and systems biology (Scheid, 2014). To understand how researchers have interpreted past meetings or confrontations between Chinese medicine and modern science, this chapter reviews significant works in the area of Chinese medicine history and medical anthropology regarding past encounters between Chinese medicine and modern science and the emergent relationship between Chinese medicine and systems biology. It aims to identify how Chinese medicine researchers refer to and describe meetings between Chinese medicine and modern science and to notice differences or similarities to the present encounter. The next section in this chapter will review medical anthropology as a feasible methodology for this thesis. This methodology will be considered in combination with concepts of STS to explore the nature and the emergence of the relationship between Chinese medicine and systems biology.

In recent literature, Scheid (2014) describes the relationship between Chinese medicine and systems biology as an "interface". He employs the concept of "boundary objects" by Star and Griesemer (1989), which analyses a concrete or an abstract object that mediates between two distinct fields to facilitate collaborative work. Scheid claims that the Chinese medicine concept *zheng*, translated by Farquhar (1994) as a pattern or a symptom in Chinese medicine disease description, serves as a boundary object between Chinese medicine and systems biology and creates and "interface" between them. Scheid (2014) presents two genealogies that argues first that *zheng* is a central aspect that joins systems biology and Chinese medicine together. In the second genealogy, Scheid (2014) elaborates on *zheng* and its role as a pivotal point in Chinese medicine that has changed its meaning several times since the eleventh century. He shows in both genealogies that *zheng* connects institutional, political and economic settings and that *zheng* historically co-created the systems biology and Chinese medicine "interface".

Scheid's use of *zheng* as a boundary object offers a new tool to study the relationship between Chinese medicine and systems biology. In order to analyse the relationship between Chinese medicine and systems biology, boundary objects requests to identify two distinct sides, such as Chinese medicine and systems biology. However, as soon as one field is integrated into the other, the use of this concept is not reasonable as one actor understands both fields without a translation tool (Star and Griesemer, 1989).

In 2005, Wang, Lamers, Korthout, Van Nesselrooij, Witkamp, Van Der Heijden, Voshol, Havekes, Verpoorte and Van Der Greef first published their interest in *zheng* as a bridge between systems biology and Traditional Chinese Medicine. Their idea is to transcribe *zheng*s with metabolomics into a biomedical and scientific context. Metabolomics is the study of a metabolite complement in biological samples through experiments and chemical analysis (Jenkins et al., 2004). Omics technology facilitates the production of large datasets such as mass spectrometry or gas chromatography and identify the metabolites in reference databases (ibid). Wang et al. (2005) defined what Scheid (2014) calls an "interface" as a bridge between Chinese medicine and molecular pharmacology as they recognised a shared system understanding between systems biology and Chinese medicine. This understanding assists systems biology to function as a translator or a bridge between bioscience and Chinese medicine. In later publications, Jan van der Greef, van Wietmarschen, Schroën, Wang, Hankemeier and Xu (2010) wrote about *Systems biology-based diagnostic principles as pillars of the bridge between Chinese and Western medicine*, which contributes to their original idea to new personalised medicine by gaining insights into pattern differentiation methods of Chinese medicine diagnosis. Van der Greef and his colleagues assume Chinese medicine as one of the most acknowledged and well documented personalised traditional medical systems in the world.

The idea of bridging Chinese medicine and systems biology soon after occurred in 2012 in a "Special Issue" on *Traditional Chinese medicine research in the post-genomic era.* The editors and authors of the special issue were members of a consortium of Chinese medicine researchers, pharmaceutical scientists, bioscientists and biotechnology scientists for the integration of Chinese medicine in the European healthcare system, which was funded by the European Research Council (ERC, see more about the funding in Chapter 7 on Networks and political ties). The authors mentioned van der Greef's et al. (2010) and Wang's et al. (2005) article as the groundwork for the relationship between Chinese medicine and systems biology (Uzuner et al., 2012; Scheid, 2014; Luo et al., 2012b; Buriani et al., 2012; Verpoorte et al., 2009). The special issue included review articles on Chinese materia medica (Chan et al., 2012; Zhao, Guo and Brand, 2012), application of omics techniques in systems biology to Chinese medicine practice and pharmacovigilance in herbal medicine research on drug safety and study designs.[3] They concluded that systems biology and omics technologies are instruments to modernise Chinese medicine regarding drug standardisation and preparation through metabolic fingerprinting. Fingerprinting is the systemic identification of drugs through measurements of global and dynamic metabolic responses of an organism to a biological stimulus, for example, medication, or genetic manipulation.

For instance, one of the aims in metabolomics is to use magnetic resonance fields, such as the nuclear magnetic resonance spectroscopy (NMR) technique. The NMR measures atomic nuclei to characterise and quantify all small molecules in a complex biological sample, for example, a Chinese medicine multiple herb prescriptions or formula (*fufang* 复方) (Wang and Chan, 2010). The authors of the special issue conclude that omics technology and systems biology enable an understanding of complex biological perturbations, the therapeutic intervention and disease prevention with Chinese medicine. However, with the demand that studies be standardised and conducted according to the required level of scientific quality, design and reporting, other authors worry about the personalised aspect of Chinese medicine (Scheid and MacPherson, 2012). Hence, the articles of the special issue manifest that a research interest between Chinese medicine and systems biology emerged with the demand for standards to validate and authenticate Chinese medicine.

The questions that surface from the publications on Chinese medicine and systems biology are two: how did the relationship between systems biology and Chinese medicine emerge? Second, what is behind the rhetoric of modernising and standardising Chinese medicine? These questions lead to the question of whether or not encounters between Chinese medicine and modern science which happened in the

[3] See, for example, Sheridan et al., 2012; Ouedraogo et al., 2012; Buriani et al., 2012; Pelkonen et al., 2012; Jia et al., 2012; Shaw et al., 2012; Zhang et al., 2012; Barlow et al., 2012; Tejedor Garcia et al., 2012; Flower et al., 2012; Luo et al., 2012b; Liu and Cheng, 2012; Jiang et al., 2012; Booker et al., 2012 and Robinson et al., 2012.

past were similar to or different from the present relationship between Chinese medicine and systems biology. In the following section, I am going to discuss the literature of Chinese medicine with the focus on encounters between modern science and Western medicine and their relationship.

2.1 ENCOUNTERS IN THE LITERATURE

In this section, I will elaborate on three separate encounters between Chinese medicine and Western medicine or modern science: (1) the modernisation of Chinese medicine at the turn of the twentieth century, (2) the standardisation of Chinese medicine in the 1960s and (3) the globalisation of Chinese medicine in the 1970s and 1980s. The literature shows historical accounts of past encounters, but not of the new relationship established in the 2000s, which is the most recent meeting between Chinese medicine and science.

2.1.1 THE MODERNISATION OF CHINESE MEDICINE

In this section, I will reflect on the phase which came after the defeat of Western and Japanese powers in the late nineteenth century and the proposal for the abolition of Chinese medicine in 1929. At this time, researchers such as Andrews (2014), Rogaski, (2004) and Lei (2014) noticed an increased interest of Chinese medicine practitioners in Western science. Andrews (2014, p. 12) claims that a "whole generation of Chinese" blamed traditional values such as Confucianism, Chinese medicine and the lack of science for the weakness of China to defend the country against the West and Japan in the nineteenth century. As a result, Chinese intellectuals looked towards the West to learn from and to integrate modern science. Science and Western medicine became crucial instruments for the modernisation and the regaining the power in the country (see, Rogaski, 2004; Lei, 2014; Unschuld, 1985; Scheid, 2002a; Croizier, 1968).

Historians have argued that Chinese intellectuals considered Western medicine and science as a kind of reification of modernity (see Croizier, 1968; Rogaski, 2004). While the Chinese associated science with modernisation, the Americans viewed it as an advancement of democracy and popular wisdom, and Europeans connected science with technology and radicalism (Barnes, 2005). Rogaski (2004) interprets the modernisation of Chinese medicine as the enforcement of political powers. The transformation of Chinese medicine was a political decision to develop this medicine along with Western medicine. Rogaski (ibid) employs Foucault's concept of "biopower" by linking the actions of a state to administrate and govern life to the modernisation of China and Chinese medicine. In this regard, she believes that individuals were organically aligned with the goals of the state by "internalising disciplinary regimes" (ibid, p. 16) such as accepting vaccinations, hygienic baths or soaps. Therefore, hygiene as part of the modernisation process in China connected Chinese nationalism with sanitary science in the nineteenth century. Both, hygiene and nationalism, connected elements to modernity regarding the reconstruction of cities, the ordering of society and the transformation of human beings into healthier and stronger people. With this strategy, reformers aimed to sanitise as the West had the image of "the sick man of Asia" which arose after Western powers defeated China in the nineteenth century (ibid, p. 302). Hence, Rogaski concludes that sanitary science served as a stable political tool to resolve social and physical deficiencies by combining Western medicine with the Chinese body as a nation and as the individual body of Chinese people.

In the past two decades, there has been literature on the notion of the purity of modernity, which asserts that neither Chinese nor Western medicine are "pure" cultures as they are influenced by the other or other cultures (Andrews, 2014; Lei, 2014). Andrews (2014, p. 7) analysed the notion of science and Western medicine and stated that the Western medicine and science are "markers of modernity" in China. She supported this by highlighting the science and technology study that the scholar Latour published in 1993, which examined the concept of "modern constitution". Andrews (2014) follows Latour's idea of modernity as an illusion and a messy construct of relationships or networks between humans and nonhumans. Andrews believed that the problem with modernity emerges unavoidably as the network cannot be continuously monitored to ensure that non-modern elements cause an impurity of the network. She continues by stating that if the actors of the network carry modern and traditional features, then the network of modernity will be mixed. Thus, Andrews claims that in whatever direction the movement goes when modern values mix with traditional values, they inevitably contaminate the network.

In her study, Andrews (2014) found that since the defeats of Western and Japanese powers at the turn of the twentieth century, China imported modern science, which influenced the transformation of Chinese medicine in various ways. Supporters of the "Self-Strengthening Movement" (*ziqiang yundong* 自强运动) from 1860 to 1895 tried to overcome the weakness of China. Thus, they started to import modern technologies and modern science and integrated them, amongst other fields, into Chinese medicine. Andrews asserts that with this occurrence, the pressure for modernisation increased and resulted in a wide-range adaption that "redefined" and "shaped" Chinese culture and Chinese medicine to an "instrument of cultural and political self-fashioning" (ibid, p. 13). Three examples in her work present the tension between Chinese medicine and modern science: theories, reforms and overseas training in modern science. For the first example, Andrews presents the reformer Liang Qichao 梁啟超 (1873-1929) who proposed to abolish Chinese medicine theories, which were incommensurable with Western medicine. For instance, Liang Qichao considered the theory of Five Phases (*wuxing* 五行) as unstable and confusing (ibid, p. 178). Thus, he hoped to reinvigorate the strength of China by eliminating those theories and by combining the best of Chinese and Western medicine (ibid). The second example includes reforms of the adaption of bacteria theory, the medication against syphilis with mercury, as well as Western anatomy and physiology into Chinese medicine practices exemplified Qiu Jisheng 裘吉生 (legal name Qiu Qingyuan 裘慶元, 1872-1947). Qiu attempted to ensure the existence of Chinese medicine in modern Chinese culture by reforming and modernising it (ibid). Finally, Chinese students studied overseas, in particular, in Japan to learn Japan's "model of East Asian modernity" and Asian thinking about Western science (ibid, p. 70). Andrews (2014) claims that students returning from Japan blamed the "inward-looking" attitude of China for the defeats by Western and Japanese powers and the loss of the former German colonies in China on Japan after the World War I and the treaty of Versailles. Those students reacted to the treaty with the "May Fourth Movement" in 1919 and demanded a radical modernisation of China by abolishing traditional values including Confucianism and Chinese medicine. Andrews (ibid) work shows that modernity of Chinese medicine was a constant redefinition by Chinese medicine advocates and politicians.

In the same vein, Lei (2014) applies STS concepts of Latour's (1993) "modern constitution" and the concept of "translation" from actor-network theory by Latour (1987), Callon (1986) and Law (1994) in his study. Lei (2014) speaks against dual historiography between traditional and modern Chinese and Western medicine and applies the concept of translation to investigate how socio-technical networks between Chinese medicine and Western medicine were formed in 1920. Based on this concept, Lei (2014) claims that the modernisation of Chinese medicine with modern science caused Chinese medicine to become a hybrid medicine with aspects of traditional Chinese medicine and modern Western medicine. For instance, his results conform to Andrews (2014) findings that Chinese medicine scholars went to Japan or overseas to study Western medicine. He adds that Chinese students engaged with Western medicine and science by either studying the literature of Western science, or by being confronted with Western medicine by returning Chinese students who were trained in Western medicine overseas. Accordingly, assimilation and convergences to Western medicine happened in an unstructured, sporadic and individual manner, e.g., by the Chinese medicine practitioners Li Hongzhang 李鸿章 (1823-1901), Tang Zonghai 唐宗海 (1851-1908), Zhang Xichun 张锡纯 (1860-1933), Zhu Peiwen 朱沛文 (fl. 1850). They added Western drugs to Chinese medicine prescriptions or learned Western pathology to incorporate them in new prescriptions for mastering unsolved issues in Chinese medicine doctrines. Another example of convergence is the Western and Chinese medicine practitioner Tang Zonghai. His idea was to converge the Chinese medicine doctrine of *qi* transformation with Western anatomy and physiology and he was inspired by the steam engine (Lei, 2014).[4] Lei (2014) argues with the concept of modernity that Chinese medicine gradually converted into a hybrid medicine.

Other researchers view the "Self-Strengthening Movement" as an index for shaping the encounter between Chinese medicine and Western science (Scheid, 2002a). Scheid (ibid) investigates plurality and synthesis in Chinese medicine with the lenses of Andrew Pickering's "the mangle of practice" (or the "mangle" as it can be known),

---

[4] See Lei (2014) for *qi* transformation *qihua* 气化 and Tang Zonghai's manuscript *The Essential Meanings of the Medical Canons: (Approached) through the Convergence and Assimilation of Chinese and biomedicine* was published later in 1892.

which is a process that transforms and creates culture, practices, subjectivity and history. Pickering (1995) defines the transformations and creations as the "dance of agency" between humans and nonhumans. By drawing on the mangle and network constructions which were inspired by actor-network theory, Scheid (ibid) identifies doctors, patients and tenets of thought within Chinese medicine tradition as agents and as constructors in structuring a medical system. Plurality and synthesis, thus, reveal the continuity of transformations within Chinese medicine but also influence from the outside, for example, the synthesis with Western medicine and science. Scheid (ibid) claims that Chinese medicine has always been plural in its practice and thoughts. Consequently, the reoccurring but varying engagement of Chinese medicine practitioners with Western medicine and science during the twentieth century created many ways to practice Chinese medicine.

In his later work, Scheid (2007) discloses that the modernisation process of Chinese medicine rearranged the various schools of thought in Chinese medicine into three groups. The groups either demanded (i) the abolition of Chinese medicine, (ii) its reformation to a social utility by introducing changes along with the Japanese system or (iii) preserving Chinese medicine but admitting some modernisations. The first group of advocates of Western medicine proposed to abolish Chinese medicine, which directly impacted the second and the third group united in the fight against the abolition of their medicine (Scheid, 2007). The first group initially attempted to synthesise Chinese medicine and Western medicine but, later they required the abolition of Chinese medicine in the May Fourth movement as a "wholesale westernisation" (*quanpan xihua* 全盘西化). This modernisation entailed the replacement of traditional values, such as Confucianism and Chinese medicine, with modern science, which was personified as "Mr Science" (*sai xiansheng* 赛先生) (Scheid, 2007, p. 176). This group differentiated the practice of Chinese medicine from older theories and employed Western scientific methods to evaluate Chinese medicine.

In contrast to the first group, the reformers of Chinese medicine were willing to accept the Western empiricism as they were familiar with it due to their training in Japan. They suggested integrating useful Chinese medicine aspects into a strong Western medical practice. This group of reformers acted according to the political tendencies towards Western medicine during the early Republican era (1911-1949) (Scheid, 2007). By reshaping both systems, the conservatives generated flexible networks of practitioners which became the fulcrum for both the transformation and the maintenance of the Chinese medicine (ibid).

The third group, the cultural radicals, safeguarded Chinese medicine as a "national essence" (*guocui* 国粹) of China. For example, Zhang Taiyan 张太炎 (1869-1936), the teacher of Yu Yunxiu 余云岫 (also Yu Yan, 1879-1954), and his followers transformed the notion of preserving the "spirit of the nation" into a vital part of China's civilisation (Scheid, 2007, p. 177). They wanted to prove that Chinese medicine was more advanced than Western medicine by showing, for instance, that practitioners performed surgeries in the Han dynasty (202BC-220AD). Preservers used the past achievements of pioneers in Chinese medicine and its value as an indigenous medical art reinforced with its long history to protect Chinese medicine against the influence of Western culture (Croizier, 1968). This discourse of modernisation shows that Chinese medicine practitioners engaged with Western medicine and science to define or synthesise their medicine.

Lei (2014) demonstrates with the concept of translation, that Chinese medicine practitioners formed alliances with politicians and Western medicine doctors in the early twentieth century. He analysed that the confrontation headed into a networking process between Chinese medicine practitioners and scholars and the politicians of the *Guomindang* (Nationalist Party, GMD or also *Kuomintang* - KMT, 1912-1949). Chinese medicine practitioners allied to fight against the abolition proposal by Yu Yunxiu. Yu Yunxiu was very well read in Chinese medicine due to the fact that he was a Western-trained practitioner and one of the cultural radicals he worked for the newly established Ministry of Health (MOH). Yu Yunxiu's abolition plan stated that Chinese medicine was an individualistic medicine, which was ineffective to prevent epidemics (Lei, 1999). Yu's proposal mobilised Chinese medicine practitioners and joined all fragmented schools of thought in Chinese medicine into one group for demonstrating unity against Yu and his followers. The unification happened with the help of Chinese medicine advocates such as Chen Cunren 陈存仁 (1908-1990) and Zhang Zanchen 張赞臣 (1904-93) who initiated a petition against the abolition in March 1929. Lei (1999) argues that this day marks the encounter of Chinese medicine with the first modern Chinese state and the beginning of the modern history of Chinese medicine by forging a network of alliances with the Chinese politicians against Western-style doctors. However, the government only supported Chinese medicine practitioners in exchange for the modernisation of their practice and organisation. Thus, Lei (1999, 2014) argues that the consequence for the support of the GMD, was first modernisations of Chinese medicine into a national medicine and the establishment of the Institute of National Medicine (*guoyi guan* 国医官).

Lei (1999) argues that it was no surprise that Chinese medicine advocates tried to find scientific evidence for the efficacy of Chinese medicine drugs. By doing so, they demonstrated the wisdom of Chinese medicine and its ability to resolve public health problems, which became a serious issue after the failing of Chinese medicine to deal with the Manchurian plague in 1911 and 1912. According to Lei (1999), historians in Chinese medicine have overlooked the significance of Chinese medicine drugs in the National Medicine Movement (*guoyi yundong* 国医运动) from 1929 to 1931 and the translation of *changshan* 常山 (*Dichroa febrifuga*) from a Chinese medicine context into a modern scientific context. The translation elevated Chinese medicine from an individualistic medicine to become a public medicine. With the help of Chen Guofu 陳果夫 (1892–1951), a Chinese medicine advocate and GMD ideologist, *changshan* became scientifically validated as an effective antimalaria drug in the 1940s. Lei (1999) argues that although *changshan* was recommended as a successful treatment of malaria and was acknowledged in English studies of Chinese materia medica, as well as Chinese paper and documents, it was not trusted until scientific evidence showed its effects. Once this had happened, it was translated into the Western medicine socio-technical network. Hence, the successful translation happened through the political power of Chen Guofu, which enabled him to bridge the barriers between Western-style doctors and Chinese medicine drugs. However, his clinical experiments with *changshan* on human subjects violated the ethical code and the Western scientific protocol. Instead of first extracting the active compounds, in the drug, which were the essential substances that have a direct effect on human health (Biesalski et al., 2009), and, then, testing them on animals, Chen Guofu started with his experiment on humans. Even though Chen Guofu shortened the translation process by starting with the clinical tests, he provided a reason for new allegations against Chinese doctors as unethical. Chen and his supporters Chen Fangzhi, the responsible Western medicine scientist for this research, defended this procedure with the explanation that the formula was not a new drug; it was in use for a long time and thus empirically safe (Lei, 2014). Chen's example demonstrated that although the content of *changshan* was for Chinese medicine and Western medicine the same, the context differed and required a translation with the means of Western science to reach a consensus of its efficacy. The evidence of the efficacy of its drug granted the position of Chinese medicine in the modernisation process of China as a useful source of drugs.

The literature, which I have discussed here, demonstrates that political discussions about China's weaknesses introduced the idea of the modernisation of China's healthcare system with what modernisers and reformers such as Yu Yunxiu and the Nationalist party in China considered as modern, namely Western medicine and science. The modernisation process of Chinese medicine in the late Qing dynasty and early Republican period demonstrated Chinese medicine advocates as fragmented groups with different interests. They unified after some advocates shifted to Western medicine and proposed to abolish Chinese medicine. Chinese medicine was confronted with mainly Chinese modernisers and doctors of Western medicine, such as Yu Yunxiu who demanded the implementation of Western science and methods as markers of modernity as a tool to reinvigorate China and its powers (Andrews, 2014; Lei, 2014). The transformation of alliances and interest changed this encounter and engaged Chinese medicine practitioners and scholars in the translation and transformation process of Chinese medicine with Western medicine. The reshaping of Chinese medicine happened through the scientific evaluation of Chinese materia medica and the institutionalisation of Chinese medicine with the example of Western medicine. Historians show different perspectives of this encounter as either driven by politics (Andrews, 2014; Hanson, 2011; Rogaski, 2004; Croizier, 1968) or that practitioners were important actors within this process (Lei, 1999, 2014; Scheid, 2002a; 2007).

2.1.2 The standardisation of Chinese medicine

In this section, I will reflect on the small body of literature before and after the foundation of the People's Republic of China (PRC) in 1949. This period refers to the Chinese Communist Party's (CCP) policies from 1949 to 1976 and their wide-ranging standardisation (*guifanhua* 规范化) and systematisation (*xitonghua* 系统化) processes that formed Chinese medicine into what is widely known today as "Traditional Chinese Medicine" (TCM).[5] Scheid (2002a) and Taylor (2005) distinguish three political phases during the standardisation of Chinese medicine: (1) the "co-operation between Chinese and Western Medicine" (*zhongxiyi hezuo* 中西医合作) from 1945 to 1949, (2) the "unifying Chinese and Western Medicine" (*zhongxiyi tuanjie* 中西医团结) 1950 to 1958, and, (3) the "integrating Chinese and Western Medicine" (*zhongxiyi jiehe* 中西医结合) from 1958 to now. These phases will now be discussed.

The historian Taylor (2005) analysed the period from 1945 to 1960 as most of the work on the Maoist era (1949-1976) discusses the historical events of the CCP with the focus after the 1950s (for example, Croizier, 1968; Unschuld, 1985; Scheid, 2002a, 2007; Farquhar, 1994; Hsu, 1999, 2008). Taylor's (2005) detailed account explores political discourses in which workers and cadres of the party participated in converting Chinese medicine into a revolutionary medicine during the early years of the CCP (Michaels, 2006). As Taylor (2005, p. 8) argues: "the role that Chinese medicine played in the Communist Revolution was passive. It was a suppressed element of society, and its representatives could by no means dictate the fate of the medicine". She claims that political and medical leaders were instigators behind Chinese medicine becoming a revolutionary medicine. As was the aim in the Nationalist era (1928-1949), the preservation of Chinese medicine as a body of knowledge, was not part of the revolutionary plan. Taylor found the CCP provided a more stable infrastructure and national support to standardise Chinese medicine. However, the standardisation of Chinese medicine increased the control of the CCP, its interpreters and implementers

---

[5] See Farquhar, 1994; Hsu, 1999, 2008; Scheid, 2002a, 2002b, 2007, 2014, 2016; Taylor, 2004, 2005; Lei, 2014; Zhan, 2009; Unschuld, 1985 and Croizier, 1968.

of policies over Chinese medicine and its fate. According to Taylor (2005, p. 1) after the foundation of the PRC, Chinese medicine representatives became "submissive" and "devoted" to the promotion of science and the advancements of Chinese medicine. Unlike Taylor (2005), Lei (2014) and Scheid (2002a) indicate that Chinese medicine advocates were actively involved in the standardisation process. As Scheid (2002a, p. 66) argues: "the role of the state in shaping contemporary Chinese medicine is that of a powerful, but not an all-powerful, agent".[6] They dispute that the transformation of Chinese medicine was a continuous process.

Taylor (2005) argues that Chinese medicine advocates played a passive role during the "co-operating Chinese and Western Medicine" phase. The CCP aimed to combine Western and Chinese medicine and promote the political line to people in remote areas, in order to gain their support during the Civil War (1946-1949) with the Nationalist party. Another reason was the shortage of Western medical supplies, which Chinese medicine was expected to fill. As CCP cadres and workers interpreted Mao's co-operation plan as "scientisation of Chinese medicine and promoting Western medicine" (ibid), they replaced superstitious and feudal elements in Chinese medicine with politically aligned Soviet theories. For example, Zhu Lian 珠链 (1909-1978), a Western-trained practitioner and wartime medical servant, scientised acupuncture with the Soviet theories of neuro-pathology theory (*shenjing bingli xue* 神经病理学). This change is seen in the military and political vocabulary used to divide the body into regions and sections (*qu* 区) (Taylor, 2005, p. 19-24). This description is still used today.

During the unification period (1950-1958) the CCP set the groundwork for the creation of a new medicine by combining Chinese and Western medicine. Scheid (2002a) claims that the CCP aimed to upgrade Chinese medicine to scientific medicine, whereas Taylor (2005) asserts that the purpose for Mao in keeping Chinese medicine was to fuse it with Western medicine once Chinese medicine had achieved a sophisticated scientific level. Taylor (2005) shows that a series of policies denoted a piecemeal process which aided the standardisation of Chinese medicine. For example,

[6] See for all three policies in particular Taylor, 2005 and Scheid, 2002a.

Chinese medicine practitioners had to take an exam that strongly focussed on Western medicine.

The following political strategy of the CCP was called "Chinese medicine practitioners study Western medicine" (1950-1953). This strategy introduced the first Chinese medicine practitioners in Western medicine and forced these practitioners to develop skills in Western science and medicine (Andrews, 2014; Taylor, 2005). Taylor (2005) found that CCP cadres and workers interpreted the unification policy according to their needs and professional orientation. Therefore, they formulated the strategy to "scientification of Chinese medicine and popularisation of Western medicine" by replacing superstitious elements with scientifically evaluated Western medicine (ibid, p. 32). Soon after the introduction of this policy, in 1954, the Chinese government reversed the policy of Chinese medicine study Western medicine to compel "Western medicine doctors to study Chinese medicine" (1954-1959). Other researchers stress the intention of the CCP as a modernisation of Chinese medicine under the leadership of a new cohort of Chinese medicine trained Western medicine doctors (Scheid, 2002a). At the same time, Andrews (2014, p. 209) interpreted it as a way for the CCP to "rectify the undesirable ideological [bourgeois] tendencies of Western-trained doctors". Croizier (1968) stresses the positive side of this policy as he views it as a way to increase the national pride of Chinese medicine practitioners when Western doctors study their medicine.

As noted by Taylor (2005, p. 73) a further step in the standardisation process of Chinese medicine occurred with the publication of the English-language article "Why our Western-trained doctors should learn *Traditional* Chinese Medicine" (italics as in the original) in 1955 by the Deputy Minister of Health Fu Lianzhang's 傅连章 (1894-1968). In this article, Fu Lianzhang first attributed "traditional" to Chinese medicine. Thanks to this article and the modernisation methods of CCP, Taylor remarks that the change from Chinese medicine to TCM was "a medical construct (which is) distinct to Communist China" (2005, p 84). Thus, TCM is a product of the CCP which integrated the best of both Chinese and Western medicines and theories. Hsu (2009), an anthropologist, interprets TCM as a Janus-faced instrument of the CCP which differentiated Chinese medicine from the modern Western medicine with the attribute "traditional" while the party also endeavoured to assimilate both medicines (Hsu, 2009).

The last phase, the integration phase, shifted the aim from one new medicine to the incorporation of standards of Western medicine into Chinese medicine (Taylor, 2005). The party manifested the integration of both medicines with the establishment of the Academies of Chinese medicine in Beijing, Shanghai, Chengdu. The establishment happened concurrently with the political change of China into a socialist state the CCP. Unlike, Scheid (2002a) believes the new academies had two main priorities: first, to bind Chinese medicine closer to the political centre and, second, to recover Mao's decline. The priority related to the fact that academies were a way to tie influential Chinese medicine practitioners more closely to educational institutions in Beijing where the political centre of China was. For example, the MOH employed famous Chinese medicine practitioners like Qin Bowei 秦伯未 (1901-1970) and Zhang Cigong 章次公 (1903-1959) to advise the MOH and teachers at the Beijing College of TCM under the supervision of mostly Western medicine trained physicians in the Ministry. Consequently, Scheid (2002a) claims that Qin Bowei shaped Chinese medicine through his social networks and contacts with politicians and strengthened his network by exploring various ways to modernise Chinese medicine.[7] Secondly, the party mobilised the cadres and Chinese medicine practitioners to establish a modern and scientific Chinese medicine in China. The scientification included strategies used to recover Mao's decline after the Great Leap Forward disaster in 1959-1961 and the split of the Soviet Union in 1963. During this period, China suffered from famine and was short of medical stuff; thus, Chinese medicine was an inexpensive and mobile resource during the Cultural Revolution and this compensated for the lack of medical care resources. As a result, Chinese medicine underwent a systematisation aligned with biomedical disease categories and institutionalisation of the practice and education of Chinese medicine in hospitals and universities.

[7] See more a short biography on Qin Bowei in Scheid, 2002a, p. 211.

Hsu (1999) demonstrates a view on the transformation of Chinese medicine education by analysing three ways of transmitting Chinese medicine knowledge. She employed in her ethnography the concept "styles of knowing" which were brought about by the philosopher of science Ian Hacking (1992), who emphasises the fluidity and individualistic aim that every style exhibit in its microsocial field which is influenced by interactions and negotiations. Hsu (1999) identified in Chinese medicine education and practice in China, three modes of transmission: personal, standard and secret transmission. These three modes encompass verbal and written transmission and first-hand stories from practitioners who describe the integration of Chinese medicine and Western medicine as the standardisation of Chinese medicine practice and education in alignment with Western medicine and science. Hsu (1999) claims that the CCP's implemented the biomedical institutionalised, pedagogical and clinical standards in Chinese medicine. For example, by disregarding the Five Phases (*wuxing*, wood, fire, earth, metal, and water) and focusing on the Five Organs (liver, heart, spleen, lungs, and kidneys) or teaching Western biomedical education thinking of Chinese medicine (e.g., *TCM Instructions, Organ Clusters, TCM Aetiology and Pathogenesis, Outline of the TCM Preventive Health Care*) instead of classical texts like the *Inner Classics of the Yellow Emperor* (*Huangdi Neijing* 黄帝内经) or the *Classics of Difficult Issues* (*Nanjing* 难经). Hsu claims that the standardisation of transmissions of Chinese medicine happened through "accidents of history" that shifted the focus to the physical body (Hsu, 1999, p. 223). She stresses that the standardised transmission of knowledge produced tension between classroom learning and strict control to unstructured and confusing practice in the clinic (ibid, p. 223). Hence, Hsu (1999) agrees with Taylor (2005) that the standardisation process was a reinterpretation of the integral elements of Chinese medicine aligned with the CCP's expectations of a scientific practice, which was grounded in an effort of being systematic.

In the analysis of Chinese medicine practice, Scheid (2002a) found that the CCP standardised and institutionalised Chinese medicine knowledge and practice with systematising its theories in 1958 in an article entitled the *Outline of Traditional Chinese Medicine* (*zhongyixue gailun* 中医学概论). The *Outline* revolutionised Chinese medicine leaning from apprentice-based learning and classical texts such as the *Inner Classics on the Yellow Lord*, the *Devine Husbandman's Materia Medica* (*Shennong bencao* 神农本草) and the *Treatise on Cold Damage and Miscellaneous*

Disorders (*Shanghan zabing lun* 伤寒杂病论) until the early twentieth century. The core categories and structure of the *Outline* were biomedical diseases which guided the diagnosis of Chinese medicine. This guidance aimed to identify biomedical diseases which subsequently break down the disease into several different, but newly standardised Chinese medicine "patterns" (Scheid, 2002a). Farquhar (1994), an anthropologist, defines a pattern as a complex of symptoms and signs based on examinations like asking, pulse taking and tongue inspection. Patterns (in Chinese *zheng* 证) are categorised into the eight rubrics of *yin/yang* (阴阳), exterior/interior (*biao* 表/*li* 里), cold/hot (*han* 寒/*re* 热) and depletion/repletion (*xu* 虚/*shi* 实) (Scheid, 2002a).

Compared to Scheid (2002a), Hsu (1999) asserts that the new systematic structure of theories in the *Outline* generated difficulties for students. Teachers introduced the concepts one by one to the students and then expected them to bring the concepts together on their own. Chinese medicine was as a systematic TCM theory which the students learnt in the classroom before they could start with their medical practice. They were not disciples or followers anymore who could learn by observing the master in practice (Hsu, 1999). The *Outline* changed Chinese medicine to a new structured theory that created inconsistencies between Chinese medicine theory and its practice. Hsu (1999) observed that students struggled to apply the newly revised and biomedical influenced theories of Chinese medicine in clinical practice, as they could not relate their observations in the clinic to the newly learned biomedical thinking. However, the structure of the *Outline* convinced later reformers of Chinese medicine. Thus, it may be seen as a blueprint for later reforms in Chinese medicine, i.e., "pattern differentiation and treatment determination" (*bianzheng lunzhi* 辨证论治).

Another example which examines integration is the "pattern differentiation and treatment determination". Farquhar (1994, p. 212) explains in her seminal work on Chinese medicine practice that *bianzheng lunzhi* is a process of "the 'four methods of examination' (*sizhen* 四诊)" which "translates concrete signs and symptoms through complex analyses into 'distinguishing patterns' (*bianzheng* 辨证) for which there is a large repertoire of 'formulae' or prescriptions (*fangji* 方剂) that are modified for each patient's personal constitution". Likewise, Scheid (2002a) holds the view that the *bianzheng lunzhi* is one example of systemised Chinese medicine knowledge as it adapted biomedical nosology with the priority to provide a correct diagnosis tool. Thus, *bianzheng lunzhi* discusses "processes as an ongoing synthesis of opposition" by employing diseases with Mao's dialectical concept of "unity of opposites" (*duili tongyi* 对立统一) with process emerging contradiction (Scheid 2002, p. 217-218). Apart from the reinterpretation of *bianzheng lunzhi*, the dialectical concept inspired Qin Bowei and other practitioners to redefine *yin/yang* and to include holism as a dialectical tool into Chinese medicine (Scheid, 2016). For example, Shi Jinmo 施今墨 (1881-1969) was one of its architects who westernised teaching materials in TCM universities by following Western medical doctors' preferences for a biomedical aligned systematic representation of Chinese medicine practice and theory (Scheid, 2002b).

Similarly, the anthropologist and STS scholar Karchmer (2010, p. 230) interprets *bianzheng lunzhi* as the "postcolonial transformation of Chinese medicine" of the 1950s. He maintains that Chinese medicine representatives stressed *bianzheng lunzhi* as the essence of Chinese medicine, which made it unique compared to Western medicine. Simultaneously, it also served as a "mechanism for translating between Chinese medicine and Western medicine" (Karchmer, 2010, p. 23). It became a tool to bridge the two medicines in the practice of Chinese medicine practitioners. Thus, Scheid and Karchmer (2016) argue that the redefinition which emerged in the 1950s emphasised the difference of China's political and medical system to Western countries biomedicine and politics. Nevertheless, he also indicates that Chinese medicine practitioners' value *bianzheng lunzhi* as an essential diagnostic tool.

According to Taylor (2005), in 1972, the consortium of revolutionary bodies (The Health Unit of the logistics department of the Guangzhou Army *Guangzhou budui houqinbu weishengbu* 广州部队后勤部卫生部) published a second edition of the *Outline*. She notes that the purpose of this edition switched from being an educational tool to a political one by stressing besides the integration of Chinese and Western medicine, the proposal to develop a "new national unified medicine and pharmaceutics" (Taylor, 2005, p. 110). In her article in 2004, Taylor argues that both versions, the *Outline* and its revision in 1972, served through their translations and interpretations, as a method to echo the reactions of the West on the production of standardised Chinese medicine knowledge (Taylor 2004). For instance, the *Outline* influenced

Manfred Porkert's *Theoretical Foundations of Chinese Medicine* (1982) and Nathan Sivin's *Traditional Medicine in Contemporary China* (1987). After the positive reaction to those works in the West, universities like the Nanjing Academy of TCM incorporated the *Outline* as standard teaching material, which Hsu (1999) confirmed. It influenced a new generation of Chinese medicine practitioners who apprehended the systematic influence of Western medicine and the Communist agenda as an intrinsic part of Chinese medicine. Thus, the integration between Chinese and Western medicine has covered an understanding gap between both medicines in China.

As mentioned before, researchers agree that Chinese medicine pharmaceuticals received specific attention as a researchable field during the integration period (Hsu, 2009; Unschuld, 1986; Nappi, 2009). Hsu (2009, p. 111) claims that the policies of the CCP transformed Chinese medicine into a medicine for chemical extraction of active compounds, the "TCM" or "Chinese propriety medicine" (CMP). Research in the 1960s was based on the extraction of active compounds in Chinese medicine to produce standardised Chinese medicine drugs. Unschuld (1986) discovered that Liu Juiheng published the first modern and westernised Chinese medicine pharmacopoeia in 1956. The pharmacopoeia described 672 drugs in monographs according to the Western "drug code", which included the place of origin, signature, function and chemical and physiological analysis of each drug. According to Nappi (2009), the *Bencao gangmu* 本草纲目, the Chinese materia medica, from 1598 was compared with the past version of materia medica substantial documentation in the Ming dynasty (1368-1644) by Li Shizhen's 李時珍(1518-1593) and was continuously expanded. Croizier (1968) states that pharmaceuticals and the mobility of Chinese medicine techniques were valuable resources for the political course of the CCP.

To sum up, in the standardisation period, the CCP party, party members, the MOH, Western medicine doctors and Chinese medicine advocates adapted medical education, practice methods and disease categories of Western medicine in Chinese medicine. From a political perspective, this supplied the population of China with Chinese medicine which was deemed an inexpensive and mobile medicine and with Chinese medicine practitioners trained in Western medicine. Consequently, most of the medical personnel were able to practice both Western medicine and the modernised and becoming to be scientised Chinese medicine. From a theoretical and educational level, the standardisation integrated Chinese medicine with Western medicine for a practice-based, pharmaceutical and institutional biomedical influenced medicine (see Scheid, 2002a; Taylor, 2005; Lei, 2014; Andrews, 2014).

2.1.3 The globalisation of Chinese medicine

In this section, I am going to discuss how Deng Xiaoping's 邓小平 (1904-1997) reform and opening up policy in 1979 changed Chinese medicine's position in China. The political change to open the country and the new economic course for exchange and foreign investment, loosened the control of the state over Chinese medicine practice. However, this new course forced Chinese medicine practitioners to orientate their practice towards the needs of a new economic system. Several lines of evidence describe these changes in six social and political characteristics. I will elaborate on the six characteristics that constituted to the globalisation phase and have led to the contemporary relationship between Chinese medicine and systems biology: (1) politics in China enacted Chinese medicine towards more scientific practice; (2) practitioners engaged in systems thinking; (3) education adapted biomedical organisation of knowledge; (4) globalisation of Chinese medicine happened through scientific interest in acupuncture; (5) standardisation processes facilitated commodification of Chinese medicine; (6) import of technoscience[8] led to Chinese medicine pharmacotherapies.

The globalisation phase of the 1980s started with the aim to rejuvenate the Chinese nation and China's economic growth with science and technology in Deng's four modernisations, i.e., agriculture, industry, national defence and science and technology (Scheid, 2002a).[9] With the reform and opening up policy in 1979, Chinese medicine

---

[8] In STS, technoscience is an interdependent concept that avoids the distinction between humans and nonhumans as well as technology and science (see Latour, 1987).

[9] The four modernisations were originally proposed by Zhou Enlai. See Scheid, 2002a. See also Fairbank and Goldman (1998, p. 343).

researchers postulated a convergence between systems theory and Chinese medicine (Farquhar, 1994; Scheid, 2002a, 2007; Scheid and Lei, 2014; Luo et al., 2012a; Shao, 2011; Qiu, 1982). According to Lou (2016), Deng aimed to integrate modern technology to enhance the scientific evaluation of Chinese medicine.[10] Evans (1997) compared Deng's strategy with Mao's new medicine in the 1950s and found that Deng accepted a three-pillar system (*san tiao daolu* 三条道路) that included Chinese medicine, Western medicine and the integration of Chinese and Western medicine, namely TCM. Chinese medicine is mentioned as its own pillar here as Deng Xiaoping policies left Chinese medicine practitioners with more liberty in their practice and orientation, this is further discussed below.

As found by Scheid (2002a), the Eleventh National Health Conference decided the plural healthcare system in 1979 with four reforms. The reforms stated that Chinese medicine had to be practised in hospitals rather than in primary or community healthcare systems, which had been the case since the Cultural Revolution. Secondly, medicine had to be administered by a professional with specialist knowledge rather than on knowledge from political cadres. Thirdly, the development of medicine was inseparable from technology. Finally, the establishment of a plural healthcare system resulted from the creativity and interpretation of practitioners and doctors to fulfil Deng's reforms and to protect their existence as practitioners on the new market-driven rather than a social healthcare sector (Scheid, 2002a). Deng Xiaoping granted Chinese medicine a place in the public healthcare system, however, Chinese medicine practitioners had to pay the price with further institutionalisation of their medicine, as well as more biomedical education and the integration of modern technology into Chinese medicine. Evans (1997) argues that the technology and know-how reform was possible through international co-operation. The exchange of experts and students enabled Chinese intellectuals at home and abroad to absorb the knowledge needed to use imported technology and science.

[10] Deng called this modernisation plan to "rejuvenate the country through science and technology" (*kejiao xingguo* 科教兴国) (Lou, 2016).

Much of the available literature on the globalisation phase deals with Deng's relaxed politics. These policies granted Chinese medicine representatives more autonomy in their practice and allowed them to regain their voice as Chinese medicine representatives in comparison with the Maoist era (Farquhar, 1994; Scheid, 2002a; Hsu, 1999; 2009). Farquhar (1994) noticed after the political turn, a change in the Chinese medicine publications, which split Chinese medicine scholarly work into two factions: the scholarly historical work and the laboratory and statistical research for clinical studies. Farquhar (1994) analyses the tension between practitioners who survived the Cultural Revolution, namely, senior doctors or *laozhongyi* 老中医, and the new generation, which she refers to as "scientizers" (ibid, p. 17).[11] The scientizers were more interested in using biotechnology and exploring Chinese medicine through systems theory or immune system theories rather than examining the stories of the senior doctors or consulting classical texts (ibid). This new generation started to write about biomedical science and the technology employed in Chinese medicine which soon dominated the field (ibid). Therefore, some of the *laozhongyi*, e.g., Ma Boying 马伯英, shifted in the 1990s to alternative areas like anthropology and history.[12] Farquhar (1994, p. 18) comments that with the scientisers "the field will quickly move far from the vision of the senior Chinese doctors". This observation might be interesting to follow in the relationship that has ensued between Chinese medicine researchers and systems biology over the last two decades to see if there is tension between different "generations" or Chinese medicine researchers with a different academic background. It might be helpful to consider tensions in the domains of Chinese medicine and systems biology compared to those between the fields of Chinese medicine and systems biology.

Others (see Scheid, 2002a; Karchmer, 2010) found that due to the three-pillar system, practitioners had to decide in the 1980s whether to include more Western medicine in their practice or explaining Chinese medicine concepts with new Western theories such as systems theory. In his article, Scheid (2014) categorises Chinese medicine

[11] After universities were reopened in China in 1978, the Ministry of Health selected leading Chinese medicine practitioners in urban regions and party members to teach in those universities (Farquhar, 1994; Scheid, 2002a).

[12] Examples for this are Ma (2010) and Wang and Chen (1996).

practitioners into the “supporters of the integration of Chinese and Western medicine” and the “introducers of systems theory, cybernetics and quantum mechanics”. Scheid explains the interest in technological and ideological modernisation of Chinese medicine with the “permeability of medicine to outside influences” (2002a, p. 34). This view is supported by Karchmer (2010) who shows that the first group almost wholly integrated biomedicine into their practice of Chinese medicine. For example, doctors follow in their diagnosis the biomedical approach of first determining the disease and then the pattern (*xian bian bing, zai bian zheng* 先辨病，再辨证), rather than first diagnosing the pattern and then determining the treatment (ibid). The interest of Chinese medicine researchers in modern technology and theories, indicate that the interest in systems biology is not odd. It shows that Chinese medicine researchers are familiar with the application of Western theories in Chinese medicine. Thus, the employment of systems biology in the 2000s might be an organic process similar to the implication of systems thinking, hence, in Chapter 4, I will discuss in more detail the integration of systems thinking and systems biology.

In the 1970s, the interest of international scientists in acupuncture supplied Chinese medicine with access to the global market (Zhan, 2009; Hsu; 1996). An increasing amount of literature reported the attempts of the Chinese government to globalise Chinese medicine (see, for example, Scheid, 1999; Zhan, 2009; Andrews, 2014; Hsu, 2009; Ownby, 2013; Lou, 2016). A seminal study in this area can be found in Zhan’s (2009) work. Zhan uses the concept of “worlding” to demonstrate the “transnational” (Hannerz, 1998) commodification of Chinese medicine through “miracle acupuncture”, which was a political measure on the part of China to “get back on track with the world” (Zhan, 2009, see also Chapter 1). Zhan (2009) claims that in 1971 a front-page article in the New York Times on acupuncture analgesia interested biomedical doctors and scientists. The writer of the article was the American journalist James “Scottie” Reston who experienced first-hand acupuncture as an analgesic after his appendectomy in Beijing (ibid). Several months after his acupuncture experience, biomedical doctors and scientists visited China with President Richard Nixon to observe acupuncture analgesia. Zhan (2009) indicates that the “worlding” of Chinese medicine emerged from the interest of American biomedicine doctors in Chinese medicine. The Chinese government followed this interest and reduced Chinese medicine to acupuncture as a “miracle” medicine for its export to American and

European countries. However, Hsu (1996) discovered that Chinese hospitals had abandoned acupuncture analgesia in the 1980s while the Chinese state continued to propagate Chinese medicine to rural and poor areas, such as Africa, as preventive medicine.[13] These accounts show that Chinese medicine was reduced to the practice of acupuncture. Acupuncture demonstrated an export value for the Chinese government, as it was not only an inexpensive and doable medical practice in Africa, but also raised medical and scientific interest in Western countries. Zhan's investigation in "worlding" or the entanglement of Chinese medicine as a local phenomenon can help us understand the various applications of system biology in Europe and Asia, as well as to avoid a simplification of Chinese medicine and its transition on account of globalisation.

In 1978, the growing interest in Chinese medicine and other traditional medicines caused a meeting of the World Health Organisation (WHO) in Geneva to discuss the education, research and the political strategies of integrating traditional medicine into healthcare systems. As a countermovement to the international interest in traditional medicine, Caudill (2000, p. xiii) reports that in the 1980s, the U.S. was ready to abandon and forbid the practice of acupuncture due to the lack of "scientific proof" for the claim acupuncturist made, for example, on acupuncture analgesia. However, it was unsuccessful, and investigations into the effect of acupuncture continued. Concerning scientific proof, Kaptchuk (2000) points out that in China acupuncture trials were always positive, which he thinks was due to a combination of biases and methodological shortcomings (Kaptchuk, 2000). The global attention that Chinese medicine received in 1982 lead the Chinese government to include Chinese medicine as a "nation's traditional medicine" in the constitution of the PRC (Andrews, 2014, p. 5-6). Thereby, Chinese medicine obtained a legitimate place in the healthcare system of China.

---

[13] See Stollberg (2009) for more accounts on the migration of Chinese medicine to Western countries, especially on Johannes Diedericus (Dick) van Buren who set up the first International College of Oriental Medicine in England and Holland in 1972 and taught Giovanni Maciocia, a practitioner who published the Foundation of Chinese medicine.

In the 1980s, Chinese medicine spread internationally, and the literature (see Hsu, 1999, 2009; Scheid, 2002a; Barnes, 2009; Zhan, 2001, 2009) refers to various phenomena of "fevers", i.e., "Chinese medicine fever" (see Scheid, 2002a, p. 92) and the effect of the interest in Chinese medicine in the West. Scheid (2002a) stresses that the "fevers" increased the number of international students studying Chinese medicine in China.[14] This increased interest in Chinese medicine which according to Taylor (2005), was due to the CCP's agenda to "open-heartedly and inseparably unite" Chinese medicine with Western medicine as a global medicine which began in the 1950s. Taylor (2005) believes that without the CCP's support, Chinese medicine would not have become an exportable product.

In the 1990s, further standardisation and regulations of Chinese medicine supported the commodification of Chinese medicine in the international market (see Farquhar, 1994, Hsu 2009, Zhan, 2009; Langwick, 2011). According to Scheid (2002b), the commodification of Chinese medicine was not only an avid step towards globalisation of Chinese medicine but also it secured the place of China as an influential role over the traditional medicine market with an export volume of USD 800 million by the year 2000.[15] Concurrently, China shielded the market against other East Asian medical traditions through the implementation of 305 international standards on Chinese medicine in 2010. A proposal to the International Organisation for Standardisation (ISO) to establish the Standardisation Administration of China (SAC) benefited research on Chinese medicine therapeutic effects. Subsequently, Chinese medicine developed into a commercial good that fitted into Deng's market policies; thus, Chinese medicine advocates were reassured of the continuation of Chinese medicine

[14] In the 1970s, Chinese scientists studied various practices of Chinese medicine to prove its essence and its wonders (Zhan, 2009). For example, David Ownby (2013) describes that respected Chinese scientists examined *Qigong* and claimed to have found the material existence of *qi*. These studies were within the plan to modernise Chinese medicine and to legitimise various practices (Ownby, 2013, p. 265). While the United States forbid its practice (Caudill, 2000) in post-colonial Macau (after 1999) the Chinese medicine practice upsurge occurred within the framework of a "cultural tradition rejuvenated with discourses of nationalism and modernity" (Lou, 2016).

[15] The export volume was also influenced by the "Chinese medicine fever". The new flow of Chinese medicine training in China provided *laozhongyi* with a new legitimation towards the state and an escape abroad (Scheid, 2002a, p. 92-93).

as a medicine. However, the downside was Chinese medicine had a commercial value on the national and international market.

A further step in the 1990s was towards technology and science (in short technoscience). Scheid and Lei (2014) note that as Deng demanded it in his reforms, technoscience created a high-tech hospitalisation of Chinese medicine in the 1990s and entangled Chinese medicine tradition into a cash-for-service system that turned away poor people (peasants), sold drugs over-the-counter in which doctors took commissions for drugs they prescribed. Additionally, the introduction of technoscience led to CMP as termed by Hsu (2009).

Towards the end of the twentieth century, Chinese medicine had converted into a scientific researchable and commercialised traditional medicine (Scheid, 2013) that was determined by studies to develop CMP as alternative modernity, which means modern according to its labels and production, but traditional compared to biomedicine (Hsu, 2009). Scheid (2013) asserts that the Chinese government planned the production of traditional pharmaceutical products for the global market, which stressed the understanding of *fufang* composition and Chinese medicine efficacy through advanced technologies. The first achievement was in 2012 with the registration of Chinese medicinal capsules *Diao Xin Xue Kang* in the European Union (EU) market (Medicine Evaluation Board, 2012). Scheid and Lei (2014, p. 260) argue that overall the integration of technoscience was seen as the only way for "developing and carrying forward the heritage of Chinese medical tradition".

During the last ten years, research into Chinese medicine has moved towards evaluations of the practice and the investigation into certain Chinese medicine drugs. Different technoscientific methods have examined Chinese medicine to evaluate the best practice for Chinese medicine research and clinical practice. Leung and Xue (2005) suggest, for example to run clinical trials for evidence-based medicine (EBM) to transform the evidence of Chinese medicine, which was based before on empirical case histories, in the universal language of (Western) science. This transformation can be observed since the 2000s with the contribution to global drug development, which I will demonstrate in Chapter 6. Conversely, Scheid and MacPherson (2012) warn that standardised trials and clinical study methods, e.g., EBM, randomised controlled trials and case studies ignore or are not capable of grasping the individual aspects or uniqueness of Chinese medicine.

The research to date, which I have reviewed, has been concerned with the continuities and ruptures in the practice and education of Chinese medicine practitioners due to encounters between Chinese and Western medicine. In the literature, it is evident that science has been integrated into Chinese medicine, for example, in textbooks, theories such as *bianzheng lunzhi*, the new formation of TCM and the use of biomedical technology for diagnosis throughout history. Chinese medicine and modern science were presented as opponents in political agendas during the Nationalist era, and during the reformation processes of the Chinese state which made Chinese medicine a political tool (see Lei, 2014; Andrews, 2014). The standardisation of Chinese medicine during the 1950s and 1960s, showed that Chinese medicine was part of the political agenda and was transformed through the interpretation of cadres or Chinese medicine scholars who worked for the MOH (Taylor, 2005). In the 1980s, Chinese medicine practitioners participated in this reformation process in order to gain a voice and influence, as much as possible, the transformation of their medicine (Scheid, 2002a; 2002b; 2013). The three encounters showed different political factions in power such as the Guomindang, the CCP under Mao and the CCP under Deng Xiaoping and their main agendas consisted of modernisation, standardisation and globalisation. Despite their different slogans, their aim was to modernise Chinese medicine. This was evident in the adaptions of institutional structure, disease classifications, their evaluation of Chinese medicine theories (e.g., with anatomy, physiology, neurology, systems theory or cybernetics), their labelling of Chinese medicine as a miracle medicine and alternative tradition for commercialisation in the global market. Chinese medicine was modernised and scientificised by others and by its practitioners. However, in the above-stated records, the Chinese government together with Chinese medicine practitioners trained in Western medicine and science and Chinese medicine practitioners and scholars participated in these changes. It can be said that for Chinese medicine to survive, it had to fight for a position in the Chinese healthcare sector, which was a fight that depended on the stance of government, party members or cadres. Typically, however, Western medicine was preferred as it was associated with modernity, and some Chinese medicine practitioners were active reformers and modernisers themselves. What also appears in the literature is that the divide between

Chinese medicine practitioners arose out of a generation gap question. It is the *laozhongyi* against the young scientizers.

In conclusion, most researchers refer to the encounters between Chinese medicine and modern science as something that happened to the medicine, and that Chinese medicine practitioners did not participate in the transformation (Taylor, 2005). Nevertheless, only some researchers view the modernisation and the influence of technoscience in Chinese medicine as a positive effect, which brings Chinese medicine forward (Scheid and Lei, 2014). Overall, Chinese medicine practitioners are familiar with encountering modern science and integrating aspects of it into their practice or theories. The question, thus, is how can the West and systems biology with the aim to establish a personalised medicine on the example of Chinese medicine cope with Chinese medicine?

My research seeks, first, to combine stories from both sides of the involvement of Chinese practitioners and researchers, as well as to consider the involvement of Western scientists in the transformation process of Chinese medicine and science in the early 2000s. Secondly, I aim to observe this emergent phenomenon in multiple locations in China and the West. Therefore, the question of how this present relationship between Chinese medicine and systems biology has emerged and still is emerging requires an empirical approach of anthropology within STS. In the next section, I will discuss how medical anthropologists in the broader socio-historical discourse have investigated and presented encounters between different traditional knowledge, as well as therapeutics and scientific practices and how multi-sited ethnography can be deemed relevant for my study.

2.2 MEDICAL ANTHROPOLOGY AND BIOTECHNOLOGY

This section refers to medical anthropology as a methodology. Medical anthropology is a relatively young sub-discipline of social and cultural anthropology. It engages with humans in the context of health-related issues (Baer, Singer and Susse, 2003), social movements and debates in public health (Manderson, Harden and Cartwright, 2016). Medical anthropologists address new developments in medicine and life sciences (microbiology, biochemistry, genetics, parasitology, pathology, epidemiology and nutrition) to assess their influence and consequences on the lives of humans (Helman, 2007). Based on these premises, medical anthropology adopts different theoretical frameworks and different foci. In the following sections, I will focus on two strands of medical anthropology: “medical anthropology of traditional medicine” and “medical anthropology at home” with the emphasis being on biotechnology and genetics.

An exploration of how medical anthropologists have conceptualised encounters between Chinese medicine and Western medicine in the section of past encounters reveals trends in cross-disciplinary theories. Since the onset of anthropology in Asian medicines in the 1970s, anthropologists challenge the theoretical impasse of anthropology’s dichotomies, i.e., of East versus West, of traditional versus modern, of science versus culture, and nature versus culture (Nichter and Lock, 2002). The focus of this sub-discipline lies in comparative studies of “present-day human societies and their cultural systems” (Helman, 2007, p. 1) to reveal cultural, scientific and professional processes that have shaped Asian medicine in the long term (Leslie, 1976). In the early 1970s, anthropologists regarded traditional Asian medicines as “other” medicines (see Leslie, 1976, 1992; Kleinman, 1980; Scheper-Hughes and Lock, 1987; Unschuld, 1973). For example, Charles Leslie studied them on a small-scale level within villages and towns and the border of colonial empire studies (Nichter and Lock, 2002, p. 2).

In the 1990s, medical anthropology developed to a critical and sometimes activist approach which was sensitive to global situated political and economic issues (Nichter and Lock, 2002). Hess (1998) argues that anthropologists began to refer to STS scholars and concepts in their research for positioning medical anthropology in a postmodernist and post-colonialist context. Franklin (1995) notes that these anthropologists started the anthropology of biomedical research, science, ethical and legal questions. Another new trend that arose was critical medical anthropology (see, for example, Scheid, 2002a; Zhan, 2009; Sunder Rajan, 2002), which relates to Neo-Marxian, critical and world systems theoretical perspectives (Baer, Singer and Susse, 2003). Many of these studies compare traditional medicines with biomedicine, Nichter and Lock (2002, p. 2) and warn that neither traditional medicine is inherently conservative, and that biomedicine is not the only "scientific" medicine. Nichter and Lock (2002) argue that scientific and rational principles are immanent in traditional medicines, for example, Ayurvedic, Unami and Chinese medicine. Thus, it is essential to employ a critical stance to see transformations in medicines.

Related to the historical and anthropological discussion of the development in Chinese medicine which was discussed in the previous section, medical anthropologists note similar globalisation and integration processes of Western medicine in several other traditional medicines. For example, Leslie (1976) demonstrates in his pioneering work on medical anthropology how Asian medicine changed. Researchers of ayurvedic medicine investigated the biomedicalisation and commercialisation of Ayurvedic medicine and formulae (Pordié and Gaudilliere, 2014; Pordié, 2012; 2014). Others investigated the transformation of Tibetan medicine into an efficacious transnational medicine (Schrempf, 2015), technoscientific medicine (Adams, 2001; Adams, Dhondup and Phuoc, 2010; van der Valk, 2017; Blaikie, 2013), an exile medicine that is globally accepted and standardised (Kloos, 2008, 2013) and the circulation of Tibetan and Chinese medicine by social actors (Springer, 2015). Other medical anthropologists studied the boundary communication between Arab medicine and biomedicine (Keshet and Popper-Giveon, 2013), investigated the hybridisation of medicine in Tanzania as a mix of biomedicine, traditional healing in Tanzania and Chinese medicine (Langwick, 2011), forms of enchantment in Western herbal medicine (Waddell, 2016) and identified Korean medicine as a heterogeneous and transnational reinvention of traditional knowledge (Kim, 2009). These examples represent only a small selection of anthropological studies in traditional medicine; however, these studies demonstrate the growing global interest in studying traditional medicines in medical anthropology.

Criticism arises with the cross-fertilisation of medical anthropology as an interdisciplinary field with the history of Chinese medicine. For instance, the idea of plural healing systems was adapted by historians as a socially constructed knowledge system that focuses on patients' strategies rather than how historians viewed it before, such as an isolated medical system of patient choices (Hinrichs, 1998). Additionally, Helman (2007) expands on the concept of culture and warns of its misuse in its generalisation of cultures as static homogeneous systems. Cultures are in a constant process of historical, economic, social, political and geographical change, which manifests in people's explanations of beliefs and behaviours (ibid).

While medical anthropologists challenge the scientific evidence, which focuses on traditional medicine, Hampshire and Owusu (2013) argue that anthropologists present biomedicine as "colonising" and "co-opting" traditional medicine to use their "resources" in biomedical endeavours (2013, p. 248). Colonialism is a profound issue in medical anthropology and this instigated in the field a critical awareness of the study of "others" as "cultural" beings but overlooking the "cultural dimension and foundations of home" at the end of the colonial era (Van Dongen and Fainzang, 1998, p. 245). Due to discussions and the shortage of field research, the budget for abroad field trips abroad stimulated the emergence of the new sub-field "medical anthropology at home" (MAAH). MAAH aided medical anthropology to distance itself from colonialism and neo-colonial intellectual imperialism in Asian and African countries by studying "our" biomedicine (ibid).

2.2.1 "MEDICAL ANTHROPOLOGY AT HOME" AND BIOTECHNOLOGY

Van Dongen and Fainzang (1998) describe MAAH as the anthropological study of health issues at the home country of the researcher. It is a sub-discipline of medical anthropology that explores particular local practices that can inform the researcher, despite a lack of proper understanding in the field of study, for example, biology, epidemiology or psychology (Helman, 2007). Helman refers to this branch of medical anthropology as the "biocultural discipline" (ibid, p. 7), which he describes as a cross-cultural study of social and natural sciences. The biocultural discipline draws on insights of anthropological and biological findings and provides in-depth data for the issue of investigation (Helman, 2007). In this field, since the 1990s, researchers have conducted ethnographies in biomedical sites such as hospital spaces (see Mol, 2002), health organisations (see Allen, 2014; Smith and Ward, 2015; Twycross, 2007) and health-related agencies (see Hare, 1993; Zhan, 2009; Jolibert, 2012; Clancey and Chen, 2013; Sunder Rajan, 2002). The main issues investigated are health conditions in relationships with policies, biology and globalised political economies (Manderson, Harden and Cartwright, 2016).

For example, Mol (2002) studies the disease atherosclerosis in a hospital in her hometown in Holland. She argues that multiple ontologies of a disease construct different realities in different localities. Her localities are in different departments of the hospital "Z", e.g., the consultation room, laboratory, operation theatre, pathology and the patient (ibid). For her analysis, Mol (2002) applies the concept of "enactment" to differentiate the perception of a disease in different contexts. For instance, the doctor perceived an impaired leg as a medical indication for surgery. While for the patient it was merely seen as a handicap which prevented him/her from going up stairs. Harbers (2005) argues that Mol's notion of ontologies is a different perspective of professional power struggles and should not be seen as an exclusion of factors but preferably as the inclusion of various elements of diagnosis resulting in a treatment. Her analysis, of "enactments", has the potential to elaborate networks beyond power struggles by taking various perspectives within a specific setting (i.e., disease diagnosis and treatment) (Mol, 2002).

MAAH, which interchangeably is used as "applied medical anthropology" and "clinical medical anthropology" (Helman, 2007), generated a vast body of knowledge in biomedical studies on biotechnology and genetics. Helman (ibid) says that in large parts, biotechnology culturally influences peoples' attitude to health, illness and behaviour. He believes that this influence originates in the understanding of our body's limits and what medicine in combination with technology can do or not to help us to overcome any physical restrains (ibid).

Hadolt, Hörbst and Müller-Rockstroh (2012) study the transformations of medical techniques and medical artefacts in the context of human health. These transformations, for example, in genomics or biotechnology often relate to economy as a new capitalist system that trades human life as an economic value. Sunder Rajan (2002) calls this the biocapital, while Kilshaw (2018) views it more positively as the intersection between the modern Western world and Middle East countries. MAAH with its focus on biotechnology will be relevant for my study, as it can be used to view, from an anthropological perspective, how science and technology are applied to engage with and study Chinese medicine with the new approach of systems biology.

Biotechnological studies show a wide range of influences of biotechnology on human lives, bodies and minds (e.g., Hadolt, Hörbst, and Müller-Rockstroh, 2012; Chen, 2003; Wiechers, Perin, and Cook-Deegan, 2013; Lock, 2015) and the monitoring of our lifestyle through smartphones (Manderson, Harden and Cartwright, 2016). The increasing use of biotechnology in the medical domain stimulated the demand for bioethical studies in medical anthropology. Sleeboom-Faulkner (2013, p.9), for example, developed in her study on bioethics the concept of "latent collaborations". She describes the co-operation between Chinese stem cell researchers and foreign research institutions (e.g., U.S., UK, Japan and Korea) as a way for Chinese institutions to adapt international regulations and standards of safety, hygiene and bioethics. Additionally, Sleeboom-Faulkner (2013) identifies hidden networks as constructs of national funding, i.e., by the National Natural Science Foundation of China (NSFC) in cosmopolitan cities of China, i.e., Beijing, Shanghai, Guangzhou and international collaborators. Her work can be of relevance to identify how actors formed connections between China and Europe in the relationship between Chinese medicine and systems biology.

The second track of biotechnology is genetics research, which investigates topics such as pharmacogenetics (Helman, 2007), genetic risk and cousin marriage (Kilshaw, 2018), genetics as a form of biocapitalism (Sunder Rajan, 2002) and genome biobanks (Pálsson and Rabinow, 2015). Helman (2007), for example, investigates the manipulation of drugs and patients' response to drugs. Pharmacologists need this information to create an individualised or personalised drug that is efficacious and safe for patients. Helman (ibid) discovered three major ethical and political issues for clinicians and social scientists in designing personalised drugs: (i) research prioritisation of certain health conditions, (ii) geneticisation, which is personal and social identification through genetic information, and, (iii) the economic interests in patents on genomes of humans, animals and plants. The third is of particular interest for my study as this commercialisation, as mentioned by Hsu (2009) in the previous section, is an increasing problem in Chinese medicine. Helman (2007) claims that the genomes of indigenous medicinal plants are in danger as large foreign pharmaceutical companies patent or integrate the indigenous knowledge in Western databanks for biodiversity (i.e., biobanks). For example, turmeric is an herbaceous perennial plant of the ginger family (Finetti, 2011). It is used in India as a spice and as a remedy to treat wounds and rashes but through the US patent no. 5401504 the indigenous knowledge of turmeric was patented as a "new" invention for the commercialisation of a reformulated drug (ibid). The problem that arises is that foreign pharmaceutical companies "steal" the indigenous knowledge and do not share the benefits with indigenous people (ibid, p. 368). Two terms describe this development: biopiracy, which is the unauthorised use of indigenous plants by a large business corporation from developed countries, and biocolonialism, which happens when foreign companies patent new pharmaceutical drugs (ibid).

Many traditional medicines are described as either "proprietary" medicine that are national and internationally recognised drugs (Pordié, 2014) or as "propriety" medicine that are medical drugs gained from traditional herbal *fufangs* and transformed into a biomedical propriety drug (Hsu, 2009). For example, Van der Valk (2017) investigates the industrial aspect of traditional medicines, patents and exploitation of indigenous products. Chinese medicine represents a source of traditional knowledge and herbal medicine that may become an issue with genetic studies. MAAH, in particular, is concerned with the issue of exploiting herbal medicine and the genetic identification and manipulation of drugs. Hsu (2009) and Efferth et al. (2018) investigate the issues of biopiracy or biocolonialism of patented Chinese medicine drugs in China and overseas. The increased use of biotechnology and omics technology in analysing Chinese medicine drugs for establishing a personalised medicine may, in the future, increase the concern of biopiracy.

The issues of MAAH are diverse: distance from the field, length fieldwork and single-sightedness. First, challenges of investigating health at home are to gain distance in the field because researchers might previously have been involved in the communities they study. Therefore, they may not be fully considered as a stranger by the community which complicates the analysis and reflection especially if the researcher is not aware of the way his own interests are culturally constructed (Helman, 2007). The study of a familiar setting suppresses the interconnectedness between “we” and the “others” thus, it reduces differences and similarities between our and the other culture (Hadolt, 1998). Hence, Hadolt (1998) suggests the concepts of “difference between” and “difference within” to study biomedicine at home. Secondly, the length of ethnographic research (of at least one year) may be inappropriate, e.g., in situations of health crises. Thirdly, phenomena are often in multiple sites, which challenge MAAH and its single-sited character. Hence, Fainzang (2010) proposes overcoming this issue by comparing studies from different research settings, e.g., a place abroad and one at home (ibid). Marcus (1995) advocates a “multi-sited ethnography” to overcome this problem by mapping relationships between local sites rather than producing a holistic representation of a world system. This method will be elaborated on in the following section.

2.2.2 MULTI-SITED ETHNOGRAPHY

To explore the “interface” between Chinese medicine and systems biology in multiple sites, an ethnography and, in particular, multi-sited ethnography can help to understand the complexities and the richness of the interactions between various actors working on scientific investigations arranged across European and Asian research institutions.

Ethnography is synonymously described as the primary method in anthropology as well as a methodology for qualitative inquiry or case studies, which can include quantitative data and analysis (Hammersley, 2006). The core of ethnography is to study at first-hand people’s actions and statements in a particular context (ibid). Participant observation and open-ended interviews are the main instruments used to gather data and perspectives of people who are members of a certain social group or society in relevant settings (Helman, 2007). Hammersley and Atkinson (2007) state that ethnography includes both observations and interviews in the field to record people’s actions and accounts. These methods help collect unstructured data without a fixed and detailed research design. Categories that are gained from the analysis can include meaning, functions and consequences of human actions and institutional practices. Through the interpretation of data, the researcher can reflect on the impact in the broader context or he or she can carry out an in-depth study of a few cases on a small-scale. From the data, verbal descriptions, explanations, theories, quantification and statistical data are produced. Data may include public or private documents and relatively informal conversations (Hammersley, 2006). It is important to produce a "thick description" of relevant and meaningful contents to describe and explain the contents of the study to an outsider (see Geertz, 2017).

A vast body of complementary and alternative medicine (CAM)[16] research and Chinese medicine research demonstrate that ethnography yields richness of in-depth data of medical systems and practices (e.g., Farquhar, 1994; Hsu, 1999; Potrata, 2005; Scheid, 2002a; Ward, 2011; Kim, 2009; McMillen, 2004; Van der Valk, 2017). Ethnography is widely-applied to investigate and reflect on local and global issues such as the transmissions of Chinese medicine in China (see Hsu, 1999) and to countries outside China and non-Chinese (Barnes, 2009).

Multi-sited ethnography moves away from single site fieldwork in conventional ethnography (e.g., used in laboratory studies and medical anthropology, see, for example, Mol, 2002; Latour, 1987; Knorr Cetina, 1983) to a mobile ethnography which takes place in multiple sites. Marcus (1995) established this method with the argument that social phenomena or economic relations became untraceable in a single site as they are shifted from studies on indigenous people (i.e., tribes) to exploration in the circulation of objects, cultural meanings, and identities that were dispersed in space and in time.

In contrast, laboratory studies (see Knorr Cetina, 1983; Latour, 1987) are rich in material and details. Doing (2008) argues that this may lead to STS scientists failing to observe cases of contingencies for the production of scientific facts. Thus, STS scientists such as Lynch (1993), propose ethnomethodology. Ethnomethodology is a

[16] CAM describes a medical practice that is not mainstream or conventional medicine and is either used with conventional medicine (complementary) or in place of conventional medicine (alternative) (NCCIH, 2018).

detailed and rigorous descriptive study which involves recording the discussions and conversations of scientists in their everyday scientific practice (Keith and Rehg, 2008). Lynch (1993) argues that ethnomethodology considers emerging contingencies during the creation of scientific facts by focussing on the methods scientists use. Ethnomethodology, nonetheless, was not considered for this research as it focuses on the mundane details of social interactions and daily communication in local and lower level practices and neglects the broader structural level of multiple interactions between multiple sites. Thus, a multi-sited ethnography approach which examines the co-ordination between various sites and disciplines was used in this study.

The relationships between sites arises from a shared object of study where contours, sides and relationships are unknown beforehand, but through juxtaposing or questioning aspects of the sites they become evident (Marcus, 1995). Falzon (2009) explains that even some advocates of multi-sited ethnography interpret the term "site" as either a location or a place or a perspective. Although multi-sited ethnography encompasses transformations and changes in space and systems, it still implicates the traditional methodological scaffold (i.e., observations and interviews). Multi-sited ethnography includes a commitment to language in a mechanical way and to practice a value-free social science with a touch of other forms of positivism (Marcus, 1995). This method emerged in the context of STS, thus, "following connections, associations and putative relationships" as a "circumstantial activist" are key to this method (Marcus, 1995, p. 97) and resonates with Latour's (1987) "follow the actors" program, which I will discuss in the next section on STS lenses. Vinck (2010) argues that in medical anthropology of traditional medicine and biotechnology, multi-sited ethnography gives insights into transnational networks, which elucidates the transmission processes of scientific knowledge, expertise, data and technologies between varied biosociotechnical networks. Likewise, Kim (2009) argues for a multi-sited ethnography to circumvent the limitation of single case studies in medical anthropology by tracing global assemblages of medical and traditional knowledge transformations. These examples are similar to the principal aim of my study which is to explore the emergence of relationships between the 1990s to 2010.

By mapping the relationships between sites, multi-sited ethnography overcomes the global and local dichotomy (Sunder Rajan, 2002). Sunder Rajan (2002) does this by mapping associations and relationships of a new object of study and sets this in the picture of earlier studies to illustrate a complex connected world. The comparative character of ethnography is maintained by questioning the contour and relationships of sites. As a result, findings of a multi-sited ethnography reveal fragments and discontinuities among sites (Marcus, 1995). Thus, Marcus and Fischer (2004) clarify that multi-sited research maps complex associations among various movements of actors, mobile objects or the transformation of objects and concepts in a transnational setting to avoid a Eurocentric or a dominant Western model, which resonates with the objective of this study.

Relationships are not always visible in scientific publications. Strathern (1995) claims that connections are an act of crossing the boundaries of disciplines, power, and organisational levels. By doing so, collaborations generate noticeable and blurred networks of all sizes and scales, e.g., on an academic level or in the daily life of researchers and scientists. Occasionally, researchers may refer to their relationships with other scientists as "best friends" (Strathern 1995, p. 28). Although connections in this emergent "interface" between Chinese medicine and systems biology are not ties of kinship, their friendships may solidify their networks as extended forms of relationships. The focus on everyday practice helps to portray how actors established ties between systems biology and Chinese medicine. It also uncovers links between European and Asian institutions, which depicts reasons, intentions, gains, and losses throughout its process.

A crucial aspect of adopting multi-sited ethnography is to understand the constructive nature of the empirical study and the field. Marcus (1995) posits that constructivism is the technique or method used in multi-sited ethnography to define the object of study. The ethnographer constructs a movement of a complex phenomenon among sites by tracing them with an initial concept that is contingent and malleable as the ethnographer traces it in the field. However, Gatt (2009) discusses various interpretations of constructivism in multi-sited ethnography, e.g., that people socially construct the field through ethnographic knowledge of the researcher and the information of the informant; or the ethnographer construct the field through the contextualisation of described and disentangled relationships. For this research, the interpretation of constructivism might influence the first stage of the research process to trace links in a socially constructed field that is only described in the scientific literature.

Hammersley (2006) makes ethnographers aware of the critical tendency to carry out part-time observations. In multi-sited ethnography, the observation time in the field is shorter than in traditional anthropological studies where ethnographers live and study day and night the people of the relevant setting. In conventional ethnographic studies, fieldwork lasts at least one year (Helman, 2007) while in ethnographic work in institutions, universities or schools, the time is shorter. The shorter observations imply a danger of insufficient sampling, generalisation, an ahistorical viewpoint that can affect, for instance, a failure of recognising the cyclical process, which are work routines that change daily or weekly and show different tasks during the cycle as well as the change of patterns in the field. However, Hammersley (2006) asserts that this problem arises from the changing social conditions as most of the people observed do not live and work in the same place, which is the case for scientists and researchers. Thus, this restriction reflects on the nature of the observed societies, and with the transformation of society therefore, the methods have to adapt respectively.

The data collected from audio- and video- recording devices produces a large amount of data in a short time and counterbalance the reduced contact with people and the lack of depth (Falzon, 2009). The lack of depth is also compensated by multi-sited ethnography with the role of the researcher as a “circumstantial activist” who reflects and tracks things and people and compares material among sites (Marcus, 1995, p. 95). Every site delivers different results through the variables of the setting but also through the time spent there. Thus, the data evolved in one single site exposes data for a comparison between local and global sites (Marcus, 1995). Falzon (2009, p. 8) argues that multi-sited research, which is conducted in short-term fieldworks covers the same data and depth by identifying the process on the example of anthropological studies at home. In-depth data is gained through a “time-space decompression”, meaning de-centring the researcher is equal to the time he spends there, by adding more sites and compensating one long-term study with several short-term observations.

In summary, medical anthropology and multi-sited ethnography are valuable for this research. Medical anthropology and MAAH facilitate insights into a merging field of traditional medicine, i.e., Chinese medicine, with biotechnology and genetics aspects in systems biology. Multi-sited ethnography in medical anthropology provides a methodology to map fragmented relationships, associations and connection between actors and sites which could describe the emergence of the relationship between Chinese medicine and systems biology.

2.3 STS LENSES

This thesis is interested in discovering the nature and the involvement of the actors with their relationship between systems biology and Chinese medicine. The first problem that arises is if there is an “interface” and what the term “interface” means to the actors that work in field sites of systems biology and Chinese medicine research. This can be found out by observing actors in the field and their most recent publications. This question relates to the nature of this “interface” and to the difference between this emergent “interface” and past encounters between Chinese medicine and modern science. The question of the difference between encounters and this “interface” has arisen from questions of who established this “interface”; how scientists became involved in systems biology and Chinese medicine studies; and what was the role of technology in the involvement of actors and the shaping of this “interface”. In this section, I will critically discuss STS, laboratory studies and actor-network theory (ANT) as fundamental theories in the study of scientific practice. Subsequently, the “modes of ordering” will be considered for the analysis of the relationship between Chinese medicine and systems biology.

Science, Technology and Society (also referred to as Science, Technology and Society - STS) offers interesting tools to study the scientific knowledge production and technological development in careful examination of interactions between scientists and with the artefacts to construct facts (Bijker et al., 1987; Knorr Cetina, 1981; Latour and Woolgar, 1986). STS is an interdisciplinary program associated with social sciences, history of science and technology, philosophy and anthropology (see Latour, 2013; Law, 2004). Social constructivists within STS investigate scientific activities and technological developments as socially constructed through local social environments that shape science and technology through artefacts and networks (see, for example, Bijker et al., 2012). However, actor-network theorists consider that scientific knowledge is socially and technologically produced through interactions between human and nonhuman actors (see, for example, Latour, 1987; Law, 1994; Callon, 1986). To reveal the social context or the “seamless web” of interactions between actors (human and nonhumans) in the production of scientific knowledge, Bijker (1993, p. 120) suggests applying a “thick description” (Geertz, 1988) approach.

STS sets its importance in investigating emerging phenomena in science by identifying knowledge production processes (Bijker et al., 1987). This section will briefly introduce STS and identifies and discusses STS insights into investigating scientific work and developing technology which is relevant for this thesis, in particular, to the role of artefacts in the connection of distributed scientific fields.

Forerunners of ANT were laboratory studies and their example of integrating observations in scientific knowledge production studies. Laboratory studies set the groundwork for studying scientific knowledge production in laboratories with ethnographic methods in day-to-day and first-hand observations (Knorr Cetina, 1981, 1983; Latour and Woolgar, 1986; Lynch, 1993). For example, Latour and Woolgar (1986) and Knorr (1995) applied an ethnographic approach in the study of scientific practices to detach their research from depending on the scientists' statement in their publications. In Latour and Woolgar's influential book *Laboratory Life* (1986), the authors provide an ethnographic account of the activities of scientists in the Salt Lake laboratory. Latour and Woolgar (1986) meticulously analyse the actions and interactions between scientists and scientists and technology and materials. Collins (1995) and Amsterdamska (2008) argue that Latour and Woolgar (1986) established with this work the first social construction of scientific facts in the laboratory as a micro-analysis that supplanted the structural analysis of macro-sociological analysis. The careful study of actions in the laboratory provided insights into the experimental processes and the formulation of an accepted fact. Knorr Cetina (1981) states that it revealed the precise organisation of experiments and projects and their unpredictable progress and outcome which is influenced by local circumstances and social interaction of decision making and negotiations on project, rhetoric and scientific publications.

Subsequent works in STS included the actor-network theory (short ANT; see, for example, Latour, 1987; Callon, 1986; Law, 1992) which focuses on technoscience as an interdependent concept that avoids a distinction between humans and nonhumans as well as technology and science. Instead ANT views humans and technology and science as joined in similar processes and only differentiated through their discipline of science and engineering (Latour, 1987). As opposed to past STS studies, ANT developed the principle of generalised symmetry between nature and society and human and nonhuman properties (scientists, materials, organisations and partners) and declined the social tradition of human-focused studies by using the same vocabulary of translation for technology and society (Callon, 1986; Latour, 1987, 1993). STS scientists view ANT as the most influential concept in the field (Anderson and Adams, 2008). Michel Callon's (1986) work on "translation" between fishermen and scientists, Bruno Latour and Steve Woolgar's (1986) experience in the Salk laboratories in California, U.S., and John Law's (1992) work on "heterogeneous network" were the first ANT studies. Law (1992, p. 380) defines a heterogeneous network as a network that is generated through society and its consequences of power relations and materials that produce or affect knowledge, agents, social institutions, machines, and organisation. Society is the connection of various actors (i.e., humans, machines, materials) in networks who interact and generate knowledge. Others definition of actors in ANT studies included scallops (see Callon, 1986), inscription devices (Latour, 1987), disability supporting technology (Moser, 2005), or organisations, governments and patient activist groups (Gottweis and Lauss, 2012) in addition to human actors who participate as actors in sociotechnical processes of knowledge building. Law (1994) argues that the agency of actors is an effect generated in a network of heterogeneous materials; thus, an agent (like a machine) is a network of different materials. To this end, STS theorists use a material-semiotic approach to map humans and materials (such as technology, lab equipment, research papers) and semiotics (such as concepts or written process of knowledge production) in laboratories of scientific knowledge production (Kim, 2009).

The research questions of this thesis raise the methodological problems of how to analyse the involvement of the actors and their relationship between Chinese medicine and systems biology research and the emergence and development of their relationships. First, Woolgar (1981) and Barnes (1981) tried to analyse involvement as a social interest in the process of either being attracted to something and engaging voluntary with it, or participating in something. For this, Woolgar (1981, p. 367) refers to the use of the "interest model" as an explanatory "resource to explain the change in (or involvement with) the content of scientific knowledge, the relationship between social and knowledge products in terms of social and/or cognitive interests of participants". Woolgar and Barnes study scientific practices as social processes, thus, Bijker et al. (2012) claim that they turn their attention to a social construction of scientific knowledge. In contrast, Callon and Law (1982) believe that knowledge production happens through social and technical interactions, which leads them to the conclusion that the interest model is a theoretical concept to understand why scientific culture grows in the way it does, and not how actors become involved in the process. Moreover, Woolgar (1981) states that the interest model was designed to study the demonstration or exposure of interests during scientific actions, which, does not aid the discovery of the involvement of scientists in a new field such as Chinese medicine and systems biology research.

In the interest model perspective, STS studies depict that scientists participate in studies within their research area and research group; their projects are within their established area of knowledge (see, for example, Woolgar, 1981). Interest in a new topic but the same field is also the usual case study format in ANT (see, for example, Latour, 1987; Law, 1994; Callon, 1986; Timmermans and Berg, 1997). ANT studies try to understand emerging technoscientific cultures by following networks of human and nonhuman actors' associations, statements and practices that show the continuous transformation of a social and technical (sociotechnical) network (Latour, 1987; Callon, 1986; Law, 2007). Thus, their points of departure are that scientists are already members of projects within their research fields, and, second, that cases are a single site, which is the centre of their study, see for example, Callon's (1986) study on scallops in St Brieuc Bay, France.

ANT scientists (Latour, 1987; Callon, 1986; Callon and Law, 1982) use the concept of "translations" to analyse the processes involved in enrolling human and nonhuman actors, the interest of the initiator of research and the so-called fact-builder (Latour, 1987). They translate "inter-esse" as in between various actors. According to Callon (1986), interessement indicates that interests are not stable and change in a competitive enrolment of and between various actors through translations of the interest into a collaborative work. In order to enrol actors into a project, it is important to make them believe the claim or argument of the fact-builder (Latour, 1987). Callon and Law (1982) justified interessement as an escape from the problem of interests by Woolgar (1981) and Barnes (1981) and assess the measurement of interest through the correlation of nominal variables as problematic. Woolgar and Barnes investigate the interest of actors working in already established research projects as continuing a scientific action. I relate to Woolgar's and Barnes' interest approach as I aim to investigate the interests of the researchers. However, I am concerned about the researchers who find a specific problem within their field, and consequently initiate various processes to generate an experiment or research co-operation with all its implications such as funding, collaborators, suppliers, technology, materials, rhetoric, spokesmen and representatives. In other words, I am interested in the motivations that leads to a scientific project.

ANT has been the object of a series of criticism. A major objection concerns the "generalised symmetry" with its resistance to differentiate between animate or inanimate actors or between individuals and organisations (Sayes, 2014; Amsterdamska 1990; Pickering, 1995). Amsterdamska (1990, p. 499) rejects the idea of a symmetry between humans and nonhumans as a "war whose only objective is domination" and a method used to find allies in and a way to strengthen a specific network. Even though Pickering (1995) relates his "mangle of practice" theory to ANT, he refuses the idea that machines, probes, microbes and quarks have intentions behind their action and perform (behaviour) intentionally. ANT proponents refuted this with the explanation that a rejection of *a priori* distinction between humans and nonhumans furnishes the researcher with a tool to investigate in a minute displacements translation, practices, processes, arguments and struggles (Sismondo, 2004).

Another critique is that the ANT studies networks as a "seamless terrain" without hierarchies and structures of politics, industry and economics that interact in a global knowledge-making practice (Kim, 2009). Hence, social constructivists argue that ANT rejects the argument that humans construct science and that science is static and socially constructed (Bijker et al., 2012). However, ANT theorists as post-humanists follow the idea that humans and nonhumans construct scientific processes and that science is not imposing itself on society, but they are co-evolving (see, for example, Latour, 1999; Barad, 2007; Pickering, 1995; Law, 1994; Mol, 2002). Latour (1987) demonstrates that scientific facts and realities are produced through the effort of associations between various actors that transform an artefact into a fact by moving and re-enacting artefacts in new locations.

In this thesis, the diversity of scientific and technical aspects that emerged from the variety of actors and their different involvement in a new multi-disciplinary and multi-sited study is essential and cannot be ignored. Biologists, biochemists, biomedical scientists, pharmacologists and artificial intelligence (AI) scientists would have all different ways of involving with Chinese medicine by engaging with another area of research. Those actors changed from biomedical studies on biomedical disease classifications and diagnoses, which they were familiar with or technological studies on intelligence in machines to Chinese medicine. Although translations provide a tool to understand how systems biology and Chinese medicine produced scientific knowledge, the crucial question of the actors' involvement cannot be answered with translation. Consequently, translation was not selected for this investigation. Instead, additional concepts that originated in ANT and which focus on the motivators and drivers of scientists to engage in a multi-disciplinary study a non-scientific field like Chinese medicine are considered next – "mode of ordering".

"Modes of ordering" (Law, 1994) can be used as an analytical tool for sense-making of purposes or activities around scientific knowledge production. This concept stresses the reflection and the self-reflection of representations, demonstrations and enactments of ordering of "heterogeneous materials" in scientific practice. Law (1994, p. 23) defines heterogeneous materials as human and nonhumans that include people, technical devices, texts, "decisions", relationships between organisations, and organisations. He claims "'modes of ordering' are about: they represent a way of imputing coherences or self-reflexive 'logics' that are not simply told, performed and embodied in agents, but rather speak through, act and recursively organize the full range of social materials" (ibid, p. 109). In this sense, "modes of ordering" are an analytical tool used to make sense of patterns that arise from the exploration. They offer an interpretation tool of how humans and materials interact and create complex effects, such as organisations through conditions of possibility, ways of ordering and webs of relations (Law, 2007).

Law (1994) rejects the idea of a single "order" such as "social order". He argues that social order is constructed of various materials - in which he includes, for example, talk, texts, machines, architecture - and of plural processes. Thus, every order consists of multiple components and processes, which consequently, rejects the idea of a single order and investigation of the processes of “sociotechnical ordering”, the ordering of social intertwined processes with technology (Law, 1994, p. 2). Mol (2010) explains that “modes of ordering” is about work, precarious achievements in open-ended processes with a particular interest in the co-existence and co-operation of merits and drawbacks, for example, networks are achievements. According to Law (1994), networks emerge from interactions between associated actors and the changes that take place in their constant making and re-making. The active association of actors and the building of networks with other actors requires the translation of scientific facts and realities into new contexts and new locations. These translation processes generate and gather representations in a single place, which is the centre of representation or “centre of translation” in the translation concept of Latour (1987) and Callon’s (1986) theories.

In “modes of ordering”, Law (1994) is interested in people, organisations and machines as agents and the kind of modes they perform. He argues that agency emerges through “modes of ordering”; it is an effect that is generated by decentring the subject and its bits and pieces; it emerges in between structures and non-structures rather than following one. For example, a vision of an invention does not follow existing structures of mundane organisation matters, it creates its way through them to generate something new. In summary, agency is not attached, embodied or acted by humans, but it is rather a matter of degree, which focuses on quantities and qualities, which cedes or can be lost through passiveness but regained through activity. Types of agency can be puzzle-solver like scientists, administration as a set of embodied skills, or vocation in the form of creativeness and consistency. Agency is nothing pre-defined but rather it is unexpected and a new adaption to a situation, e.g., the consortium can be seen as an agency that emerges through the interaction between systems biology and omics.

Moser (2005) remarked that the “modes of ordering” draw on material semiotics as a strategy to trace materials in local, situated practices and broader sets of relations and arrangements that conditions and limits practices. However, practices are limited to the range of their networks and material arrangements and cannot go further to reach actors outside of the network or reflect on the broader context (Hedgecoe and Martin, 2008). Moser (2005) shows in her study that “modes of ordering” extend out of the normal scope of networks and specialisations in the lab to any process that relates to the network. Moser (2005) uses the "mode of ordering" to investigate how people deal with their disability and to avoid a study design that highlighted the representation of differences between normal and not-normal and their distribution of power and agency which excluded alternative ways of living. Her "modes of ordering" do not demonstrate an ordering that relies on Law's (1994) categorisation of administration, enterprise, vision or vocation but enactment through disability in the "ordering of normal, lack, fate and passion". Moser (2005) identifies the ordering of perceptions and opposes categorising them as management arrangements.

Additionally, Moser (2005) uses the "ordering of normal" as a category to the other modes and claims that actors move between different modes as they co-exist and are partially related. In her terms, modes are not only categorisation of organisations, but also ordering of ways of life that are classified by feelings and overlap with other modes; they are multiple and dynamic. Another example for the extension of ordering is given by Gottweis and Lauss (2012) where their use of ordering is as a strategy to pattern a network of interaction between biobanks and associated organisations for evaluation of failures and success.

Critiques made claim that "modes of ordering" do not clearly define useful explanatory or interpretive categories and they do not reveal how Law (1994) moves from observation to abstraction and back (Gerson, 1995). Others warn of the reification of abstract metaphors from field concepts (see for example, Czarniawska-Joerges, 1996). However, Czarniawska-Joerges (1996) commends Law on the step beyond positivism and grounded theory. The idea that human and nonhuman actors are connected in a network that forms and creates a scientific practice that interests me. Mol (2010) defends "modes of ordering" and ANT by stating that it is a repository of terms and modes which describe what is going on. These modes are unpredictable and flexible in what deserves concern or care, strength in adaptability and sensitivity to underlying cases and stories. They draw contrasts, articulate silent layers and turn questions upside down.

Moser's approach of ordering based on conceptions describes involvement as a process of ordering in multiple and overlapping modes. However, a further issue is the multiplicity of field sites that generate this "interface". The problem with an "interface" or a relationship between systems biology and Chinese medicine requires at least two partners to co-operate. Thus, if actors are Chinese medicine researchers and systems biologists, they incorporate the knowledge of both sides and do not need to co-operate with each other to gain the others expertise. Different ways of involvement suggest that various networks have been established in different sites worldwide. The idea of a "heterogeneous network" or multiple networks offers an understanding of multiple and various actors which are connected to one network. Latour (1987) describes networks as a collection of information, scientific results from other scientists, politicians, industries, collaborators, students, leaders, supporters, clinicians and scientists which are embedded in the structure, power and organisation. Law (1997) distinguishes three types of heterogeneity: materiality, alterity (being different) and fractionality (not singular, something different, which is more than one). Moreover, various parts of networks are juxtaposed into a patterned network to overcome resistance - of a material or an organising and ordering matter of materials – through complex engineering of fitting together social, technical, conceptual, textual and convert (translate) them into a set of equally diverse scientific practices (ibid).

This study questions the emergence and nature of this "interface", which includes a historical component, which observations cannot cover. Latour (2013) and Law (1994) agree that ANT and anthropology are deeply intertwined through the use of ethnography, which offer a method to look beyond dichotomies of us and them and nature and culture. In a later paper, Law (2012) confirms and adds that "modes of ordering" are a set of threads that are entangled in the ethnographic practice. However, the way we collect data in fieldwork and how we look at things and pose questions is more like a method rather a theory (ibid, p. 11). Kim's (2009) successful combination of multi-sited ethnography with STS theory of global assemblages provides the necessary method to extends the range of networks as seamless terrain to multiple terrains and to multiple sites. Hence, multi-sited ethnography and "modes of ordering" might serve as a useful tool set to detect this "interface" through scientific publications of actors in this "interface" and by following them in their workplaces.

2.4 CONCLUSION

In line with the research aim and objectives, this chapter has reviewed anthropology and STS scholarly efforts in the areas of traditional medicines, biotechnology and actor-network theory. The anthropological perspective on traditional medicines is valuable for this research, as anthropology's toolset enables insights into traditional medicine, biotechnology and genetics. Medical anthropologists often employ STS concepts to acquire in-depth understanding beyond colonialism and dualism, and STS scientists apply ethnography to research scientific processes in real time (Hackett et al., 2008). Multi-sited ethnography and "modes of ordering" on the agency and interactions of humans and nonhumans and the move beyond the single-sitedness of laboratory studies, propose interesting conceptual and methodological instruments. This combination facilitates this research project with lenses to view multiple perspectives of the emergent "interface" by tracing human and nonhuman actors of various sites in a complex network of collaborators both from industry and public sector and state (i.e., government, funding agencies, academia, as mostly being partly supported by governments and federal money). Thus, the combination of multi-sited ethnography with "modes of ordering" will be the methodological framework of my study which concerns the emergent "interface" between systems biology and Chinese medicine in multiple sites worldwide. The methods of this thesis will be elaborated on in the following chapter.

3. RESEARCH METHODS

This chapter will discuss the methods best suited to investigate the emergent "interface", which was the arising phenomenon of a relationship between systems biology and Chinese medicine in the 2000s. In order to outline how human and nonhuman actors have generated this relationship between two different disciplines as well as to identify actors and their backgrounds, a methodological triangulation is proposed. In the following, I will provide an overview of the methodological triangulation followed by an outline of key methods applied in three main stages, namely: literature survey, participant observation, and episodic interviews. The last section will contain data analysis, data presentation and ethical issues concerning the research process.

3.1 METHODOLOGICAL TRIANGULATION

In order to address the research questions of is there an "interface", what is the nature of it, how did actors become involved and how did it develop I have decided to employ the methodological triangulation by Flick (2014). A triangulation combines different research methods and information sources to gain saturated data of multiple fields and its dynamic from diverse stories. Flick (2014) defines three stages: taking a sample through a literature survey, analysing relationships and interactions between human and nonhuman actors and sites, mapping those actors and sites to case studies. I will adapt these steps to: (1) literature survey, (2) participant observation and (3) episodic interviews in the field sites and to relate them, and (4) data analysis and presentation. These methods will facilitate a systematic comparison to investigate relationships, partners and topics for co-operation, and will reflect on tensions within groups that shed light on the development of this new phenomena.

3.1.1 LITERATURE SURVEY

In order to identify the nature of the arising relationships between Chinese medicine and systems biology, I conducted a secondary scientific literature survey by following references. The first article I found was by Scheid (2014) on *Convergent Lines of Descent: Symptoms, Patterns, Constellations, and the Emergent Interface of Systems Biology and Chinese Medicine.* Scheid (2014) claimed that an "interface" between Chinese medicine and systems biology was emerging and calling for further ethnographic investigations on this "interface". In this article, Scheid refers to the Chinese scientist Shen Ziyin 沈自尹(2005) who concurrently with a group of scientists in the Netherlands (Wang et al., 2005) discussed the possibility to bridge Chinese medicine and Western medicine with systems biology. Scheid's article and the others will be discussed in more detail in Chapter 4. A further search on articles written and published since 2005 supported this claim of a contact between Chinese medicine and systems biology. The search contained the words "systems biology" and "Chinese medicine" in the title and was conducted in the databases Web of Science (see Figure 1). The findings revealed that between 2005 and 2018 a total of 229 publications (141 articles, 73 reviews, 8 proceedings papers, 5 editorial material, 1 letter, 1 meeting abstract) were published with a highpoint in 2012 of 41 publications (see Figure 1). An evaluation of the citations per year demonstrates that the attention on this topic rose from 4 citations in 2004 to 552 in 2012 (Web of Science, updated 23 January 2019).

FIGURE 1: PUBLICATION NUMBERS ON "SYSTEMS BIOLOGY" AND "CHINESE MEDICINE" FROM 2005 - 2018

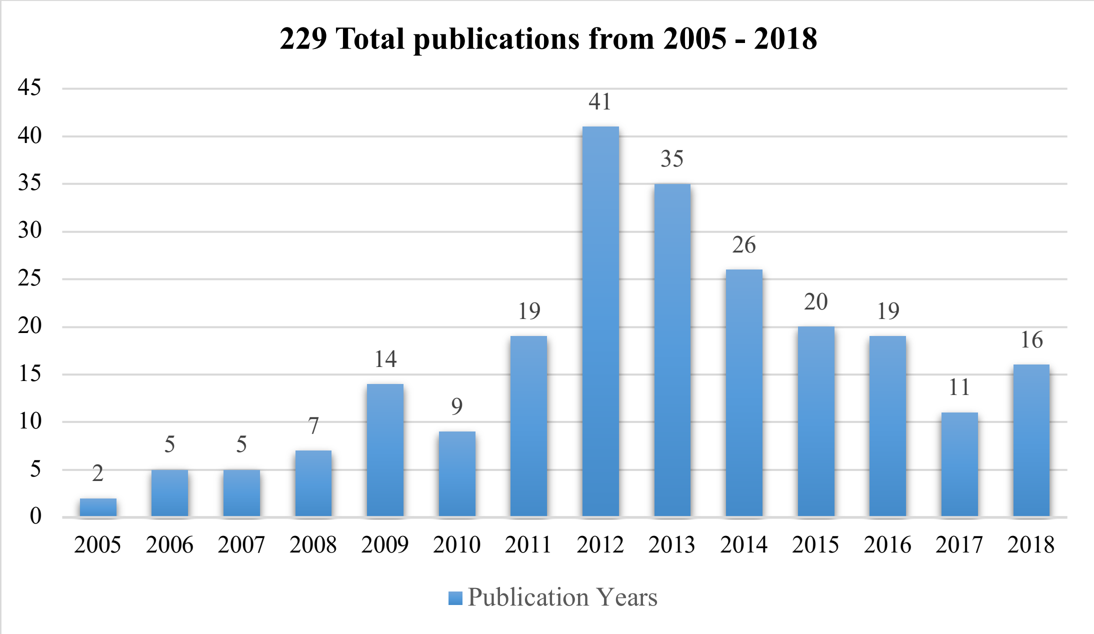

Figure 1: Web of Science statistic on publications from 2005 to 2018 on "Chinese medicine" and "systems biology", which indicates the starting point in 2005 and the peak in 2012 with 41 publications (y=number of publications, x=year) (Source: Web of Science, updated 23 January 2019).

Research on the publications in 2012 demonstrated that many of the articles referred to the "Special Issue" of the *Journal of Ethnopharmacology* in 2012. The Special Issue contained the results of a three-years funded (2009-2011) project by the European Research Commission (ERC) during the Framework Program 7 (FP7) to investigate scientific methods to study and regulate Chinese medicine (Web of Science, 2018). By tracing the ERC TCM consortium to the first scientific publication on systems biology and Chinese medicine, I discovered that Wang Mei, a molecular plant scientist in the Netherlands, and her colleagues, published an article on Metabolomics in 2005 on the context of systems biology bridging Traditional Chinese Medicine and molecular pharmacology (Wang et al., 2005). The article was printed in the *Journal for Phytotherapy Research* and up until 2017 it had received 148 citations. Jan van der Greef and colleagues have written the later publication *Systems biology-based* *diagnostic principles as pillars of the bridge between Chinese and Western medicine* in the *Journal Planta Medica* (van der Greef et al., 2010). Authors of the TCM consortium and in this field cited these two articles as the groundwork for this "interface" (Uzuner et al., 2012; Scheid, 2014; Luo et al., 2012b; Buriani et al., 2012; Verpoorte et al., 2009). The citations deliver another indicator for a relationship between systems biology and Chinese medicine. It also suggested that the first relationships emerged in the early 2000s and peaked out in 2011 and 2012.

The literature survey provided an overview of the multi-dimensional context under investigation and set up a timeline of the relationships between systems biology and Chinese medicine. However, these articles did not reveal how the interest and the connection between the actors in those two fields were set up before 2005 and developed after the first publications. In order to uncover those stories behind the scientific papers about this what Scheid (2014) calls "interface", I employed field research. The selected methods to investigate the "interface" were participant observations and episodic interviews. These methods supported me to collect data in the field about the human and nonhuman actors, the development of relationships between them, and to find meaningful relations, perspectives and intentions of actors that participated in generating and shaping this "interface" from the beginning.

3.1.2 Participant observation

In this section, the data collection through participant observation will be described.

The literature survey provided a list of key persons for participant observation. They were selected because of their participation in establishing relationships and collaborations and due to their research studies and their research discipline. These key persons were contacted to gain access to their labs for observations.

Participant observation served as one of the three data collection methods (besides literature survey and episodic interviews) for this research. First-hand observations are one of the main methods typically used in ethnographic studies as they facilitate a flexible approach to study human and nonhumans, i.e., technology and material in their natural environment (Marcus, 1995; Latour, 1987). Participant observation is a responsive tool to investigate an uncertain phenomenon by shifting interest as the researcher encounters the unexpected (Boellstorff et al., 2012). Similarly, Fusch, Fusch and Ness (2017) have advocated that in participant observation the researcher becomes the data collection instrument due to the role as observer and interactor with members in the field. In order to perceive how the "interface" unfolded in the field by understanding their experiences in and perspectives on this "interface" participant observation is a feasible method.

In my participant observations, I decided to use the regular and traditional method of paper and pencil, rather than using new gadgets such as a smartphone or a tablet. The traditional notebook was more useful as I was able to write in unexpected situations, which made using a notebook and pencil in the field more flexible. A laptop with all its extras such as cables would have been too heavy to carry around. Additionally, in settings outside of a laboratory, it would have attracted the unnecessary attention of the patients, for example, if I had used a laptop in the TCM hospital in China, the patients would have been more distracted by it and this would have inevitably disrupted my observations. Moreover, I found that paper was more reliable especially as it meant there were not any issues with battery life, and I was not faced with technical issues.

I decided against what Tricia Wang (2012) calls "life fieldnoting", which is a blog post on any social media that makes the research traceable and transparent. "Life fieldnoting" is similar to the social media Twitter in that you can post a photo and add one to five sentences, which presents at the end of the fieldwork a "thick description". Wang also used "life fieldnoting" as a digital footprint that enabled people to locate her position in case of emergency. However, I found the approach with photos and note taking in the form of short sentences on the mobile phone feasible and employed it to take pictures, or I used this method in situations where I had no notebook.

The study of Hein, O'Donohoe and Ryan (2011) confirm that mobile phones are popular in ethnographic work. However, I found that in the lab, the use of smartphones was tricky as the touchscreen did not react with the latex gloves; thus, it was to record my thoughts and observations in a notebook. Apart from that, laptops were not allowed in labs due to the chemicals and gears the students used. Consequently, I used eight A6 notebooks, which fitted in the pocket of my lab coat and were light when travelling.

Field sites (see Table 1) were located in the UK (Oxford), the Netherlands (Leiden, Zeist), Austria (Graz), China (Harbin, Dalian, Hangzhou) and Japan (Tokyo). Field research was conducted for four months in 2015 and seven months in 2016 (see fieldwork schedule in Table 1). The number of sites amounted to 11, including Chinese medicine pharmaceutical and pharmacokinetics[17] laboratories, hospitals affiliated with Chinese medicine research institutions, systems biology and metabolomics research institutes, as well as one acupuncture research institute. I undertook "probes", which are short field trips of 1-3 days to each site. They were this length due to lab restrictions but were long enough for me to get an overview of the research site. The probes followed the example of Sunder Rajan's study in Silicon Valley and India (2002). For the probes, I went to Leiden, Zeist, Oxford, Tokyo and Graz. Following on from these, I conducted intensive short-term participant observations, which are common in multi-sited ethnography as I discussed in Section 2.2.2. These were longer field research periods of 1-2 months at each site. For my research, I went to Harbin, Dalian and Hangzhou (see fieldwork schedule in Table 1).

My observation schedule followed a two-stage process (see Table 1). First, I conducted fieldwork in Europe, then in China and Japan. The actors I observed were nine doctoral students (Year 1 to Year 3) in laboratories, five Chinese medicine practitioners in hospitals, and five scientists in their labs and offices. At the Chinese metabolomics and the Chinese herbal plant medicine research site in Harbin, I was able to gather in-depth data in the lab. I observed twenty students and scientists who I selected due to their publications I always contacted them before my fieldwork. Only at the Harbin site, was I assigned by the head of the department to spend most of my observation time with one student. However, in other sites I was allowed to freely follow any student or scientist in the lab. During my observations, I had conversations with the scientists, I observed and followed them in their daily work in their labs and in their workplaces.

[17] Pharmacokinetics is a branch of pharmacology that studies the dynamics of drugs in the metabolism by using omics techniques (Rajan, 2003).

Table 1 summarises the time and duration of my visits to field sites as well as what I observed in the field. During my observations from all eleven field sites, I took extensive unstructured fieldnotes, photos, photocopies and collected pamphlets, magazines and books, which I used for my data analysis (see Section 3.2).

TABLE 1: THE FIELDWORK SCHEDULE

Where?	Time & Duration	What observed?
	1st stage of fieldwork	
TCM research in Graz, AT	June 2015, 1 day	Chinese herbal medicine, acupuncture research unit
International Conference on Health, Healthcare and Eco-civilisation at the London South Bank University, London, UK	September 5-6, 2015 2 days	Latest research on Chinese medicine and systems biology, Gaining access to Chinese metabolomics, Harbin field site
Research Council for Complementary Medicine - Demonstrating the value of Integrative Medicine, London, UK	September 10, 2015 1 day	Discussion on research results and evidence base for integration of Chinese medicine, showcase new initiatives in provision and policy and funding issues, Gaining access to *in vitro* fertilisation field site
Chinese medicine diagnosis project, Leiden, NL	December 2015 2 days	Laboratory and technology observations Chinese medicine practitioner, workshop
Cardiac project, University of Oxford, UK	January 2016 1 day	Research leader of cardiac disease project
	2nd stage of fieldwork	
Chinese metabolomics research, Harbin, CN	April-June 2016 2 months	Wet laboratory experiments on Chinese metabolomic research, Chinese medicine consultations, Blood and urine sample collection in hospital
Lipidomics research, Dalian, CN	June-July 2016 2 months	Wet laboratory experiments
Medicinal plant garden	August 2016 1 month	Observation in medicinal plant production
***In vitro* fertilisation (IVF) project, Hangzhou, CN**	September 2016 2 weeks	Chinese medicine practitioner, consultations
Fast examinations kit, Hangzhou, CN	September 2016 2 weeks	Wet lab experiments, systems biology research only
Artificial intelligence, Tokyo, JP	October 2016 1 day	Visit to systems biology institute, systems biology research only

Table 1: The Fieldwork schedule describes places, time and duration as well as the objects of observation at the field sites between 2015 and 2016.

During the fieldwork, I regularly consulted the literature to identify and contact further actors. More actors and sites were identified through "snowballing", which Helfferich (2005) describes as recommendations of gatekeepers to further actors in the field. Further identification sources of actors were websites such as researchgate.com, academica.edu and linkedin.com. In addition, I attended conferences, i.e., the International Conference on Health, Healthcare and Eco-civilisation, London South Bank University from September 5-6, 2015 and the Research Council for Complementary Medicine - Demonstrating the value of Integrative Medicine, September 10, 2015 to approach further systems biologists and Chinese medicine researchers and to gain access to their laboratories.

Table 2 provides an overview of projects, funding, timeframe and co-operation partners of their projects. Some actors denied fieldwork in their site as they either had insecure financial status for the research site or conducted high-confidential research projects. The names of all projects and informants (interchangeably used with actors) in this thesis were anonymised to preserve confidentiality and to capture the research focus with a simple designation (see Section 3.2.1 on ethics).

TABLE 2: DESCRIPTIONS OF FIELD SITES

Ethnographic sites				
Project	**Brief description**	**Timeframe and funding**	**Partner organisations**	**Thematic priority**
European Research Council (ERC) TCM project	ERC networking & coordination project with China for best practice, safety and efficacy of CM	09/2009 - 05/2011 € 1.1 million	200 members (13 EU, 6 Non-EU states), 120 institutions in 24 countries; 10 research groups in quality, efficacy, safety research in CHM and acupuncture	CHM and acupuncture
CM diagnosis	SB to study Chinese medicine hot and cold pattern diagnosis	2007 - 2013 KNAW industrial funding	2 partners in 2 countries: 1 SB laboratory, 1 metabolomics institute, 1 plant research co-operator, 1 CHM research university lab, 1 CM university department, ERC consortium beneficiary member, 1 spin-off company	SB, new perspectives on health, life and medicine; metabolomics research
Lipidomics research	CM drugs, efficacy on lipids	2007 - 2012 NSFC, MOST	2 partners in 2 countries, 1 SB laboratory, 1 metabolomics research institute, 1 plant research department, 2 university labs, technology producer	Lipidomics, CM drugs, efficacy

Chinese metabolomics	Metabolomics study on CHM	2005 - 2015 NSFC, MOST, industrial funding	1 Confucius institute 2 research institutions, 1 technology producer, industrial partners, ERC consortium non-beneficiary member, 1 hospital technology producer	*In vivo* studies on CM formulae and acupuncture
Acupuncture research	Acupuncture points investigation with biotechnology	1999 - public funding industrial sector	1 university lab, 4 research partners, ERC consortium non-beneficiary member	Acupuncture studies, biotech research
Fast examination blood serum diagnostic kit	SB study on biomedical diseases	2009 - 2016 NSFC, MOST	3 research institutes, 2 university labs, industrial partners, 1 spin-off company	SB research for fast diagnostic kits, lab kits for blood serum for specific diseases
TCM research	CHM and acupuncture research	2006 - 2015 Future Fond Styria € 300.000 2 university funding	2 university departments, 1 network organisation, ERC TCM consortium non-beneficiary member	CHM and acupuncture, Chinese co-operation
***In vitro* fertilisation (IVF) with CHM**	IVF complimented with CHM to promote fertility	2009 - 2016 MOST NSFC public funding	1 hospital, 1 university lab, ERC consortium beneficiary member	CHM to recover and restore fertility
AI and CM	AI and biomedicine and recently interest in CM and Kampo	2002 - 2007 public funding industrial funding	2 research institutes on SB, 1 disease modelling institute, 2 university labs, industrial partners	SB, disease modelling, AI diagnostic machines

Table 2: A description of the selected ethnographic sites and their projects themes, which were except of AI linked to the ERC TCM consortium.

Abbreviations: Systems biology (SB), Chinese medicine (CM), artificial intelligence (AI), Ministry of Science and Technology (MOST), Royal Netherlands Academy of Arts and Sciences (KNAW), Chinese medicine (CM), systems biology (SB), artificial intelligence (AI), Chinese herbal medicine (CHM) and in vitro fertilisation (IVF).

The field sites were selected according to the key persons that I identified during the literature survey. I contacted these key persons for an enquiry about their involvement and experiences in this "interface" between Chinese medicine and systems biology (see Table 3). Their leading roles have rendered access to essential information about their own projects and the historical process of this "interface". They also provided information to other actors and sites working on Chinese medicine or systems biology. Actors were mostly related to the European Research Council Traditional Chinese medicine consortium (ERC TCM) as the ERC project aimed to identify scientists and researchers working on Chinese medicine and systems biology. Thus, the four key informants (see Table 3) were identified as "gatekeepers", i.e., "actors with control over key sources and avenues of opportunity" (Hammersley and Atkinson, 2007, p. 34). Hammersley and Atkinson (2007) describe gatekeepers as people connected with other actors who established themselves as contact or information points. Thus, a gatekeeper was the first person to contact for the coordination of the research and the communication between two or more sites as well as they decided with whom to co-operate. Hence, I decided to identify and approach gatekeepers first as they were well grounded in the field – which was seen in their publications – and had information about the historical process and individual perspectives on relationships between Chinese medicine and systems biology.

Table 3 lists the gatekeepers, their roles, involvement in projects and connections to further sites and actors. This table shows the four gatekeepers I identified through a literature survey and who I interviewed in my research. The table lists the role of the gatekeepers, the projects they were involved in and their Chinese medicine and systems biology research contacts, which are referred to or described in my thesis. Based on the information of these gatekeepers, I identified further actors and field sites in Chinese medicine and systems biology research.

TABLE 3: LIST OF GATEKEEPERS

Gatekeeper	Role	Project Involvement	Connection to other actors
Gatekeeper 1	Head of institute	CHM research TCM research association (2014-)	5 members of the ERC TCM consortium, 6 research program leaders: 1 head of a university co-operation network, 2 heads of acupuncture projects, 2 heads of CHM phytotherapy projects, 1 head of a Chinese medicine modernisation project
Gatekeeper 2	Team leader	SB for CM diagnosis project (CM diagnosis)	members of the ERC TCM consortium European Pharmacopoeia researchers 1 practitioner Chinese medicine researchers in China scientists in China politicians in China
Gatekeeper 3	Senior researcher	SB for lipidomics project (CM lipidomics)	2 heads of institution 4 principal investigators 1 collaborator of first CM/SB publication
Gatekeeper 4	Post-doc student	SB for CM diagnosis project (CM diagnosis)	3 members of the ERC TCM consortium 1 practitioner 4 researchers

Table 3: Gatekeepers, their role and connection to other actors in Chinese medicine and systems biology research. Abbreviations: Chinese medicine (CM), systems biology (SB).

Figure 2 shows the selected field sites. I narrowed the field sites to nine namely the ERC TCM project, Chinese diagnosis study, Lipidomics research, Chinese formula metabolomics, Acupuncture research, TCM research, *in vitro* fertilisation with Chinese medicine herbs, fast examination blood serum diagnostic kits and AI with Kampo.

FIGURE 2: THE FIELD MAP

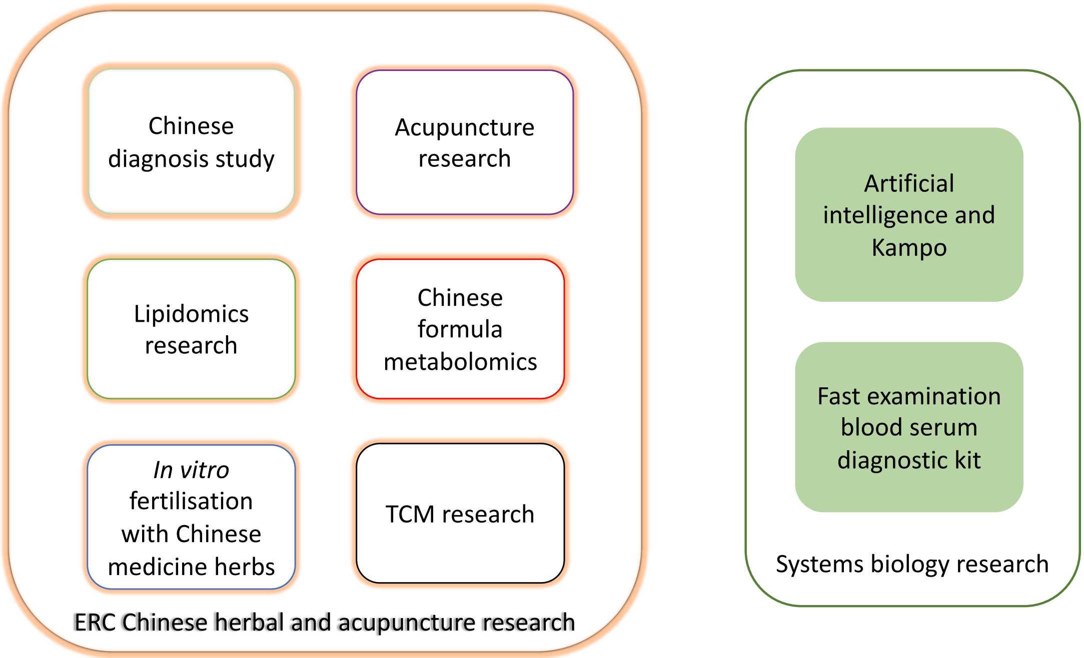

Figure 2: Field map of the observed research projects. Projects on the left were involved in the ERC TCM research while projects on the right focussed on systems biology and those only recently started to investigate Chinese medicine and Japanese medicine (Kampo).

The selection of the field sites was done by tracing research funding and co-operation partners of the ERC TCM project. This included a flexible approach in the field for changing sites or identifying new sites according to the restriction of access or new information gathered in the field. Thus, I applied a theoretical sampling as a procedure of sampling data after collecting and analysing a certain number of field site data that were relevant to the theory of the study (Flick, 2014). Coyne (1997) links analysis and decision processes together to make an impromptu decision for the next field site and for establishing a theory of the study. This theoretical sampling method assured both the comparability of the topics, the openness to other views as well as the organisation of field trips between the sites in Europe, China and Japan (see fieldwork schedule in Table 1).

For this research project, actors from seven of the considered field sites (i.e., the ERC TCM project, Chinese diagnosis study, Lipidomics research, Chinese metabolomics, Acupuncture research, TCM research, *in vitro* fertilisation) were participants in the ERC TCM research for investigating Chinese medicine regulation and research in European healthcare services. The Chinese projects (i.e., Lipidomics research, Chinese metabolomics, *in vitro* fertilisation and the fast examination kits) received funding from the NSFC (see Table 2 for project funding and Appendix A for NSFC funding details). The NSFC financed projects to modernise Chinese medicine with the omics techniques. The European Research Commission (ERC), which I will describe in detail in Section 7.3.2, supported the ERC TCM consortium with EUR 1.1 million, which financed the management project team, including the principal investigator of the *in vitro* fertilisation project. All other co-operating projects, such as the Chinese diagnostic project, the Acupuncture research project, the Chinese medicine formulae metabolomics project and TCM research project did not benefit from the funding but became consortium members (see Table 2 for detailed description of projects). The field map (see Figure 2) shows that two systems biology projects were not affiliated with the ERC TCM research. The reason for my choice to include them into this research was to learn about the perspectives of systems biologists on Chinese medicine research who only recently started to scrutinise traditional medicines (Chinese and Kampo). Next, I will discuss the network map.

FIGURE 3: THE NETWORK MAP

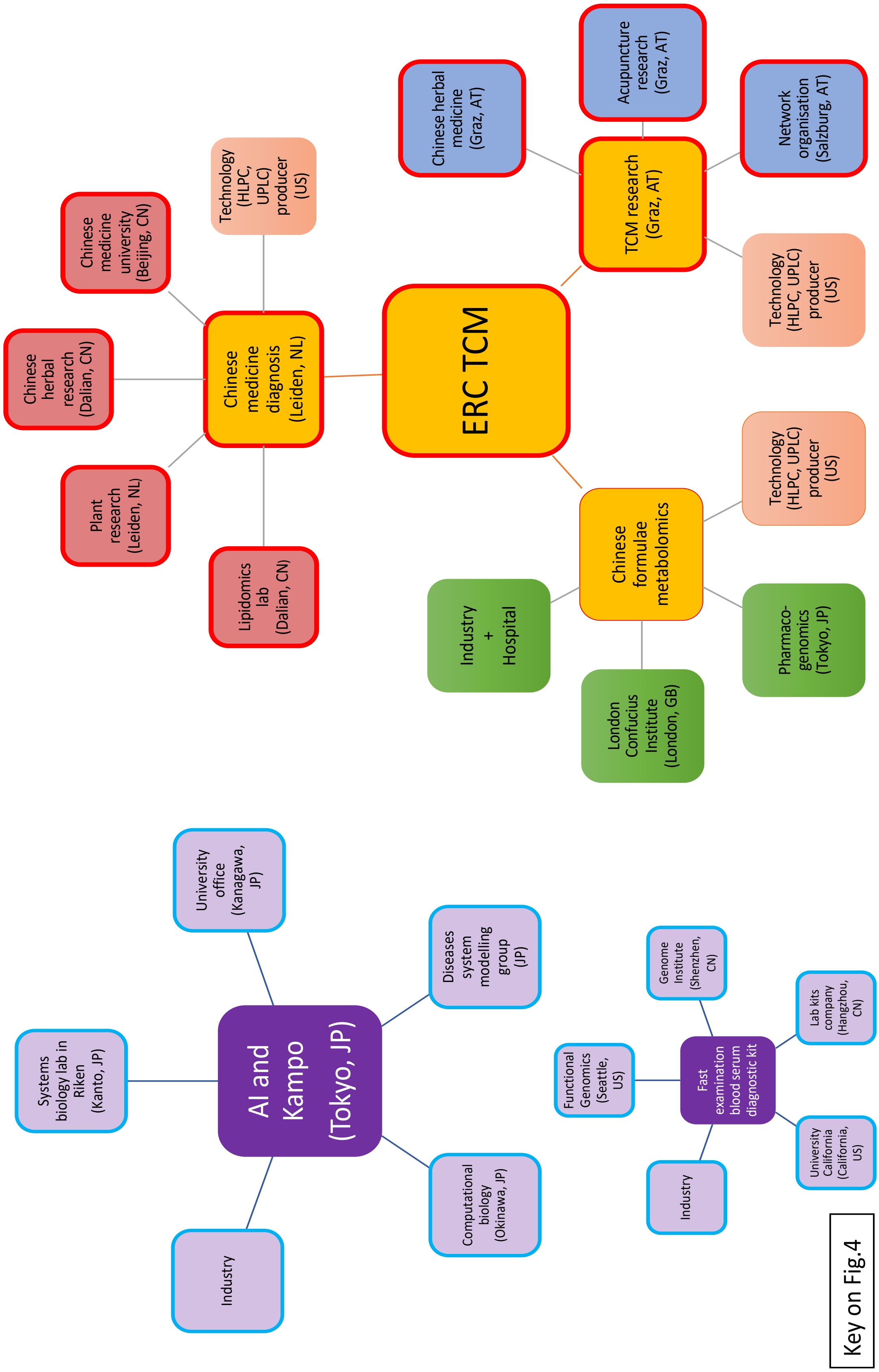

Figure 3: The network map expands on the field map (see Figure 2) and shows the relationships between the sites connected to the ERC TCM consortium's project, AI systems/systems biology and industrial partners. Orange fields with a red frame relate to the ERC TCM consortium, and the purple fields with a blue frame represent the separate network of AI and systems biology which observed systems biology and Chinese medicine research projects. Those without a frame stand for the partners, as indicated through the lines, who had no relationship to the ERC TCM. This network map informs the analysis on the relationship between Chinese medicine and systems biology which is shown in Chapters 6 and 7.

Abbreviations: HLPC means High Liquid Performance Chromatography; UPLC stands for Ultra High-Performance Liquid Chromatography and Kampo is a traditional Japanese medicine.

FIGURE 4: KEY TO THE NETWORK MAP

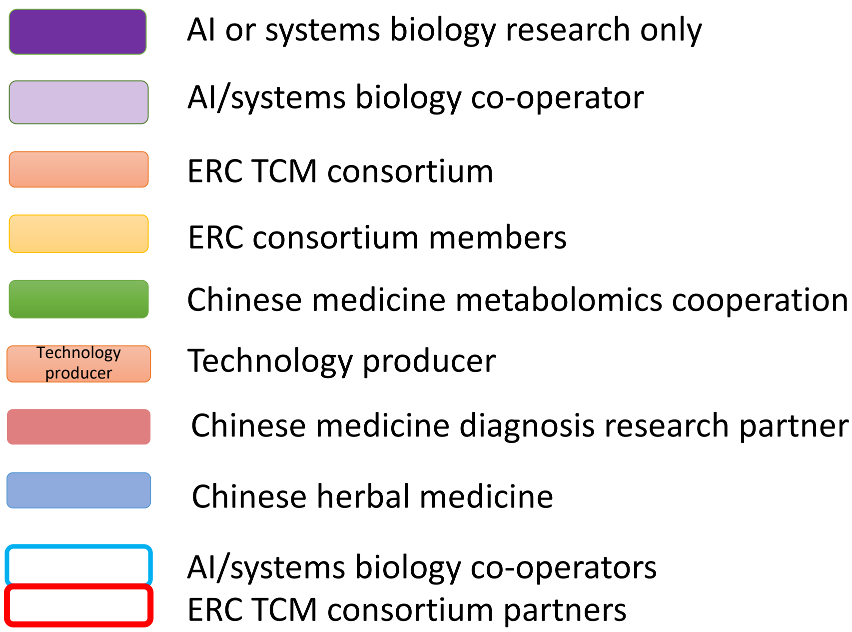

Figure 4: Key to the network map, the different colours depict the relationships between the identified sites in this research project.

Figures 3 and 4 depict how I analysed the relationship between the different sites, which I introduced in Table 1, 2 and Figure 2, to the ERC TCM and the separate AI/systems biology projects. This figure only includes the sites I will include in my analysis in Chapters 4, 5, 6, 7 and 8.

Compared to Figure 2, the network map illustrates the connections between the sites according to institutional affiliation, associations to research partners and industry. Figure 3 shows the connections between the countries involved in their research and how the actors and gatekeepers (see Table 3) were located for the projects undertaken. The network on the right side (in orange with a red frame) in Figure 3 represents the network of the ERC TCM, including the three projects that were involved in the project for the ERC TCM. These include the Chinese medicine metabolomics co-operation, the TCM research and the Chinese medicine diagnosis group. I will analyse the involvement of the actors in these projects and in the ERC TCM consortium, in more detail in Chapters 6 and 7. On the left side of Figure 3, the two AI/systems biology expert projects (the AI network and the fast examination kit network) can be observed. The AI/systems biologists involved in these projects did not participate in the ERC TCM consortium, but wanted to conduct Chinese medicine studies. Therefore, they are illustrated in a separate network. The next section will discuss the episodic interviews I conducted with the main actors in the field.

3.1.3 Episodic interviews

Episodic interviews are biographic-narrative interviews that invite interviewees to tell their life story about a specific period in their life. The third research question focuses on the actors' involvement and the development of the "interface" between Chinese medicine and systems biology. Sieder (2008) developed biographic-narrative interviews to investigate child abuse in boarding schools. The difference between episodic interviews and biographic-narrative interviews is that the episodic interviews focus on a specific period in the life of an interviewee and that does not follow the strict rule of first letting the interviewee tell his/her story, and then interviewer asks implicit questions for clarification (i.e., questions directly addressed to the information given in the narrative). Subsequently, the interviewer asks explicit questions (e.g., concerning any other interest that was not covered) (ibid). In the episodic interview, Flick (2014) propose the interviewer to ask open-end questions to further stimulate a narration from the interviewee.

Flick (2000, 2014) claims that the significant advantage of using episodic interviews is its strength of gaining a rich and detailed narrative of actors in their personal and natural voice. The actors talk not only as scientists or professionals but also as participants in a free and more associative narrative on their experiences. This approach facilitates to discover what led to the decision to turn towards holistic research paradigms systems biology and Chinese medicine in co-operation with Chinese or European partners. First, the understanding of the involvement of scientists in this research granted insights into the development of their participation in Chinese medicine and systems biology research. I invited my interview partners to tell a story, e.g., "Can you tell how you became involved in systems biology/Chinese medicine research?" or "Can you tell me how you became an expert in systems biology?" This method enabled me to build a rapport and to give the interviewees enough space to expand on their stories. Building rapport is crucial for interviews to gain the trust and sympathy of students and researchers to tell their stories (see, for example, Berthin, 2014). In the dynamic of the narration of selected periods in the life of the actors, unexpected things evolved. For example, some informants started to talk about key moments in their lives, which encouraged them to investigate Chinese medicine. Interviewees described changes in their lives. Those changes were what Sieder (2008) calls transitions as key happenings in the life. Thus, it became clear that the actors opened their mind to Chinese medicine following a transition. Secondly, to understand the present situation for the participants, I asked them for instance, "How do you position yourself in the field of systems biology and Chinese medicine research?" This question had the purpose of challenging the broadly defined field of systems biology and to understand why some actors in this "interface" have written differently about it. Therefore, by asking them to explain their position in the field, they could refine systems biology and Chinese medicine without any judgment from me as a researcher or any other scientist like collaborators or critics. Hence, the interview setting provided enough space for interviewees to tell their experiences in open dialogues but within the frame of my questions. The last question in my interviews followed Flick's (2014) suggestion of asking the informants if they wish to add any information.

Personal interviews with actors on a one-to-one basis were considered favourable for the thesis compared to group interviews since the time to unfold personal views and interpretation of this the term and nature of this "interface" and the space for a certain level of confidentiality and trust were required and established (Flick, 2014). Moreover, the individual setting allowed me to interact with the interviewees and to acquire a substantial and profound material (ibid). The mix of an active and passive interviewer role to listen to the interviewee's story and to ask questions throughout the interview process rather than at the end avoided a one-sidedness of a solely narrative interview. Consequently, it generated a conversation between the researcher and the interviewee, which makes Flick' (2014) episodic interview different to Sieder's (2008) biographic interview.

In 2015, test interviews were conducted before entering the second fieldwork stage (see Table 1 for fieldwork schedule). During the test stage, the researcher is given the opportunity to trial the proposed questions and discover more about the research field (Flick, 2014). In this phase, I used semi-structured interviews with a topic guide that covered central questions (see Appendix B). After I had conducted four test interviews and undertaken a first analysis of the data to evaluate the method, data depth and further interview partners, as suggested by LeCompte and Goetz (1982) and Flick (2014), I recognised that those test interviews offered valuable traces to the historical process and were intertwined with life stories. The life stories could not be gathered through the short question-answer process of semi-structured interview as the intention was set differently at the beginning of the interview. As a result of this evaluation, interviews were adapted with a focus on scientists and their personal experience and involvement. Semi-structured interviews use open questions; however, they are limited in the space to develop a narrative about a significant period in the life of an interviewee (Flick, 2014). While in the episodic interview the interviewer opens with the question that addresses a specific period and let the interviewee tell the story until a further question emerges or fits into his narrative. With this approach, a broader spectrum and more in-depth information can be gathered. Thus, a change from semi-structured interviews to episodic interviews was undertaken.

Throughout the project, I carried out episodic interviews with fourteen actors. Interviewees included Chinese medicine pharmacognosists [18] (3), chemists (2), molecular biologists (2), systems biologists (3), Chinese medicine practitioners (2), and industrials (2). They were post-doctoral students, senior researchers, assistant professors and professors. Most of the scientists, I interviewed in the workplace and three interviews have been carried out via Skype. However, Hammersley (2006) has argued that the limitation of interviews is that interview data alone are not ethnographic. Thus, interviews served as a supplement to participant observation, which I described in the section above.

The episodic interview method supplemented the literature survey with, what Kvale (2006) argue, subjective experiences and personal views and meanings of actors' life situations. This perspective provided a look behind the publications of actors, which was crucial to understand the actors emerging interest in Chinese medicine or systems biology. The interview data revealed the development and change of relationships between the Chinese medicine and the systems biology side. The interview method was a flexible and powerful tool to investigate research questions with immediate relevance to the everyday work of actors (Britten, 1995).

[18] Pharmacognosists study natural products from organisms such as plants, microbes, and animals. Their research area includes traditional medicines (see Orhan, 2014).

3.2 Data analysis and presentation

This section will talk about the data analysis methods used. Thematic coding as explained by Flick (2014), was selected in this thesis as an appropriate tool to analyse data gained through a triangulation of methods (participant observations, interviews and literature survey). It is a reasonable technique as it aims to present the data in specific themes, relationships and periods, which seemed significant for answering the research questions of this research.

The thematic coding used in this thesis followed the procedure by Martini, Massa and Testa (2013). Martini, Massa and Testa (2013) describe the coding of data as a gradual refinement by investigating specific sets of data, i.e., interviews, observations, first to generate broad categories. These broad themes are then analysed again to refine them into more detailed codes. The data from the literature survey was analysed in broad categories. Subsequently, the categories were refined according to the rhetoric used to present the research of Chinese medicine with systems biology to the public and to attract the scientific community, as well as, political interests and instalments for funding.

The results of the thematic coding will be presented in Chapters 4, 5, 6, and 7. The third step was to read the empirical data through the lenses of "modes of ordering" (Law 1994) which will be presented in Chapter 8. This analytical tool helped identify the emergence of this "interface" over time. It was used to categorise meanings of the different actors and their perceptions of the term "interface" from their work and their involvement in the research of Chinese medicine and systems biology or research projects.

The interview and observation materials of this study were first analysed using the broad categories of (i) "interface" and the emergence of similarity between Chinese medicine and systems biology, (ii) involvement, (iii) laboratory practice, and (iv) networking and politics. In the refinement round of the coding, all data in the categories was split into coded segments, and the detailed codes were (a) definition of this "interface", (b) Chinese medicine, and (c) systems biology (these will be elaborated on in Chapter 4). Chapter 5 will show four different types of involvement through (a) technology and health, (b) complexity, (c) family and exploitation and (d) the discontentment with research practice. The codes in Chapter 6 will refer to (a) research projects, (b) technology, (c) industrial ties. Finally, Chapter 7 will present (a) political networking, (b) Chinese medicine studies, and (c) funding and regulations.

Data on the emergence of an "interface" between Chinese medicine and systems biology and the similarities and difference to past encounters between Chinese medicine and modern science will be presented in four chapters according to the development of interest in Chinese medicine and systems biology studies. These chapters will demonstrate different perspectives and research sites in the world on this "interface". Each chapter will initially introduce the setting and the actors with quotes and ethnographic descriptions to provide the reader with a global picture. The collected samples as represented in Chapters 4, 5, 6, and 7 are an extract of the global, diverse and vast networks. Some segments will offer a brief analysis of the data. An overall analysis will be presented in Chapter 8. This chapter will categorise the coded data of Chapters 4, 5, 6, and 7 and view it through the lenses of the concept "modes of ordering".

The interviews were either conducted in German, English or Chinese, depending on the wishes of the actors. The interviews and field notes for the analysis were transcribed verbatim (Hammersley and Atkinson, 2007). The specific segments that represented episodes relevant to the research questions were translated into English for common understanding. In order to transcribe, analyse, apply thematic coding and interpret the data, I used the computer assisted qualitative analysis software (CAQDAS) NVivo 10 and 11. It was expedient to organise different kinds of data and the enormous amount of materials I collected (e.g., publications, papers, articles, brochures, images, field notes, and audio recordings).

3.2.1 Ethical considerations

Following the ethical guidelines issued by the ethics committee at the University of Westminster, privacy and confidentiality were respected throughout the research process. Before every observation and interview, actors were informed about the aim of the research and the nature of the study was clearly explained to them. Requests were made for them to participate in the laboratory and workplace observations and interviews, as well as audio recordings and photographs on a voluntary basis. They were provided with copies of Participant Information Sheets (Appendix C) and Consent Forms (see Appendix D) on the day of the first observation or interview. For those who denied an audio recording, informed consent was given to use field notes without disclosing information about their identity. Signed or oral consent was obtained from all participants before the commencement of the study. Participants were provided with the right to withdraw until 1 January 2017, without giving a reason.

Sieder (2008) warns that episodic interviews can cause a psychological effect for both the interviewer and the interviewee as they uncover a hidden narrative. Therefore, all participants were assigned pseudonyms that only share the academic title, i.e., Prof or Dr, in order to ensure the confidentiality of their identities (Flick, 2014). Project names were anonymised with fictional names following the example of Callon and Law (1982, p. 616) by using, for instance, the pseudonym of “Chinatown” for a British group of biochemists or “Stiftung” for a German team of polymer chemists.

3.2.2 Reliability and validity

In order to achieve valid and reliable results, methodological triangulation was used. As this thesis is an ethnographic study, it was difficult to detach myself from the study and be objective. LeCompte and Goetz (1982) indicate that perfect objectivity cannot be granted during ethnographic studies, as they record processes and actions, while they are happening in a natural setting as observed by the researcher. Ethnography is not a designed experiment that allows an exact replication of the situation. Thus, LeCompte and Goetz (ibid) claim that complete reliability and validity is impossible in ethnography. However, they agree that a triangulation of methods increases the validity and reliability of data. Likewise, Bauer and Gaskell (2007) argue that triangulation is an excellent method used to validate data by reflecting on an event from various perspectives (i.e., interviews, observations), which decentres one's own person for reflexivity and thick description. Marcus (1995) claims that the description of ethnographic data delivers a certain amount of validity and offers the authenticity of the theoretical elaboration which often appears in the second part of the study, which in this thesis is presented in Chapter 8.

A mixture of methods can also highlight inconsistencies. Flick (2014) warns that inconsistencies arise either from methodological limitations or the different angles the researcher takes to look at a phenomenon of interest. Inconsistencies will be attained in this thesis, which might appear between the data of the literature survey and interviews. For example, inconsistencies might be different descriptions of this relationship of an "interface" or match, incomplete historic background information from interviews, or between statements of actors in their texts and their narratives, or between the various publications of the actors. To this end, this thesis aims to recognise and complement inconsistencies with other methods. However, Burgess (2013) reminds us that sources of information are limited and that informants do not always get it right. In order to overcome these inconsistencies or having taken these inconsistencies into account, I opted to carry out a literature survey in order to add historical background information for the interviews. This was then followed up with interviews with the actors from the literature survey. The aim of the interviews was to gain personal narratives of the research that had been performed on Chinese medicine and systems biology as described in the literature. Once the interviews had been conducted, observations were performed to add first-hand data on the novel approach of systems biology to study Chinese medicine. The combination of the literature survey, observations and interviews was seen as the best methods to gain saturated and in-depth data about the event and to present valid and reliable data.

3.3 CONCLUSION

This chapter has outlined the research methods and described the research procedure in detail. A qualitative approach was adopted to fill a gap in the literature that called for an empirical investigation of the emergent "interface" between Chinese medicine and systems biology. Moreover, a triangulation approach of data collection methods will allow a comprehensive collection of data. The data from the literature survey will be supplemented with observations and episodic interviews. Observations are intended to capture interactions and technology in the field while interviews sought to record personal experiences, perspectives and historical processes. The data analysis will identify themes and the structure of themes and chapters to answer the research questions. The four Chapters 4, 5, 6, and 7 will give a fair representation of the various perspectives, experiences and processes in the "interface". Data validity and reliability will be achieved through the adoption of methodological triangulation. Finally, efforts will be made to ensure the ethical integration in this research process.

The next chapter will present the four finding chapters from the emergent "interface" between Chinese medicine and systems biology in the 1970s to the peak of Chinese medicine and systems biology publications in 2011/12.

4. RHETORIC AND PERCEPTIONS OF AN EMERGENT RELATIONSHIP BETWEEN CHINESE MEDICINE AND SYSTEMS BIOLOGY

This chapter will answer the research question “Is there an ‘interface’? and if so, can this latest contact between Chinese medicine and systems biology be referred to as an ‘interface’? and what is the nature of this ‘interface’?” The questions look to be answered with the use of a literature survey and episodic interviews which aim to identify the rhetoric in publications on this relationship and the perceptions of actors in the field.

I will first explain (i) the coining of the term “interface” between Chinese medicine and systems biology by examining the literature. Then, I will present the codes identified through a thematic coding of the episodic interviews that I performed. The two codes of the interviews reveal (ii) a perception of this “interface” and (iii) the sameness of Chinese medicine and systems biology. The second code of perceptions shows the interpretations of actors in the field of this relationship between Chinese medicine and systems biology as co-operation, molecules as the “interface” and technology as a bridge. The third code of sameness includes the definitions for Chinese medicine and systems biology. The fourth and last code (vi) the historical trace of the sameness is gained from a literature survey. Results from the literature elaborate on the development of systems thinking and holism as constructing a “sameness” of Chinese medicine and systems biology. The results of this code contribute to answering the question “How does this ‘interface’ differ from previous encounters between Chinese medicine and modern science and Western medicine?”, which will be analysed in Chapter 8. The results of this chapter and Chapters 5, 6 and 7 will be drawn together and an in-depth analysis of themes and coded data will be given in Chapter 8.

4.1 RHETORIC AND COINING THE TERM "INTERFACE"

As I pointed out in the literature review of this thesis (see Chapter 2), the term "interface" concerning the emergent relationship between Chinese medicine and systems biology in the early 2000s was first used in Scheid's (2014) paper on *Convergent Lines of Descent*. In this section, I will elaborate on his investigation of this "interface" and how it emerged.

Scheid (2014) argues that since the 2000s, having examined publications and interactions between Chinese medicine and systems biology, *zheng* seems to connect both sides and, thus, forms an "interface" between the two fields. Scheid argues that *zheng* is a boundary object that connects to distinct sides through patterns which both sides can understand and use for their communication without following the same aims for their co-operation, which I explained in Chapter 4. Scheid (2014) argues in his historical analysis that the "interface" was built on three pillars: shared ground, shared interest in personalised medicine and the dissemination of ideas through publications. First, he shows that systems biology and modern Chinese medicine have "structural commonalities and shared ideologies" of complexity and systems thinking (ibid, p. 115). Second, they share an interest in a "new" personalised medicine with *zheng*. "New", as far I understood, is opposed to the individual diagnosis and treatments Chinese medicine offered in the past 2000 years, which were in this "interface" newly deciphered with Chinese medicine and systems biology based on biotechnological tools.

The final pillar is the dissemination of publications by Shen Ziyin (2005). Scheid (2014) discovered that Shen researched Chinese medicine in the 1950s and 1960s and undertook the first metabolite research on Chinese medicine *zheng*, however, he could not illustrate the whole *zheng*. In 2005, he published a paper on systems biology and Chinese medicine as a bridge. Scheid (2014) claims that Shen's paper was taken up by a Chinese medicine researcher in Beijing, Lu Aiping (Lu et al., 2012), and by van der Greef and his colleagues (2010). He found that some of these papers claimed from a Chinese medicine perspective that *zheng*s were in Chinese medicine as a central element and that they connected Chinese medicine with systems biology. While the systems biologists in van der Greef's team interpreted *zheng* as a network or a system that was illustrated as a phenotype through metabolic fingerprinting. Scheid (2014, p. 122) highlights that the connection between Lu and van der Greef was that they established a method to "objectify" Shen Ziyin's unseen *zheng*, which he studied in the 1950s and 1960s.

In summary, Scheid describes this "interface" as a bridge between the modern West and ancient China. This is due to various actors in this "interface" who still perceived a gap between the West and China probably due to their "historical ignorance and arrogance" as Scheid (2014, p. 108) argues. *Zheng* is seen as a bridge between Chinese medicine researchers and systems biologists as it connects both sides, but they understand it differently and use it to achieve different goals.

Having established the origin of the label "interface" in the literature for the emerging relationship between Chinese medicine and systems biology, the interview performed on fourteen people will now be analysed. By analysing the data from the interviewees, I hope to reveal if there is an "interface". If so, what the nature of this "interface" is. On the contrary, if no "interface" is revealed, I hope to find out how the actors perceive the relationship between Chinese medicine and systems biology.

4.2 PERCEPTIONS AND DEFINITIONS OF THE "INTERFACE"

By turning now to the empirical evidence from the systems biologists, Chinese medicine researchers and Chinese medicine systems biologists interviewed on the topic of an "interface" between Chinese medicine and systems biology, it is hoped to discover whether it in fact exists or not. In the following, I will present representative examples of interview data that will demonstrate in three codes the perception of the "interface" or relationship between systems biology and Chinese medicine. The codes were (i) co-operation, (ii) biochemistry as a bridge and (iii) technology as a bridge. This section will outline the interpretation of the nature of this "interface" from the actors' view in more depth.

4.2.1 CO-OPERATION

Those interviewed who perceived the relationship between Chinese medicine and systems biology as an "interface", described its nature as a co-operation. They claimed that the co-operation was established for data and knowledge exchange. Other systems biologists shared this opinion and added that the co-operation with Chinese medicine researchers was crucial to receive samples for their studies and to compensate for the lack of Chinese medicine knowledge. As one actor said:

> "For example, one does not have a background in Chinese medicine and does not know the fundamental things. Then, another one has a Chinese medicine background. In co-operation, we can compensate what we do not know about Chinese medicine with the knowledge of the other. For example, we do not have samples, so we have to co-operate to get samples." (Lingma, 2016, Dalian)

Co-operation was closely related to the worldwide rise of systems biology institutions and training programs. However, the research of Chinese medicine with systems biology had not made the expected progress due to the lack of technology and understanding of systems and the attitude of imposing a Western methodology on Chinese medicine studies, as a systems biology expert added:

> “I think they try to do things together, but I think they don’t have much progress. People keep trying but I don’t see any good outcome from Chinese labs yet. But I think people have this philosophy or idea and trying to do something. We are waiting for the results. I think there is definitely an interface and I think this systems biology thinking or systems biology, this word, is becoming more and more practice or the word for this kind of systems biology approach may be for the students or PhD students and professors.” (Prof Meng, 2016, Hangzhou)

> “Because they measured and could not get anything interesting, I mean, it is not that there isn’t anything interesting, but they haven’t got what they expected. Because after the omics [genomics era in 2000] they tried to identify the active compounds, and that is not how things work here. That is the modern systematic network like they actually try to bring Chinese medicine into the Western deduction idea and that failed. Because it doesn’t function that way. And then there is a lot of interesting things in Chinese medicine and how we can use the network approach from systems biology to study it. I think we will have more papers on that.” (Prof Musashi, 2016, Tokyo)

The perception of an “interface” was defined as an attempt to establish co-operation between systems biology and Chinese medicine by interlinking them through expertise and materials. Besides the comments on the outcomes of this co-operation and the suggestions on a better approach for studies, they all agreed that there was an interface, and the nature of the interface was defined as co-operation between systems biology and Chinese medicine researchers.

4.2.2 Biochemistry as a bridge

A common view amongst actors was the description that biochemical information was a bridge between Chinese medicine and systems biology. For them, biochemistry was the language both understood and used to communicate and describe the study results. With knowledge of Chinese medicine, researchers and systems biologists in molecular biology, could both explain in detail what was happening at the lowest level of the body and use the molecular data to describe processes in healthy and diseased bodies as a whole. As one interviewee claimed:

> "There are a few publications where they try to understand the networks and the pathways. They are actually using molecular biology as a bridge. One side is like a pathway and a network, and the other side is TCM. They can identify which is the possible active compound and bring that active compound in combination with others into network-based biology or systems biology. So that's how they interface at least of a molecule. I think that's okay. That is a right approach, so at the end of the day what is working is the molecule right? So, it is good that we can attribute things to molecules and from molecules, we try to understand what is going on in our body. That is the right approach." (Prof Musashi, 2016, Tokyo)

Another interviewee understood biochemistry as a translation from biomedicine or biomedical drugs into hot and cold patterns of Chinese medicine diagnosis. The interviewee explained this with the example of aspirin, which demonstrated in Chinese studies that its use for cold diseases is better, due to the warm property the drug has in Chinese medicine. Apart from its biochemical bridge, this example is interesting as it reports a different interest in this "interface", namely the translation from biomedicine into Chinese medicine and not from Chinese medicine into biomedicine. In contrast, most of the actors were interested in complex *fufangs* and not in investigations of biomedical drugs with Chinese medicine concepts of pattern differentiation.

According to the definitions of interviewees, interface meant a place where systems biology and Chinese medicine met, which was the molecular level. The idea of molecules as an interface between systems biology and Chinese medicine or Chinese medicine and biomedicine was found in articles, such as by Wang et al. (2005), which proposed metabolomics as a bridge between molecular pharmacology and Chinese medicine. Those authors claimed that new technologies from the genomic era such as transcriptomics, proteomics, and metabolomics were used to analyse metabolites with a systems approach to phenotype the chemical characterisation of sample.

Many interviewees claimed that molecules are the common ground between systems biology and Chinese medicine and that technology generated the information, which could be translated into both fields. This, of course, implies that since the 1950s, Chinese medicine practitioners have learned a standardised and modernised Chinese medicine which inevitably arose when the political agenda of the CCP put pressure on the introduction of Western medicine into Chinese medicine studies (see Taylor 2005). Therefore, the perception of an interface based on a shared molecular understanding predates the integration of modern science in Chinese medicine, which has enabled

Chinese medicine researchers over the past 60 years to translate parts of their medicine into molecular data and, thus, have made it accessible for systems biologists. Biochemical analysis has brought about the meeting between systems biology and Chinese medicine. Based on the molecular data they can apply concepts to link Chinese medicine with systems biology and Chinese medicine with biomedicine (van der Greef et al., 2010).

4.2.3 Technology as a bridge

A recurrent description of this "interface" between systems biology and Chinese medicine is that technology acts as a bridge between them. The majority of interviewees feel that technology is used as a translation tool between Chinese medicine and systems biology and that technology is utilized to understand fundamental biochemical processes and to investigate Chinese medicine. Nonetheless, systems biologists also recognise the need to understand processes before they translate them into metabolomics. One interviewee explained the translation as follows:

> "Chinese doctors, kind of group or cluster patterns together and give them certain kind of treatments, so we thought that is very important to know something about *zheng*s before we can translate them like in really herbal medicine." (George, 2015, Leiden)

Technology functions as another bridge (e.g., biochemistry) between both systems. Technology is a crucial part of systems biology and its practice while omics are organically integrated into Chinese medicine research to advance the field. The integration in Chinese medicine happened as a result of the Chinese medicine modernisation that took place in the last century, which is outlined in Chapter 2. Modernisers employed technology and science into Chinese medicine and omics were seen as a further update of the technology Chinese medicine researchers already used for their studies. The frequent use of omics in systems biology and Chinese medicine emerges as a way to translate Chinese medicine into a scientific context as a "bridge" between the Chinese viewpoint and Western medicine.

4.3 Chinese medicine and systems biology are the same

In the code on "Chinese medicine and systems biology as the same", interviewees denied calling the relationship between systems biology and Chinese medicine an "interface" because they argued that systems biology and Chinese medicine share commonalities such as holism and systems thinking.

Three factors constructed the argument that the relationship between Chinese medicine and systems biology had was no "interface". The interviewees referred to a sameness of Chinese medicine and systems biology as seen in the shared ideology of systems thinking and holism and the difference through the idea of Chinese medicine essentialism. First, I will present the data that shows systems thinking as being synonymous with holism. Then, I will elaborate on the difference between the two fields which led to the denial of an "interface".

The interviewees were of the opinion that Chinese medicine and systems biology appeared as an ontological similarity as they both used the concepts of systems thinking, which they correlated to holistic thinking in Chinese medicine and at systems-level understanding in systems biology. They saw connections between Chinese medicine and systems biology through the way both fields conveyed their ideas about the emergence and development of things. Systems biology was an ontological similarity or even the same as Chinese medicine. As two actors say:

> "I think there is no interface because between systems thinking and Chinese medicine there is no difference. Only people now use the term systems biology, which is basically the holistic thinking in Chinese medicine. I don't think there is an interface at all. So, the way of thinking in systems biology and in Chinese medicine is always the same - there is no difference." (Dr Huang, 2015, Leiden)

> "It is a concept to write a story. It is holistic, and Chinese medicine is holistic; therefore, they fit together to conduct research… because in the core of their ideas they are both a perfect match." (Lingma, 2016, Dalian)

Nonetheless, systems biologists highlighted that within their field they used the Western scientific terminology to avoid, for example, holism, as an inappropriate expression for the scientific community and journals. Systems biologists used terms to describe the methods they used and resonated with the holistic idea in Chinese medicine. For example, systems biologists explained a phenomenon with biochemical mechanism, while Chinese medicine used an energetic understanding of *qi*, *yin* and *yang*. Systems biologists described the various functions and relationships between molecules differently. This demonstrates their belief that humans and all levels of an organism (i.e., genes, tissues, organs) are interrelated and interconnected with nature, as expressed by Kitano (2002). The relationship between the different levels facilitates communication between different levels in the organism and nature. For instance, Prof Musashi used the *Taiji* symbol (太极), which represents how systems biologists now view systems thinking. Schroën et al. (2014) state that *Taiji* translates to mean "great pole" which means two extremes or contradictions, such as, light and darkness, strong and weak, front and back. Prof Musashi uses the *Taiji* symbol to relate to Daoism and holism. This notion is supported by Prof Frank and Prof Musashi who assert:

> "I talk about systems biology as a bridge but actually I am looking at the systems as Chinese is and as Western should be. You know words are always creating polarities, so if you have a word like the light there is also dark, up there is also down. That is why we have polarities when we talk, and some people are more in one polarity and the others are in the other. That's why you get some sort of unbalanced life but if you talk about what actually is there, then, names are just names and what you see. But it's you who is talking about a holistic view on life and systems biology tends to be more biochemistry in daily life in Chinese medicine is explaining things more energetically and these are very close together. Actually, they are the same because if everything is connected and you cannot separate them out." (Prof Frank, 2015, Leiden)

> "Holism, so the holistic view of the world and Fritjof Capra's Daoism are a kind of the good old age of science. I like that. At the same time, holism is pretty much a systems way of thinking. In a way, it is how a system as a whole impact the function and behaviour of the system. If you look at the figure in my Science paper, you will see in the background the *Taiji*, the *yin/yang* symbol. So, I intentionally used this image. One is the dry [experiments], and one is the wet experiments. The dry side is the computational part, which has to be merged with the wet part. That is a mirror image, so actually in the figure one is the designer of the research, which comes up with the dry side, and the wet side is a kind of a background. I specifically use this sign. So, this is systems biology from the beginning, and in the first paper and the first figure I have imposed holism." (Prof Musashi, 2016, Tokyo)

The use of different terminology included the term holism, which systems biologists interpret as systems-level understanding. Holism is the shared idea of a living organism, which demarcates the fields of systems biology and Chinese medicine from a reductionist approach and its study of single molecules, genes or proteins.

Interviewees of both fields viewed the human organism in a bigger picture. One interviewee explained that both fields share the same understanding of the whole organism as interactions and relationships between the lower level, which is the molecular level, and the upper level, which is the whole organism, as well as its interactions with the environment. One interviewee referred to systems biology as being based on molecular biology, which was integrated to explain the lower structure to build relationships in the whole organism. In this understanding, systems biology and Chinese medicine met conceptually and philosophically. As the actor states:

> "When we see a whole organism in relation to his environment, this is much too complex so in the last 400 years we understood the lower layers now it is about time to understand the top layers, but we cannot skip the lower layers. What the Chinese did is describing the upper layers the human being in its relation to its universe and also the complexity of what happens in the processes in the body in these 15 conception ways… but they never had and were not able to explain what they were seeing, so they don't understand the lower levels. So now they are meeting [two levels through systems biology] and this can be so enriching I think." (Kevin, 2015; Leiden)

A further example of the existence of similarity between systems biology and Chinese medicine is that they both apply a multiple-to-multiple approach. One interviewee emphasised that Chinese medicine diagnoses multiple symptoms and treats them with many herbs - a formula or a prescription (*fangji* 方剂）(see Farquhar, 1994). While systems biologists use various techniques to detect numerous variables for a holistic analysis of biomarkers[19] and relationships between proteins, genes and metabolites. This perception stresses another similar grounding of the two fields.

The majority of interviewees claimed that systems biology and Chinese medicine share commonalities and, therefore, believe that there is no "interface". Likewise, Chinese medicine researchers argued that there was no "interface" between Chinese medicine and systems biology but said that the reason is that systems biologists did not understand the Chinese medicine essentialism. They referred to Chinese medicine essentialism, as a quality of Chinese people and culture or experience that could not be translated by omics. Some interviewees mentioned the classification of diseases as

[19] A biomarker is a chemical or biological test result of an analysed biological material, which relates to a particular exposure, susceptibility, or biological effect (Biesalski et al., 2009).

challenging to understand for non-Chinese, such as the eight rubrics (*ba gang* 八钢) analysis, which are *yin* and *yang*, exterior and interior, cold and hot, depletion and repletion (see Farquhar, 1994). They associate Chinese medicine as a central idea they learned as part of their upbringing. To understand this essentialism, systems biologists would have to learn the Chinese medicine theories and understand the Chinese language. For example, the following Chinese medicine researchers asserts:

> "This interface can only be established if systems biologists understand Chinese medicine theory and in order to understand the theory, they must learn Chinese." (Prof Xiong, 2016; Harbin)

> "For Chinese, it is easier to understand Chinese medicine. Right? For example, if you have a balanced constitution, or a cold, hot, warm or cool constitution, that is easy to understand for us, but for you it could be difficult." (Long, 2016; Dalian)

This group of Chinese medicine researchers was reluctant to discuss omics as a way to translate Chinese medicine theories into the language of systems biology and to make Chinese medicine understandable to non-Chinese medicine researchers. However, the specific Chinese medicine characteristics could not be clearly defined by them. They did define Chinese medicine as a Chinese cultural heritage and emphasised the fact that a crucial part of Chinese medicine was reserved for the Chinese and their understanding of Chinese medicine. This distinction indicates a particular right of studying Chinese medicine for Chinese researchers and scientists. Evidence can be found here:

> "Omics are translation tools to make Chinese medicine understandable to Westerners because they cannot understand the 'essence' of Chinese medicine like Chinese do due to their cultural background." (Ruili, 2016; Harbin)

The emphasis on essence or essentialism links to the labelling of Chinese medicine as a "national essence" during the modernisation phase of Chinese medicine. As elaborated in Chapter 2, the formulation "national essence" categorised Chinese medicine as a "Made in China" product (Croizier, 1968, p. 344). However, the essence was also detached from Chinese medicine. *Jingyan* (经验) can be translated as an experience and has two different meanings. Lei (2014) discovered that in the late nineteenth century, *jingyan* referred to evaluated and effective drug prescriptions, and not the experience of the practitioner as Yu Yan, a moderniser of Chinese medicine, redefined it. The label of Chinese medicine as an "essence of the nation" has been in place at least since the early twentieth century. Therefore, socio-political struggles in the twentieth century tied the rhetoric of essentialism or “spirit” of Chinese medicine to the nation and the people and as being something unique.

The Chinese government and Chinese medicine modernisation and globalisation associations maintained in their different globalisation plans for Chinese medicine, the continuation of the Chinese medicine essentialism. Such associations were founded in 2003 and 2004 in mainland China, Hong Kong and Macao and were, for instance, the World Federation of Chinese Medicine Societies, the Consortium for Globalisation of Chinese Medicine and the International Society for Chinese Medicine. However, in the latest globalisation aspirations, Wu et al. (2015, p. 4) state that the successful globalisation of Chinese medicine requires the essence of Chinese medicine to “annotate” its theories into a scientific language to acquire a “universal acceptance by the modern scientific community”. Wu’s claim may change the mystic condition of Chinese medicine’s essence and which may dissociate it from the social feature. The discussion of a concept that disassociates Chinese medicine and systems biology coincides with the attention paid to omics and the help that omics provide to bridge the gap between Chinese medicine and systems biology actors in this “interface”.

In this code we have seen that systems biologists and Chinese medicine research claim that both fields are ideologically the same. This now raises the question as to whether these actors define systems biology and Chinese medicine in the same way. If not, is it important to investigate what differences they believe appear between the two fields?

The definition of sameness will be discussed in the next part of this sections. First, I will present the actors’ interpretation and descriptions of the two fields. This will lead to the question of how the idea of similarity between cutting-edge science and ancient medicine emerged, which I will answer with the use of a literature survey which will be presented in the last section of this chapter.

4.3.1 Definitions of Chinese medicine

In the previous section, most interviewees reported similarities between systems biology and Chinese medicine. At least six of those interviewed referred to there being a cultural difference between the two whilst others claimed that Chinese medicine is an ethnomedicine, a medicine based on observations and a vast resource of knowledge.

The exciting part in the definition by those interviewed was that there was a clear differentiation for the definition of Chinese medicine between Chinese medicine researchers and Chinese systems biologists. Chinese medicine researchers in China defined Chinese medicine as an ethnomedicine or traditional medicine. The description followed the official description of Chinese medicine as a traditional medicine of China when Chinese medicine and the medicine of China's non-Han minorities were included in the new constitution of the PRC (see Scheid and Karchmer, 2016, p. 169).

> "Chinese medicine is an ethnomedicine or traditional." (Prof Lou, 2016; Dalian)

From a practical point of view, Chinese systems biologists stressed the different approach of Chinese medicine and biomedicine on the importance of the senses, such as the feeling of the pulse, or the experience of the Chinese medicine practitioner to establish a diagnosis and the energetic explanations. The Chinese systems biologists believe that the feeling of the pulse is an essential practice in Chinese medicine and a significant difference to biomedicine and science. As one interviewee stated: "Chinese medicine is not *kexue* [science] medicine, it is all about feelings of the doctor" (Long, 2016, Dalian). Pulse diagnosis is not practiced for the same reasons and with the same detail in biomedicine. In Chinese medicine, the practitioners established the diagnosis through their observations and the experience (Farquhar, 1994; Kuriyama, 1999). Reading the pulse was part of the *sizhen* 四诊 with the four methods of diagnosis (observation (*wang* 望), auscultation and olfaction (*wen* 闻), interrogation (*wen* 问), touching pulse feeling and palpation (*qie* 切)) needed to make a diagnosis. There were distinct characteristics between Chinese medicine and biomedicine. Kuriyama (1999) described the pulse diagnosis as: feeling the pulse is knowing about the disease and a way to confirm the diagnosis against the symptoms the patient described. Interviewees when comparing biomedicine with Chinese medicine, claimed that because of the Chinese medicine practitioners' observations and their experience in practicing Chinese medicine, they are less likely to depend on technology when it comes to examining the body. Whilst, biomedicine experts, on the contrary, rely on technology to diagnose diseases. Karchmer (2010) contradicts this claim as he found that Chinese medicine practitioners more and more employ biotechnology to confirm or consult their diagnosis.

Another Chinese biologist addressed in her definition that previous engagements with Chinese medicine resulted in exploitation of Chinese medicine. Helman (2007) calls this biopiracy or biocapitalism, which is a growing problem, not only for Chinese medicine but also other traditional medicine. I will discuss this in detail in Chapter 8. First, this is what the interviewee said:

> "Some of them they are quite good interactions and others just use Western technology and they hope to get the target and the component of Chinese medicine. So, they use the Chinese medicine as a sort of pool to fish out what they want. Then you have different people interacting with Chinese medicine. Some of them think that Chinese medicine is a concept that guides them to understand biology and others think Chinese medicine is just a rich pool and they can try to get out what they want. Both of them are quite interesting; and both of them can get the results they want." (Dr Huang, 2015, Leiden)

It is important to note that Chinese medicine researchers and systems biologists believe that there is an "interface" between Chinese medicine and systems biology. Chinese systems biologists and Chinese medicine researchers agree that Chinese medicine is different to biomedicine. Chinese medicine researchers maintain the official description of Chinese medicine while Chinese systems biologists stressed the observational skill of Chinese medicine practitioners that facilitated a diagnosis without technology. Another systems biologist mentioned the issue of exploitation of Chinese medicine. She claims that the beginning of its exploitation started in the 1990s when science and technology were the focus of Deng's political agenda and the four modernisations (this was discussed in Chapter 2). The link with technology appears in the definitions of Chinese medicine essentialism that protects the crucial difference between Chinese medicine and biomedicine as well as technology is observed in Chinese medicine practices and its herbal drugs. Subsequently, the next section will reveal the aspects of systems biology which depends on technology and which correlates with Chinese medicine.

4.3.2 Definitions of systems biology

Interviewees defined systems biology in three detailed codes: systems biology as a concept, systems biology as a set of technology and systems biology as a discipline. As a point of reference, in the literature (see Alon, 2007; Ideker, Galitski and Hood, 2001; Scheid, 2014; Wolkenhauer et al., 2013), systems biology is described as an amalgam of disciplines (i.e., physics, chemistry, computer science, biology, engineering) that correlate with each other through the theoretical basis of systems thinking and the rejection of reductionism (Calvert and Fujimura, 2011). Systems biology has developed over the past two decades from a technology-driven enterprise to a new tool in life science with the aim to understand biological systems as complex networks (see, for example, van der Greef, Hankemeier and Mcburney, 2006; Calvert, 2008, 2013).

The first detailed code of "systems biology as a concept" tried to understand Chinese medicine holistically, namely systems-level understanding, and to discover new holistic approaches for bioscience and personalised medicine. However, the perception of holism in systems biology was somewhat counter-intuitive. Systems biologists used holism to distinct systems biology from molecular biology, while they integrated molecular data for holistic studies. Calvert and Fujimura (2011) confirm the contents of different epistemic virtues of reductionistic and holistic methods, which are necessary for generating computational models. As the following systems biologists stated:

> "This thing about using the binoculars both ways is indeed interesting and key to systems biology. In systems biology, we deal with both the details, all the individual molecules that are measured or symptoms that are registered with questionnaires. But then we try to fit the information into a wider picture." (George, 2015, Leiden)

> "The only definition is this is the system-level understanding but how you understand the system-level or which part does not really matter. At least that is how I thought about. Systems biology is very vague, and a boundary is not created that is an intention, then we have a breath over the field and more people getting involved. That is by design. Systems biology is a systems-level understanding of biological system." (Prof Musashi, 2016, Tokyo)

> "First, we are taking the human body and different organs on a molecular or cellular level. By analysing all the organs from a special level, we understand which gene is expressed the most in the liver compared to other organs. So, this is the way of a systems approach. It is not just talking about the liver or liver tissue, but you compare the liver with all the other organs, and then you come up with something maybe different or specific. Then, [in the sample of] the next patient you ask why is this different or specific if it must perform a different function, which is important for the liver." (Prof Meng, 2016, Hangzhou)

What emerges from these definitions here is that all interviewees agreed that systems biology followed a holistic paradigm used to distinguish molecular biology as a disciplinary difference while it also depended on molecular data to establish a holistic analysis. However, the difference between the two definitions is that the first group refer to the dependence on reductionistic data collection, whereas the second group referred to a combination with various high-throughput technology that produced reductionist data. Another Chinese biologist went further and claimed that systems biology is reductionist in the context of the Chinese notion *huanyuan lun* 还原论, which goes hand in hand with "the theory of return to the original condition" or "reconstruction theory". The reconstruction theory is a guidance for research whereby systems biologists first understanding specific details and then using a holistic approach, they can understand the bigger picture. Chinese biologists believed that both approaches are important for the research of systems as through reductionism, a speculative study can be avoided while holism provides the overview of the general problem (Yang, 2016, pers. comm. 16 December).

The actor also commented that a single study in systems biology referred to a study of one isolated pathway, which is the same principle as in reductionism. Her understanding of systems biology research was that systems biologists first deconstruct isolated paths in a system, then, they reconstruct them again by using different methods like a scientific study, statistic informatics and data interpretation. According to her, this combination of approaches makes systems biology holistic. The general view of this actor is that it is impossible to study every aspect within a specific problem as every method has its limits. Accordingly, reductionism and holism are not mutually exclusive in systems biology.

> "For studying systems biology, we have to conduct several steps: sampling, sample preparation, analysing the samples and the use of bioinformatic tools to analyse the data. After that, we can compare the results of different groups to find the biomarker. After that, we focus on the data interpretation - this is the most important thing because we need to use the holistic knowledge to interpret the data, which is not a single biomarker, there are several biomarkers in the context of a disease and according to the increase and decrease we explain what the reason is." (Lingma, 2016, Dalian)

Another actor comments on the reconstruction theory as a different cultural background that equips Chinese scientists with a distinctive viewpoint on data. This viewpoint equips them with a different way of doing science and interpreting a relationship in a network that involves all molecules, which he would like to see in science and in healthcare.

The second detailed code defined systems biology as a method or a set of technology to study in a mechanistic way Chinese medicine through pathways and active compounds. Similar to the first group, they refer to systems biology as a holistic study. However, they interpret holism as an approach that employs various cutting-edge technology sources and perspectives and establishes its analysis in a combination with reductionistic data to model pathways in the organism with molecular data. For drug discovery in Chinese medicine, some suggest applying computational models. Gu and Pei (2017) describe this as a common method, which uses chemical similarities from discovered molecules in herbal medicines for a computer simulation of the effect of the drug. To quote three interviewees:

> "My personal and easy definition of systems biology is to study a problem from various levels, e.g., metabolites, properties of genes and to use various omics technologies in order to understand the whole system. You can say that systems biology is a kind of hot technology." (Ang, 2016, Harbin)

> "People have different definitions, and then you talk to some of the omics approaches and believe that is the way to do it. Systems biology is a large omics and a network analysis. Or if you go to someone else who does another detailed modelling and understand the control mechanism or pathway; or if you go to metabolomics systems biology about understanding the behaviour of network using, the large-scale, mass spectrometry, and pathways analysis and flux analysis, they all try to understand a particular aspect of a system using whatever they have." (Prof Musashi, 2016, Tokyo)

> "I think they combine the systems thinking in Chinese medicine or the philosophical systems thinking with the modern technology with the hope to get the whole set… if you have this data set [of various formulae tested on numerous people] up you can maybe try a different combination, or you can even do computational herbal medicine modelling to have data for some herbal medicine. Once they have some effect on the liver, then, with a special protein and a link you can model a sequence, which might have a different combination and then you have a different disease. You know diseases are like pathway networks, you can understand many things and like different models might be good for you. But this is a huge task, and I don't think we can do that, there is no way I can see this happening." (Prof Meng, 2016, Hangzhou)

However, systems biologists stress that the most advanced technology was necessary to study pathways and the whole system. Another interviewee stressed that the combination of different experiment phases and analytical tools are necessary to conduct a systems biology study on different levels of a system or disease. He said:

> "Systems biology is to understand systems at different levels like proteins or dissect each component. You need to use the most advanced technology to understand each component; we call them pathways if you don't have the technology the pathway is not complete, thus, you cannot do systems biology." (Prof Meng, 2016, Tokyo)

What is significant in any definition of systems biology regarding technology is that the study of all levels of a system is dependent on various technologies or omic techniques. Some actors stress that the technology used is not sufficient for this undertaking, which indicates that systems biology did not achieve its conceptual aim of systems-level understanding. Chapter 8 will examine the advancement of technology in more detail.

The last detailed code was that systems biology is a discipline and is different from the discipline "biology". Interviewees who worked in systems biology as part of a Chinese medicine project did not call themselves systems biologists because they did not consider systems biology as a discipline. The reasons were that it was a part of biology, that uses the same technologies as biology, or it does not fulfil the aspiration to understand biological processes in living organisms found in two interviews that spoke against the notion of systems biology as they claim:

> "Systems biology is part of the biology. I am a biologist, and systems biology is part of the biology. And only because now we use more omics technology and even other technologies to show the holistic behaviour in human beings or medicine is still basically biology. I am a biologist. I think that is fairer." (Dr Huang, 2015, Leiden)

> "Systems biology is until now no discipline if it would be a discipline it would explain all the processes in biology, which it does not." (Long, 2016, Dalian)

However, some systems biologists observe that biologists practice systems biology by measuring systems performance, at the beginning and the end of an experiment, without paying attention to the development in-between. This approach contradicts the systems biology idea of understanding processes in living organisms:

> "Instead they have a complete rubbish understanding of systems biology. They also do experiments, before and after, like two points. They only look at the things that have changed but without intermediate measurements. Thus, we don't know how things have changed." (Prof Musashi, 2016, Tokyo)

Some systems biologists claim that the name systems biology was imposed as a methodology that was practised in biology. Omics technologies such as genomics, proteomics, and transcriptomics were not a new invention. Evidence of this can be found in an article about metabolomics, which demonstrates the latest development of omics technology, in the use of biological research in the Netherlands (see van der Greef et al., 2013). Whilst one systems biologist has claimed that since the 2000s systems biology is considered a discipline, other systems biologists believe that it might become a discipline in the future. But in order for it to be considered a discipline, some limitations in the measurement and analysis need to be solved.

> "Actually, it is less, because it was more ego-driven from the desire to connect. So, people say, okay, there has been a long-time systems biology, it has not just appeared, it [systems biology] is just a name. The name appeared at a certain point in time, because people wanted to claim something." (Frank, 2015, Leiden)

> "Definitely it is going to be a discipline, especially if it has an advanced measurement to practice systems biology better. Then, we [systems biologists] will become more discipline. But now, I think we are still in the formative years, there are so many things we don't know yet, and we are still limited by how much we can see things." (Prof Meng, 2016, Hangzhou)

In contrast, other systems biologists refer to systems biology as an independent discipline. They argue that the establishment of various systems biology conferences, journals, departments worldwide is a clear sign that systems biology is a discipline. As one participant articulated:

> "We have a society, we have much public funding programs or the system biology program, and Harvard created a department for systems biology. There are a lot of systems biology research centres around the world, so if there is a social definition of being established. I think this is the one turning point in terms of stimulating people's awareness and systems way of thinking in biology and let people recognise that this is a modern kind of field systems biology. I started doing systems biology in about 1995-96, and then we [the community] started using the term in 1996-97. It was about a decade when I started talking about it and people started recognising it and using the term in funding programs or for departments." (Prof Musashi, 2016, Tokyo)

> "It is a kind of discipline which uses multiple technologies and not the single versus the multiple approach." (Ang, 2016, Harbin)

Overall, systems biology can be viewed as being in-between a discipline and a branch of biology. Some actors are convinced that it is an independent discipline due to the institutional and representational character it has established since the 2000s.

4.3.3 Does the "interface" exist or not?

The results show that the overwhelming majority of those interviewed are against the term "interface". They disagree with the description of the interaction between the various actors involved in the research of Chinese medicine and systems biology and the meeting of distinct fields. "Interface" would connotate that Chinese medicine and systems biology are different, which is not the case for those interviewed. They argue that Chinese medicine and systems biology share the same concept of holism, which they view as equal with systems thinking in systems biology. Most of the actors implicitly describe the relationship between the two fields as a connection through molecules, ideologies and technologies and not as a face-to-face relationship between humans. Thus, technology and molecular understanding are crucial to translate and communicate their results.

Cultural differences surfaced in some interviews. Some of the participants mentioned characteristics of Chinese medicine that are not scientific and not prominent in biomedicine anymore. Other cultural differentiations referred to essentialism as a kind of preservation of the cultural values of Chinese medicine against the globalisation attempts of the Chinese government and various associations. However, their perception of difference may also express a reaction to the continuing attempt to globalise Chinese medicine since the 1980s, which we saw in Chapter 2.

In conclusion, the data shows that many perceptions and descriptions of this "interface" are based on the similarity between Chinese medicine and systems biology. Despite the definition the actors use to define this "interface" between systems biology or Chinese medicine, they all agree that systems thinking or holism are integral parts in both. Thus, systems biology and Chinese medicine are defined either the same or can co-operate with this similarity. The question that arises is: how was systems thinking integrated into systems biology and Chinese medicine to connect both fields in the early 2000s? To answer this question, I will analyse the literature on the integration of systems thinking in systems biology and Chinese medicine in the last section of this chapter.

4.4 Historical trace of sameness

Results from interview material presented the idea that Chinese medicine and systems biology are the same, as they refer to systems thinking and holism synonymously. A look at the historical development of systems thinking in systems biology and Chinese medicine in this part will reveal that systems thinking in Chinese medicine and systems biology in the 2000s emerged from the integration of cybernetics in Chinese medicine and the development of systems biology from cybernetics. This will analyse the emergence of the perception that systems biology and Chinese medicine are the same.

4.4.1 A shared interest in the "problem" of life among Chinese medicine practitioners and biologists

The interest in life and its study existed for a long time not only for biologists but also for mathematicians, physicians and social scientists. In the early twentieth century, the American mathematician, child prodigy and one of the founders of cybernetics, Norbert Wiener (1894-1964), became interested in life as a form of control and regulation. Wiener wanted to formulate a theory of the control and regulation of communication between humans, machines and animals in 1948, which required an understanding of life and humans as systems. According to Ilgauds (1984), Wiener borrowed for his theory, the term "cybernetics", which derives from the Greek *kybernetes* and means "the steersman". Wiener's (1994) theory *Cybernetics or control and communication in the animal and the machine* was first published in 1948 and became one of the key theories of cybernetics among John von Neumann and Oskar Morgenstern's *Theory of Games and Economic Behaviour* (1944) as well as Shannon and Weaver's (1949) *The Mathematical Theory of Communication* (see Umpleby, 2008). Seising (2010) reports that cybernetics became a scientific theory for information control and regulation.

Parallel to cybernetics, the Austrian biologists and philosopher Ludwig von Bertalanffy (1901-1972) observed butterflies to study systems. He published his findings on *General Systems Theory* (1968), on which he had been working on since the 1920s. General Systems Theory (GST) is the science to uncover universal principles that govern open, evolving systems (von Bertalanffy, 1968). To establish this theory, Bertalanffy and Bogdanov employed systems science, which was based on cybernetics but focussed more on social science models to overcome the problem of linearity in mathematics (ibid). Although von Bertalanffy's GST stressed the principles in general systems and did not specifically target and control related systems, like systems scientists, Heylighen and Joslyn (2001) found that von Bertalanffy and second-order cyberneticians influenced each other's work.

Heinz von Foerster, another founder of cybernetics, founded the Biological Computer Laboratory (BCL) at the University of Illinois in 1958. He exchanged his ideas on self-organising systems with systems scientists on a regular basis (Capra, 1996). According to Umpleby (2008), these systems scientists included the founders of the Autopoiesis theory: the Chilean biologists Humberto Maturana and Francisco Varela on a regular basis (see for Autopoiesis theory in Varela, Maturana and Uribe, 1974). Autopoiesis explains that systems are capable of reproducing and maintaining themselves. Hence, Autopoiesis, General System Theory and cybernetics underlined the beginning of a new era on the study of biology and life.

In Chinese medicine, the interest in life was different. Qin Bowei (1955), a famous Chinese medicine practitioner (mentioned in Section 4.4.4), introduced holism as dialectic materialism into Chinese medicine. Along the same lines, Ren Yinqiu (1956) subsequently argued that since remote antiquity, Chinese medicine did not understand the material base for life, but it understood *yin/yang* as processes that constitute to life and to study life as being holistic. For example, the exterior of the body is *yang*, and the interior is *yin*. However, the organs are not all *yin*. Some of the organs are *yin* organs (*zang* 脏) as they store either *qi*, blood or fluids like the liver, and some are *yang* organs (*fu* 服) as they receive nutrition, such as the stomach. In this microcosmos, the human body is a small world that relates to its environment and is defined as heaven in Chinese. This model was known as the *tianren heyi* 天人合一. Qin (1955) compared the human *yang qi* with sunbeams because warm weather needs sun just as a healthy human body needs *yang qi* to warm the body. Thus, both heaven and human are two individual ecosystems that interrelate and depend on each other through similar composition and needs. Hence, they compose a holistic body-environment.

Holism plays a vital role in the understanding of life. The word holism refers to the Greek word *holos* which means "whole". In his seminal paper, Scheid (2016) found that despite the latest emphasis on holism as being intrinsic in the ancient tradition of Chinese medicine to distinguish Chinese medicine from complementary and alternative medicines (CAM), or biomedicine's reductionist perspective, it is only a hundred years old. Zelko (2013) found that the former South African Prime Minister Jan Christiaan Smuts (1870-1950) coined this word holism first in his book *Holism and Evolution* (1926) as a translation of the German word *Ganzheitlichkeit* into English. According to Scheid (2016), Smuts added to Aristotle's definition with the description that evolutionary processes form wholes through emerging properties, as opposed to the perception of a collection of parts. Although Smuts used holism to justify apartheid in South Africa, the recently invented term "holism" is still widely used in Chinese medicine and complementary and alternative medicine (CAM) fields.

In the past century, holism was widely used. Holism appeared in connection with *Gestalt* psychology, Nazism, vitalism and later with Marxism in China (Scheid, 2016). Levine (2012, p. 30) demonstrated that in Weimar, Germany (1919-1933) and then under Nazism, holism was applied in cultural politics and science for example in eugenics and racial policies of the Germanic "Übermenschen" which was otherwise known as master/Aryan race. In Max Wertheimer's (1880-1943) *Gestalt* psychology, living organisms are perceived as meaningful wholes, as a *Gestalt*, and not as isolated elements. Therefore, Capra (1982) argues that living organism exhibit qualities that are absent in the perception of isolated parts. The notion of holism used in *Gestalt* therapy became the utopian model for ethical frameworks of co-operation instead of conflicts, which were dominating the globe after the WWII and Vietnam war and during the Cold War.

To sum up, the study of life is of interest for Western science and Chinese medicine. Cyberneticians were curious about the systems in machines and living organisms. They believed that living organisms are systems that control and regulate the transmission of information. In the same way, they hypothesised that machines are system that are either controlled by the technology or by the engineer. While in systems science, life was seen as a general system that governs and evolves through principles or maintains and reproduces itself. Similarly, in Chinese medicine life is viewed as combinations and interrelations between *yin* and *yang* in the human body and its environment. What Western science and Chinese medicine still lack is the precise description or the evidence for their theories and holism.

4.4.2 A "CRISIS" AMONGST BIOLOGISTS LEADING TO A RETURN TO HOLISM/VITALISM

A crisis in biology arose from the increasing molecularization of biological and medical phenomena. During the 1920s and 1940s, the interest in biology and medicine diverged into molecular biology and the investigation of the smallest parts. In the 1950s, the "Golden Age of Theoretical Biology" occurred through the shift in biology to mathematical descriptions of biological phenomena (Green and Wolkenhauer, 2013, p. 559). The Bertalanffy's Society for General Systems Research (SGSR), which is now the International Society for the Systems Sciences (ISSS), initiated this shift to quantify transformations in biological systems. In the 1970s, the mathematical approach quickly advanced to interdisciplinary fields such as mathematic biology, biochemistry and biophysics and linked engineering in biology and biomedical science to the biotechnological industry, researchers and clinicians (Kaimal et al., 2011). The biotechnological methods followed a linear process of researching a phenomenon from the cause to the effect and became known as a "bottom-up research", which used the reductionistic approach in molecular biology (Green and Wolkenhauer, 2013, p. 555). Thus, some biologists returned to the understanding of the wholes and holism.

The reductionistic view in biology aroused a "crisis" amongst biologists and the idea of holism re-surfaced. Wood (2010) discovered that during the 1940s and the 1970s, various groups accentuated their opinion against reductionist thinking by stressing the value of humans as part of society and the global community. They wished to unite what was previously separated, for example, the body, mind, spirit, nature and technology. Likewise, Scheid (2016) found that in France, holists engaged with vitalism in opposition to mechanists. Weber and Esfeld (2003) explain that mechanists viewed everything as a system that consisted of interacting particles with a focus on a limited number of properties. In contrast, vitalists were interested in the whole body and its capability to defend itself against illness.

The holists idea emerged again to oppose, according to Lawrence and Weisz (1998), the idea of the dominating interest in biology in mechanism and reductionistic understanding of the body as a set of organs or physicochemical processes. Similarly, the holist advocate and physicist Capra (1996, p. 77) describes molecular biology as "originally a small branch of life sciences has now become a pervasive and exclusive way of thinking that has led to a severe distortion of biological research". The result of the increased focus on molecular biology was the search for holistic ideas and approaches to studying biological phenomena. This influenced the development of linear and reductionistic, i.e., bottom-up research (i.e., detailed anatomical and mechanical models), to more holistic approaches.

In this context, Noble (2010) proposed a middle-out approach in systems biology as a combination of the reductionist bottom-up and the holistic top-down approach (i.e., computer modelling of the cell). The middle-out approach deliberately starts at the biological level (i.e., tissue or cell) of the body and builds upwards until the researcher reaches enough knowledge and subsequently investigates the relationships between cells, tissues and organs of an organism. Thus, the researcher generates a comprehensive understanding of the system around his starting point and the relationship to lower or higher biological levels (Noble, 2010).

As a reaction to molecularization in biology, in 1975, a group of scientists started to popularise Chinese Daoist philosophy. Pickering (2010) claims that Capra's book on the interpretation of Daoism in physics provoked a rethinking of a holist approach in and outside of science. In the same vein, others refer to the last century as holistic due to the employment of holism into systems science, which generated a "Holos Consciousness" (Jaros, 2002, p. 14). This shift had an impact outside academia. Thus, the absorption of holism created the new fields of holistic medicine, holistic diet and holistic lifestyle which were invigorated by the Holos Consciousness (Jaros, 2002).

A further shift to holism happened in the late 1990s. Scientists initiated a scientific turn by discussing the concept of holism in biology, physics, physiology, medicine and philosophy and by contrasting it with a reductionist approach of those disciplines (Capra, 1975, 1982; Zhang et al., 2010; van der Greef et al., 2007, 2010; Tong, 2009; Gatherer, 2010; Noble, 2010; Luo et al., 2012b). During my fieldwork, several of my informants mentioned Capra's (1975) *The Tao of Physics* as an inspiration behind their motivation to establish and engage with systems biology (see Chapter 4.3). Actors in this new “interface” did not comment on these associations of holism with apartheid, *Gestalt* therapy, Nazism, vitalists and utopian ethical frameworks in their rhetoric on the systems biology and Chinese medicine “interface”. They referred to holism in China and Chinese medicine, where it became a way to catch up with the world and as a tool of resistance against Western imperialism. This will be expanded on below.

4.4.3 CYBERNETICS AND SYSTEMS SCIENCE OPENING UP THE POSSIBILITY OF A RECOVERY OF HOLISM

The interest of cyberneticians in the holism emerged from the keenness of British cyberneticians to Eastern philosophies and the establishment of a “nonmodern ontology” (Pickering, 2010). Pickering explains a nonmodern ontology as an ontology against the Western dualism of mind and matter, and rather influenced by Eastern philosophies. At the same time, American cyberneticians had to reorientate their field towards second-order cybernetics and social science by focusing on the role of the observer in modelling systems (see Heylighen and Joslyn, 2001). In this section, I will first reflect on Pickering’s (2009, 2010) exploration of British cyberneticians and ifs affinities to Eastern philosophy and then on the American shift to the second-order cybernetics.

According to Pickering (2009, 2010), the first generation of British cyberneticians developed an interest in performances of Eastern philosophy and spirituality in the course of the counterculture movement. These cyberneticians used Eastern philosophies as a nonmodern ontology or as an alternative to conventional psychiatry in the 1960s to inform their studies on the brain. The leading figures were Grey Walter (1910-1977), William Ross Ashby (1903-1972) and Gregory Bateson (1904-1980). Bateson played a double role in cybernetics as he was one of the founders of cybernetics and a systems scientist together with Margaret Mead in the US as well as he was also a British cyberneticist. Pickering (2010) connects British cybernetics with Alan Watts, who was a British expatriate and a populariser of Eastern philosophy during the counterculture movement in the US. Watts consulted Bateson’s schizophrenia project to re-conceptualise drugs. Watts’ writing on *Zen* Buddhism influenced Walter's and Ashby's (1968) studies on homeostasis and his illustration of the human brain as a performer, e.g., of hallucinations, of trance or the nirvana of Indian yogis and fakirs experience. Walter explored with cybernetics the altered stages of Indian yogis and their bodily experience for example, the suspension of their metabolism. He investigated those effects on healthy and diseased brains. The interest of the first generation of British cyberneticians in Eastern philosophy showed that cyberneticians in the 1960s looked beyond the reductive neurophysiology and aimed to study the brain as a holistic and "complex adaptive system" (Pickering, 2010, p. 8). Systems scientists adopted this holistic viewpoint and popularised it in their fields, e.g., Capra in physics (1975) and Laszlo in philosophy of science.

The second generation of British cyberneticians, for example, Stafford Beer took a more radical approach and engaged with Indian philosophy through practising and teaching tantric yoga. Pickering (2010) states that Beer was an active promoter of holistic teaching and played an essential role in the integration of holism in cybernetics in various complex systems models he created for management or political cybernetics (see, for example, Beer, 1994). Both generations of British cyberneticians included Buddhist and Indian philosophy into their research, and opened first systems science and later other Western scientific fields in the holistic paradigm (Pickering, 2010).

The shift to second-order cybernetics and the focus on systems science opened the field in the US to an observer centred and signified a further step in the integration process of cybernetics in other disciplines. Heylighen and Joslyn (2001, p. 3) argue that the new second-order cybernetics emphasised the "autonomy, self-organisation, cognition, and the role of the observer in modelling a system" as a distinction to first-order cybernetics and other relating disciplines such as computer science. Umpleby (2008) stated that the development of the second-order cybernetics occurred as a rescue measurement of the field to pacify the student protests, as cybernetics was linked to missile and machine research. Consequently, the neurophysiologist and one of the founders Warren McCulloch created the second-order cybernetics in the 1970s to calm the situation. Besides this, through the integration of cybernetics into other fields such as control engineering, computer science and social science, as well as the death of the two founders and active promoters of cybernetics, Norbert Wiener and John von Neumann, after the heyday of cybernetics (Umpleby, 2008). Cybernetics struggled to survive as a discipline but joined in the late 1980s with systems science to form "Cybernetics and Systems" (ibid, p. 6).

Although, in the 1960s and 1970s, cybernetics was integrated into other disciplines, Pickering (2010) claims that the core idea of systems thinking continued in systems science and the emerging conferences, journals and new fields such as brain science, psychiatry, neurophysiology, management and organisation, robotics, engineering, science of general systems, biological computing, politics, entertainment, the arts, theatre and architecture, music and education. Systems thinking became a way of life that reached into and beyond the academic world. It was incorporated into family therapy, complexity theory, robotics, AI as well as cyborg studies by Haraway (1991) or the posthuman by Hayles (1999) and as a new kind of science (Pickering, 2009). Some claim systems biology was influenced by systems thinking through systems science cybernetics (namely Bateson), whilst others believe that it was influenced by physiology trajectories (Noble, 2010; Strange, 2005).

Physiologists argue that physiology was the origin of systems biology (Noble, 2006, 2010). This assumption stems from cybernetics and systems science as these groups of scientists consisted of physiologists like McCulloch (Umpleby, 2008). Additionally, Noble (2010) promotes systems biology as the reinvention and the logical successor of physiology. In his view, physiology has always dealt with the communication between distinct levels of the body (i.e., cells, tissues, organs) and its systems, which is not different to systems biology. In the face of this transition of physiology to systems biology, Strange (2005) fears that physiology could fade away due to the emergence of system biology and the trend of applying systems biology methods, such as functional genomics, genetics, non-mammalian model organisms, computational biology in physiology. Thus, Strange (2005) suggests a "renaissance of physiology" rather than moving systems biology into physiology departments and risk the "fading away of physiology" (2005, p. C986).

The second trajectory of systems biology derives from molecular biology and genomics as opposed to cybernetics and physiology. Green (2014) claims that the connection to genomics arose from the development of systems biology after the age of molecular biology in the 1970s and the genomics boom in the 1990s. The substantial gene sequences were produced during the Human Genome Project (HGP) which took place between 1997 to 2007. Researchers agree that the HGP was the "'holy grail' of genetics and molecular biology" as it produced profound information on the organisation and structure of DNA, RNA, and proteins and a database of three billion nucleotides in the 24 chromosomal strings, however, it did not answer the cardinal question of "what is life?" (see for example Noble, 2010; Müller-Wille et al., 2007, p. 16). This happened because the research paradigm of the HGP was reductionistic and it distorted the view on the human genome with molecular biology that had no idea of the syntax of genes (Capra, 1996). Consequently, Noble (2010) restated the question about what life is and stressed the importance of understanding the bigger picture and the relationships between cells rather than its smallest parts.

The move to genomics research and the focus on genes with the HGP opened the floodgates in China for international research programmes, as well as for scientific research into diseases classified under Chinese medicine categories. Chee and Clancey (2013) disclose that the HGP included 80 laboratories in 15 countries worldwide. The HGP thrust China's science into a new direction, for example, the Human Physiome Project or China's Genomic Research Centres sequenced the last one per cent of the whole human genome of the HGP. On the whole, the HGP provided China with a new tool to make up leeway with science and the West. It developed a competitive and prestigious "big science" in China with "national" characteristics, which was comparable to genomics research in the United States (ibid, p. 313). In particular, Chinese scientists such as He Fuchu proposed to the committee of the HGP, a subsequent Human Liver Proteome Project (HLPP) and China hosted it to secure the participation of China in the HGP (see He, 2006, 2011).

Liver research has been and still is a major research field in Chinese medicine. He (2006) proposed the HLPP due to the fact that hepatitis was a problem in China. After the HGP, China established four large-scale HLPP[20] research institutions one being the Beijing Proteome Research Centre which joined the HLPP in 2004 (ibid). It became one of the most invested research centres among the "Giant 4" of quantum mechanics and nanotechnology in China (Chee and Clancey, 2013). Over the past two

[20] Large-scale methods include a large number of technologies to identify large sets of data (Hackett et al., 2008).

decades, systems biologists and Chinese medicine scientists have increased their investigations into liver diseases (see, for example, Jiang, 2005; Zhang et al., 2010; Yao, Li and Pei, 2013). These studies have applied genomics, proteomics and metabolomics in order to detect the effect of a *fufang* on a person's metabolism (Angelova et al., 2008, p. 10). With genomics and subsequent omics technology, these studies have produced a wide range of genetic, protein and metabolic data from *in vivo* and *in vitro* studies that examined physiological effects after the intake of a *fufang*.

Cybernetics developed and split into many disciplines. That said, systems theory remained a cardinal theory in systems science and the evolving field of systems biology. Whilst those interviewed claimed there is a similarity or sameness between systems theory and holism as demonstrated in the first part of this chapter, the development of cybernetics showed that cyberneticians and systems scientists employed holism in *Zen* Buddhism and Indian yogi practices and spirituality as an alternative to the reductionist and mechanists view in the 1970s. Bateson, Walter and Stafford integrated systems theories to exceeded the physical form of a brain or other substances and materials into interrelationships in the body, i.e., as a homeostasis system, or with nature or cosmos, i.e., as the mystery of God. During the counterculture movement, cyberneticians and promoters of Eastern philosophies influenced each other.

Systems biology, in the cybernetic and genomics trajectory developed as an interdisciplinary field with different research and disciplinary foci. In the first part of this section, I presented the systems biology's trajectory in cybernetics and physiology, which partly prepared the second trajectory of systems biology in genomics. These trajectories formed the multi-disciplinary character of systems biology. Alon (2007) argues that systems biologists recognise the value of interdisciplinary work, e.g., from mathematics, biology, chemistry, physics and computing to examine and calculate interactions on a molecular basis to answer the question what life is. The integration of various disciplines was displayed in the co-operative work between engineers, chemists and physicists to reveal and encode relationships between RNAs, transcriptomes, proteomes, metabolomes and interactomes from large datasets irreplaceable (Auffray et al., 2003). From the above, it is evident that systems biology is a multi-disciplinary pedigree of cybernetics, physiology, genomics and molecular biology. From those disciplines and through the engagement and integration systems thinking in cybernetics and systems science and of holistic approaches in Eastern philosophies the new field systems biology emerged.

4.4.4 The import of the old holism into Chinese medicine and China

The previous section showed the crisis in biology regarding molecular biology and the significant role that Eastern philosophies played in solving this crisis by importing holism into systems science and cybernetics. When systems biologists imported the Chinese medicine holism, they did not distinguish that, what they considered as “old” holism, was in fact the holism that was imported in the 1950s from Europe into Chinese medicine. In this section, I will give a brief history of holism and then discuss two groups which integrated holism and systems thinking into Chinese medicine. The first group integrated dialectic materialism and holism into Chinese medicine theory by following the political agenda of the CCP. The second group employed systems theory into Chinese medicine.

To give a brief summary of the development of holism, Scheid (2016) shows in his paper *Holism, Chinese medicine and Systems Ideologies* that the common genealogy of holism in Chinese medicine and systems biology started before and during the interwar years (the 1930s), respectively. In the eighteenth century, holism emerged in Germany from the interaction of two different understandings: the cultural/structural and idealist, and the second was based on science, processes and materiality. The cultural/structural holism derived from idealist philosophers, such as Herder, Humboldt and Kantian, who viewed cultures as distinct parts that intimately connect and work together as a whole with its members contributing in unique ways. Scheid (2016) further claims that Hegel developed historical dialectics that underpinned history, emergence and process. Friedrich Engels criticised Hegel’s historical dialectics in 1972 and created his scientific holism (ibid). Engels claimed that Hegel’s historical dialectics lacked the interrelationships between all parts of the world and the temporary character that constitutes history. Scheid (2016, p. 68) argues that Engels suggested a “science of interconnections” to understand the world as processes and dynamics that formulate scientific laws and organise principles to reveal the world as emergent relationships to humans. Hence, Scheid claims that holism is a concept that has its beginning in idealism, which Engels supplemented with the importance of emerging properties.

Tonietti (2003) argues that in ancient Chinese science, the concept of holism is unknown. In his view, the dual role of *yin/yang* as holistic and opposites was not inherent in Chinese medicine and science before Chinese medicine scholars implemented them for political reasons in the 1950s (ibid). What Tonietti (2003) asserts about holism in Chinese medicine is not to be confused with Ren Yinqiu's argument, stated above, that Chinese medicine did not understand the material substance of life. Chinese science has always been interested in the correlations between phenomena from the Daoist's perspective. Daoism viewed natural phenomena as an infinite cycle of transformations, which were unstable movements and changes that generated beginnings and ends in the whole universe (ibid). Therefore, Chinese medicine received Daoism's notion of transformation and change which penetrates and transforms into each other and, thus, eliminates any dualism. Hence, Tonietti (2003) claims that any distinction between the components is undefinable as they continuously transform and interpenetrate each other without becoming static. He concludes that the implementation of dialectic materialism and holism affects the dualistic or oppositional character in Chinese science and medical theories.

Many scientists and researchers may disagree with Tonietti (2003), however, some studies agree that holism in Chinese medicine was integrated in the 1950s to assimilate and distinguished Chinese medicine from Western medicine (see, for example, Scheid, 2016; Hsu, 1999). Scheid (2016) links the origin of the concept of holism to late eighteenth century Germany and which was further expanded on by Engels and which claims that everything in the world is interconnected through scientific laws and principles that form emergent relationships. In the following, we will see how Engels' idea was implemented in Chinese medicine.

In the early Communist era, Chinese medicine scholars followed Mao's instructions and introduced dialectic materialism and holism into Chinese medicine to assimilate and differentiate their medicine to the epistemic level of biomedicine (Scheid and Karchmer, 2016) as well as a strategy of resistance against Western imperialism

(Scheid, 2016). Besides the political aim to integrate Chinese and Western medicine (1958-1959) at that time, Scheid (2016) and Hsu (1999) claim that due to the new connotation of the classical Chinese medical conception of *yin/yang,* the discrepancy between the two medicines increased.

Chinese medicine scholars embedded the translation of holism (*zhengti guannian* 整体观念) into the *yin/yang* theory. As Scheid (2016) found, in Chinese, the term holism (*zhengti*) was a loanword borrowed partly from Mao Zedong and Ai Siqi (1910-1966), a Marxist philosopher and populariser of dialectic materialism, who worked on Engels' dialectic materialism as well as on Buddhism and the translation of holism, which means "the conception of the wholes". *Zhengti* stands for the "whole" coming from Mao's *On Practice* and *On Contradiction* works (Scheid, 2016; Hsu, 1999). The Buddhist expression *guannian* is translated as the "direction of one's attention" (Scheid, 2016, p. 69). For the assimilation of dialectic materialism, Mao and Ai used the notion of *tongbian* 通变, which means "interpenetration of opposites", to grasp the dynamic of the relationships that constitute the world. By doing so, they changed Engels' focus on the matter of things to processes of change and transformation (*biantong* 变通) (ibid).

The first implementation of Engels' dialectic materialism into Chinese medicine followed the instruction of Mao Zedong to accomplish the main political aim of modernising Chinese medicine (see Huang, 1962). Scheid (2007) views Qin Bowei, as the first Chinese medicine practitioner who applied dialectic materialism into the *yin/yang* theory of Chinese medicine. Qin (1955) explained in his article that *yin/yang* is a dialectic principle in which the two are conflicting but also interpenetrating each other. Therefore, they support Qin's thesis that they are transforming opposites that create a unity between the body and its environment (ibid). To verify his theory, Qin used the characters of *yin* 阴 and *yang* 阳 as an objective reality and categorised the body into different sections which also vary according to the perspective of the observer. Eleven papers were published after Qin's paper in 1955. Among them were Fang Yaozhong 方药中, Ren Yingqiu 任應秋, Ran Xiaofeng 冉小峰, Xiao Xi 萧熙, Zhang Juying 張巨應 (Scheid, 2002a). Both Qin and Ren explained dialectic materialism through the transformation of *yin/yang* and its interrelationship between the body and the environment.

In his article, Scheid (2016) claims that first Qin and his colleagues employed the theory of the "Unity of Opposites" (*duili tongyi* 对立统一) in Mao Zedong's essay *On Contradiction* and generated a (proto-)science of Chinese medicine and textbooks for students. In Qin's 1964 article, he demonstrated that holism in dialectic materialism offered a theoretical framework to refashion Chinese medicine. With *yin* and *yang*, he classified symptoms and patterns and systematised Chinese medicine by its functions, transformations and the differentiation between interior and exterior, depletion and repletion, hot and cold as well as ascend and descend (see also Qin, 1955). Scheid (2016) asserts that Qin's systematisation became later known as the system of "pattern differentiation" (*bianzheng lunzhi*). He believes that *bianzheng* is the exchange between the understanding of a relational world by using the notion of "interpenetration of opposites" (*tongbian* 通变) and Engels theory on "dialectics" in Chinese medicine (ibid). Hsu (1999) argues that *bianzheng* affected a new way of explaining physiological and mental phenomena in Chinese medicine.

The integration of holism in the form of Engels' dialectics materialism in Chinese medicine is, to quote Scheid (2016, p. 71), "expunging all traces of the origins of this accommodation in the specific political context of the 1950s, Chinese medicine physicians today read European holism and dialectics back into ancient texts without experiencing any apparent sense of discontinuity". He refers to the issue that dialectic materialism and holism were well integrated into the context of Chinese medicine theories and that they do not reveal any difference to *Huangdi neijing* and the *Yijing* (易经 *Book of Changes*). They became intrinsic concepts in Chinese medicine (ibid). The oppositional character of *yin/yang* differentiated Chinese medicine from European philosophies and medicine while Chinese medicine was assimilated with *yin/yang* and dialectical materialism to European theories. Other Chinese medicine scientists employed cybernetic theories to explain the function of *yin/yang* (see Qiu, 1982, 1987).

The second group of Chinese medicine practitioners integrated systems theory in Chinese medicine. Since the 1960s, they scientifically discussed Chinese medicine's five elements theory (*wuxing*) and the congruence of *yin/yang* with the black box theory in cybernetics (Qiu, 1982). Qiu (1982, 1987) claims that, in 1960, Ren Shu first applied cybernetics in Chinese medicine acupuncture and reinterpreted it with information theory. For example, Ren explained meridians (*jingluo* 经络) as information channels, and acupuncture points (*xuewei* 穴位) served as generators of information. Secondly, Ren Shu related *yin/yang* and *wuxing* to feedback theory. He assigned *yin*, as the interior, to the number 1 and *yang*, as the exterior, to the number 0. His hope was that a computer could use the translation of *yin/yang* and calculate a diagnosis one day (Qiu, 1982). These studies preliminary established the philosophical attempt to explain Chinese medicine theory that advanced until the proclamation of Deng Xiaoping's three sciences (see Chapter 2).

The integration of systems thinking resurfaced again in the 1980s when Deng Xiaoping proclaimed a new effort to evolve the domain of TCM with cybernetics, systems theory, and information theory started with the initiative of political leaders at Chinese TCM colleges (Fruehauf, 1999). Additionally, Chinese medicine practitioners were confronted with the abolition of *yin/yang* and *wuxing* theories by the supporters of an integrated Western and Chinese medicine. Thus, Chinese medicine practitioners aimed to accommodate systems thinking as a seamlessly integrated part in Chinese medicine. For example, Lü Bingkui (1981), a practitioner, called on Chinese medicine students to study medical systems theory for the further development of Chinese medicine, however, in this case to preserve the context of the old wisdom of Chinese medicine. He claimed that Chinese medicine was a system of relationships between nature, human and heaven and that pattern differentiation correlated with systems thinking by arguing that diseases are always connections of various processes in the human body (Lü, 1981). Subsequently, Scheid (2002a, p. 82) claims that Lü not only influenced a reinterpretation of Chinese medicine theory with his interventions, but he also sought "to preserve and promote the independent character of Chinese medicine". Hence, Lü linked Chinese medicine with the systematic and regulative concepts of systems theory.

Chinese cyberneticians and systems thinkers supported the integration of systems theory in Chinese medicine. Qian Xuesen (also written as Tsien Hsue-shen) 钱学森 (1911-2009) and Zhu Shina 祝世纳 strongly emphasise the importance of cybernetics in Chinese medicine as it demonstrates the scientific nature of Chinese medicine (see Scheid, 2014). According to Wang (2011), Qian Xuesen is one of the most important scientists in Modern China. Qian Xuesen is known as the father of China's ballistic missile, rocket and space program (ibid). Since the 1980s, he engaged with the integration of cybernetics in Chinese medicine due to the increased attention Chinese medicine was gaining at that time from foreigners and other cyberneticians (see Jiang, 2005; Xu, 1999; MacPhail, 2009). Qian delivered a method that was holistic and provided a solution to interlock ancient Chinese wisdom with modern Chinese science, but which also attracted foreigners to investigate other practices, such as *Qigong* 气功 (see Hsu, 1999; Xu, 1999). However, the inferior quality of *Qigong* studies led to the label of Chinese medicine as "pseudo-science" (Xu, 1999, p. 966-967). Scheid (2014) considers that, since then, Chinese medicine has become a scientific field trapped in the perception of being a pseudoscience.

Researchers found that Qian Xuesen was interested in the application of a shared holistic perspective with cybernetics and systems theory in Chinese medicine (Jiang, 2005). Qian proposed an "open complex giant system" as a new method to transcend reductionism by advancing holism. By building on "image thinking" (*xingxiang siwei* 形象思维) of *zheng* as a whole body examination method, Qian and Dai (2007) established sub-models for diagnosis.

To this end, Qian and Dai (2007) gathered information from the experiences of the practitioners with the four examinations (observation, interrogation, auscultation and olfaction, and touching the pulse and palpation) and collected classical texts. They compared the results from the diagnosis with the classical texts to find an "image" of the diagnosed *zheng*. This was similar to the translation of Chinese medicine diagnosis with pattern recognition, which van der Greef et al. (2010) described in his first trial as connecting mass spectrometry with computer software. According to Qiu (1982), image thinking led to computational diagnosis studies which aimed to verify Ren Shu's hypothesis of the 1960s on the calculation of a Chinese medicine diagnosis with the fuzzy and probability theory (see, for example, Guo et al., 1981). Although Chinese medicine researchers lacked appropriate software, the experiment set a further step in the computational approach to Chinese medicine. Therefore, Qiu's (1982) findings show that the idea of computational modelling existed already before the encounter with systems biology.

From what has been discussed in this section, holism was integrated into Chinese medicine in the 1950s when Chinese medicine practitioners and researchers interpreted Mao's policies of modernisation as dialectic materialism and systems theory in Chinese medicine. Although both groups used different methods, they reached the same conclusions that cybernetics, as well as holism, were compatible with Chinese medicine concepts. Hence, the relationship between Chinese medicine and systems biology derives from the long processes of integration which took place before the first studies on systems biology and Chinese medicine were published in 2005 by Wang et al. and Shen.

4.4.5 The many personal East/West connections

An investigation into the shared ideology of systems thinking and holism between Chinese and Western scientists was based on the parallel evolvement of cybernetics in both the East and the West between 1930 and 1960. Links between the US and China, and medicine and Eastern philosophies, strongly influenced cybernetics and the juxtaposed field of systems science, which set the corner stone of systems biology. Thanks to the co-operation of the Chinese electronic student Li Yurong 李郁荣 (1904-1989) and Wiener, a connection between Chinese and American cyberneticians facilitated the invention of one of the fundamental theories in cybernetics, the wave filter theory in 1934 (Wiener, 1994). Additionally, through their co-operation early cybernetics was introduced in China in the 1940s and in fact predated the "emergent interface".

The first contact between Chinese and American cyberneticians was in the 1930s before Wiener (1994), von Neumann and Morgenstern (1944) and Shannon and Weaver (1949) published the first books on cybernetics. Chinese exchange students, for example, Li Yurong, Qian Xuesen, Song Jian 宋健 (1932-), Guan Zhao Zhi 关肇

直 (1919-1982) and J.C. Yang (1919-2006) studied and worked closely with pioneers in this field from the early 1920s to 1960s. Li and Qian, for instance, worked with the mathematician Norbert Wiener. Song was a student of the famous control theorist Alexander Aronovich Feldbaum in Moscow and Guan worked with the mathematician Maurice Fréchet in France (Chen and Cheng, 2007; Greenhalgh, 2008). Secondly, through the co-operation of Wiener with Li, two fundamental theories in cybernetics were formed: the “wave filter” and the “prediction theory”. In 1934, during Wiener’s visiting professorship at the twenty-five years old Qinghua University in Beijing, the two scientists formulated the wave filter theory (see Wei, 1996; and Masani, 1990). Li, at that time was a young professor at Qinghua University and he assisted Wiener with an analogy-computing machine and electrical feedback understanding, to develop the wave filter theory based on harmonic analysis of probability calculation in 1934 (see Wiener, 1994). The theory was used to improve radar systems during WWII by filtering out disruptions in incoming messages and later for information technology, such as televisions (see Ilgauds, 1984). Li trained and established one of the first cyberneticians and institutions in China (see Peng, 2004).

The second connection between cyberneticians in America and China was through Qian Xuesen. According to Wang (2011), Qian received his Master of Science degree at the M.I.T in 1936 and his PhD in 1939 at the California Institute of Technology (Caltech). His return to China was during the Korean War (1950-1953); thus, the Federal Bureau of Investigation of the U.S. accused him of spying during the Cold War for the Communist Party as an ally to the Soviet Union and Qian’s expertise in rocket science. After his detention, Qian returned to China in 1955 and served his country as a missile and rocket scientists and lead various nuclear-weapons and space (*liangdan yixing* 两弹一星) programs. He also played a significant role in the progress of technical science. His career was supported by the PRC’s twelve-year plan, which aimed to develop science and technology (Cao, Suttmeier and Simon, 2006; Peng, 2004). In the 1930s, cybernetics was mostly transferred from America to China. However, in the 1960s, the political alliance between China and the Soviet Union changed the situation, and as a result, the student exchange programmes offered between China and the Soviet Union increased together with technological imports. The Soviet political connection led also to the import of the Soviets’ theories as they were already formulated in a socialist framework.

The dissemination of cybernetics happened at various levels in China. Chen and Cheng (2007) remark that Li and Qian set up cybernetics departments and societies in China to teach and instruct students and researchers in this new field. Peng (2004) argues that the excellent reception of cybernetics in China was influenced by the philosophical implications of cybernetics, e.g., the behavioural function with concepts of control, feedback and information. Chinese medicine researchers and modernisers found that the philosophical component resonated with the Chinese philosophy of harmony between human and nature and the *tianren heyi*, which the Chinese were keen to explore.

In summary, the second part of this chapter described the relationship between Li Yurong and Qian Xuesen with US inventors of cybernetics and the dissemination of cybernetics in China in the 1950s and 1960s. It is important to note that not only scientific and technical interest played a crucial role in the dissemination of cybernetics in China, but also the philosophical commonalities with *tianren heyi*. In general, the implementations of feedback theory, wave filter theory and missiles shaped the Chinese research landscape and paved the way for an "interface" between Chinese medicine and systems biology. In particular, cybernetics permeated into Chinese medicine theories and became organically blended into Chinese medicine in the last decades of the twentieth century.

The almost seamless integration of systems theory and holism in Chinese medicine seemed to have faded into oblivion in the twenty-first century. However, those processes of integration facilitated the correlation between systems biology and Chinese medicine. Thus, actors in the Chinese medicine and systems biology research assumed that the similarity originated from the ancient Chinese medicine and earlier forms of biology (see, for example, Li, Yang and Gong, 2009; van der Greef et al., 2010; Wang, Zhang and Sun, 2012; Xu et al., 2013; Guo et al., 2014). Nevertheless, the rhetoric of holism in this relationship lacks specification. Actors often refer to ancient Greek philosophy and Aristotle (van der Greef et al., 2010) or Plato and Hippocrates (Wood, 2010; Weber and Esfeld, 2003). Despite the variation in the origin, they all use Aristotle's definition of "the sum of the whole is bigger than its parts" (Zelko, 2013).

The above-stated literature survey reveals that holism and systems thinking in Chinese medicine were adapted versions of holism. In the early twentieth century, Western scientists avoided this term after it was used by Nazis and in the apartheid movement. Nevertheless, by connecting it with old Chinese medicine theories, it became an “old” holism for Western systems scientists, while it was a “new” concept for Chinese medicine. Cybernetics and systems theory were melted into Chinese medicine in the same way as holism was integrated in Chinese medicine. They became an integral part of Chinese medicine concepts, beyond the recognition of systems scientists and later systems biologists. The historical integration indicates why most of the interviewees denied an “interface”, as both systems thinking developed into systems biology and holism melted into Chinese medicine in the last century through the influence of cybernetics.

5. INVOLVEMENT IN CHINESE MEDICINE AND SYSTEMS BIOLOGY RESEARCH

As we have seen in the previous chapter, the emergent "interface" arose from a pre-existing structure of systems thinking that was transmitted through cybernetics in Chinese medicine and systems biology during the twentieth century. This chapter will answer the research question of how the actors became involved in Chinese medicine and systems biology research. Episodic interviews together with thematic coding were the primary methods used to address this question. This chapter therefore focuses on interviews and descriptions of involvement, and has been divided into four codes according to the presentation of how actors became involved in Chinese medicine and systems biology research. The codes are (i) technological and health problem, (ii) search for complexity, (iii) family and exploitation of Chinese medicine and (iv) discontentment with a reductionist presentation of medicine and health.

The question of involvement in systems biology and Chinese medicine is driven by the following two decisive issues in this research:

- What motivated, inspired or fascinated scientists to risk their reputation by engaging with Chinese medicine and systems biology?
- How did they deal with the bias of Chinese medicine as pseudoscience?[21]

The question of why scientists with a reputation and rank in academia would risk their career was interesting in the context of the increasing pressure on scientists for professional achievements, which related to publications in high quality academic journals, such as *Science* or *Nature*. According to PubMed (2019), these journals have only recently started to publish articles on Chinese medicine.[22] From this viewpoint,

---

[21] The connection of Chinese medicine with pseudoscience was discussed in Chapter 4, see also Xu 1999; Scheid, 2014.

[22] In a research on the platform *Web of Science* with the search criteria journal "Science" and the term "Chinese medicine" resulted in eight articles of them were published two on the history of Chinese medicine and hospital care in Tianjin before 2003. The other six were published after 2003 on the examination of Chinese medicine. The data were collected on January 4, 2019 (see PubMed, 2019).

the question about the involvement of the actors in the research on Chinese medicine and systems biology is of crucial interest in this study and will be elaborated on in this chapter.

The label of pseudoscience has been attached to Chinese medicine since the introduction of science in China in the early nineteenth century and still exists to this day (Ward, 2011). Ward (2011) claims that the dualism of science/pseudoscience appeared when China started to associate biomedicine with science and the returning Chinese students from Japan introduced the Japanese word *ke* (meaning "making things orderly"). These students experienced public health movements in Japan, which initiated the implementation of Western medicine in the Japanese healthcare system. In China, the request for the implementation of Western medicine into the healthcare system peaked during the May Fourth Movement which occurred in 1919, and with the attempt of Yu Yunxiu and his proposal to abolish Chinese medicine in 1929 (this was discussed in Chapter 2; see also Ward, 2011; Lei, 2014; Andrews, 2014; Scheid, 2002a). The struggle between Chinese and Western medicine continued in the twenty-first century when opponents of Chinese medicine called in China for the abolition or exclusion of Chinese medicine from the medical system. The last attempt to abolish Chinese medicine was carried out by Professor Zhang Gongyao 张功耀 in 2006, he based his argument on the fact that Chinese medicine was a backward and farcical medicine (Ward, 2011). Overall, all the implementations and alignments with Western science by Chinese political agendas during the twentieth century, have not guaranteed the scientific status of Chinese medicine, neither in China nor overseas. This highlights the importance of the question of how scientists in Europe dealt with the label of Chinese medicine as a pseudoscience in their involvement in Chinese medicine research. In describing and analysing the themes gained from interview data, I will reflect on the effect the association of pseudoscience has had on those scientists and their Chinese medicine research.

In this chapter, I will present the involvement of four actors who learned about Chinese medicine before they professionally conducted their first studies on systems biology and Chinese medicine in the early 2000s. The four actors are Prof Frank, Dr Huang, Kevin and George (see Table 2 for a detailed description of the Chinese diagnosis project). They decided to engage with and study Chinese medicine for a number of reasons: health problems, interest in complexity presented in Chinese medicine, the exploitation of Chinese medicine and discontentment with the reductionist representation of health and diseases. Their interest in Chinese medicine in the first place was not influenced by external factors such as research projects or funding. These actors hoped to find an alternative approach to study life and complexity and they wanted to regulate the pharmaceutical production of Chinese medicine. These scientists were interested in the complexity of Chinese medicine, which they related to Chaos Theory[23] and they aimed to approach Chinese medicine with mathematical, statistical and computational methods coupled with omics technology. Due to their role as the initiators of Chinese medicine and systems biology research and the fact that they aimed to change approaches in medicine and healthcare, I call these actors the inner circle.

When I introduce each actor, I will first give a brief description of the actor, I will then offer some data from the interviews on the involvement of actors in Chinese medicine and in systems biology and I will end by showing the involvement of actors in Chinese medicine and systems biology research. At the end of this chapter, I will conclude with the characteristics of their involvement. Due to ethical requirements, all names in these case studies are pseudonyms that correlate to the position of the actor, i.e., Professor.

[23] Chaos Theory is a "the qualitative study of unstable aperiodic behavior in deterministic nonlinear systems", such as nature, which is used in mathematics and physics (see Bishop, 2017, p. 5 of 42).

5.1 INVOLVEMENT THROUGH TECHNOLOGICAL AND A HEALTH PROBLEM

Prof Frank is a systems biologist who works with biotechnology and omics technology in a pharmaceutical institute and his own systems biology company in the Netherlands. He demonstrates an involvement first in systems biology through his technological keenness and in Chinese medicine through a disease that could not be treated with biomedicine. His involvement in Chinese medicine is connected with his interest to bridge the gap between unrelated disciplines or technologies and to investigate human and nature as interconnected. For him, systems biology is not only a bridge, but also a tool to investigate systems, which are central to Chinese medicine, but which are missing in Western medicine.

The first involvement of Prof Frank was in systems biology research, which started with his research on mass spectrometry and the measurements of molecules involved in biological pathways. His research contributed to the development of the main technique used to analyse biofluids in Chinese medicine studies. However, in the 1980s, when he conducted experiments for his PhD, the problem with the available techniques, as defined by Prof Frank, was that he could only analyse a small number of unknown properties or chemical components to match them with a small number of samples. The process was slow and inappropriate for the identification of big data sets. His idea was to overcome this bottleneck with the new method of biofluid profiling and pattern recognition. For this, he used multiple technologies such as the PDP-8 minicomputer as an electric control unit, specific software for the analysis, electronics for emission control and an ion formation for the mass spectrometry and chromatography. With the connection of these technologies, he measured atom masses through ionisation and analysed them with statistical, mathematical and computational methods. The combination of these technologies accelerated the analysis process from a few hundred to 1000 samples a day, and enabled lower weight molecular compounds to be measured in blood serum, urine, saliva and semen. Together with statistical tools for drug administration he corrected individual differences by profiling metabolomics. Hence, he bridged hitherto unrelated technology that enabled him to assess multiple variables in his study to gain a pattern of the variables for further examination as needed for Chinese medicine drugs studies.

Prof Frank's change is owing to a conceptual shift in biology. Prof Frank demonstrates this shift by using computer software to analyse and illustrate the data and measuring technologies, and by debating his undertaking with his colleagues and supervisors who were against his technological experiment. Prof Frank defended his standpoint as a systems theorist by applying a complex and systems approach and multiple techniques and mathematical tools. Former systems theorists (e.g., van Bertalanffy) criticised as they believed they reduced its biological complexity (Green and Wolkenhauer, 2013). At the time of this experiment, systems biology was an unknown concept or discipline, however, according to the description of Green and Wolkenhauer (2013), the integration of mathematics and systems theory to describe biological phenomena was already the shift from biology to systems biology. This results from their interpretation that systems theory is the precursor of computational modelling of quantitative transformations. According to their definition, Prof Frank is a forerunner of today's systems biology practice.

Prof Frank does not view the development of omics as an invention. He argues that the technology and the methods he and other scientists used in the 1980s were the same as those used during the later renamed omics techniques or technologies in the 2000s. The use of several techniques, i.e., genomics, proteomics, transcriptomics, were holistic and built the new field of systems biology (see Chapter 4 for more information on systems biology) as he explains:

> "… the profiling of blood and looking at many things, looking at patterns, already started in 1980, but the names were not there, like metabolomics, became a word because everybody wanted to say a word with omics for something, so this is just trendy. So certainly, protein analysis became proteomics, and then people say okay metabolite analysis must become something, so they said now it is metabolomics or metanomics, or people start to invent new names, basically because people want to have new names so they can claim something, a new word." (Prof Frank, 2015, Leiden)

Despite Prof Frank's opinion on the use of the name omics technology, his colleagues were against his first experiment which aimed to prove his hypothesis using a multivariant analysis, which utilised multiple technologies. His colleagues objected to his project which aimed to determine the gender of urine samples as they thought that he would deliver more unknown variables that could not be related to adequate objects. As a result, it would not be considered sound science. Nevertheless, the doubts of Prof Frank's colleagues did not stop him from undertaking an unsupervised blind study of ten urine samples from female and male co-workers. In doing this experiment, he proved his hypothesis to his colleagues and gained their support and to publish his results. Without knowing which metabolite would express the gender, he discovered that in some samples the steroid levels were higher than in others. Thus, he concluded that those were male urine samples. With this method, he confirmed the obvious that more variables meant more information about the sample and allowed him to see a pattern that determines biomarkers for the prediction of diseases. Later, based on the evidence for his urine identification method, Prof Frank started his biofluid metabolomic analysis. His vision was to establish a personalised medicine with the insights gained from biofluid examination of Chinese medicine diagnosed and treated patients.

The connection for Prof Frank between systems biology and Chinese medicine is that they both acknowledge the idea of holism. First, the dominating reductionist paradigm restricted Prof Frank to use holism in the context of systems biology and Western science. Due to the development to reductionism in science in the last century, holism has become negatively associated with Nazism, apartheid and with the counterculture movement. As shown in Chapter 4, most scientists relate holism to non-science or CAM. Consequently, Prof Frank could not use the term "holism" in biological and pharmaceutical studies. Western scientists and doctors were ignorant to inform themselves about Chinese medicine or the meridian theory because according to Prof Frank they did not fit into the box of Western science and medicine. As he says:

> "I think systems biology existed already for a long time because that's a holistic view on life, but at this point in 2000... nobody wanted to use the word holistic although I think it is a better word, but it is not accepted in the scientific world. If you use it, then you are a complementary, alternative, or a crazy type. So, if you choose that word, you cannot use it. It still has a similar effect on Chinese medicine. Some Western doctors are interested in Chinese medicine and others think that it cannot be true. And if you ask them, why it cannot be true, they say, well because, in theory, it doesn't fit to anything, it is just ridiculous. Then you ask: Have you ever read any manuscript? They reply never. So how do you place your opinion on that? Yeah, I am talking about strange meridians that don't exist. They don't understand the difference between concepts or physical items, or they don't know how to translate it into their own world." (Prof Frank, 2015, Leiden)

One of the ways to translate Chinese medicine into Western science was facilitated by the Human Genome Project (HGP) project. From Prof Frank viewpoint, this project is an excellent example of the domination of reductionism. He argues against focusing on DNA sequencing in the hope to find out what is life what he calls the "mystery of life". Biologists, cyberneticists and systems biologists widely discuss the question of what is life. For instance, Noble criticised the HGP as a failure in answering this question (see Chapter 4 and Noble, 2010). Instead of searching for the answer in genes, Prof Frank refers to nature, systems theory and an ecological viewpoint that increased his interest in other perspectives of life.

> "Then the Human Genome Project (HGP) came. The HGP people believed that if we know the sequence of DNA, we have solved the mysteries of life. That was how it started. For me, it was very strange. We used this in our presentation often, if you have a caterpillar it starts to eat and eat, and then it becomes a butterfly, but the gene sequences are still the same, so there is much more to this than just the gene sequence. You have to look at it from a more holistic perspective a more systems perspective. Then, I also started to become interested in other philosophies as to look at it from a systems perspective." (Prof Frank, 2015, Leiden)

Prof Frank refers to the "ecological" viewpoint of the physicist and populariser of systems science Fritjof Capra and his book *The Tao of Physics* (1975), whom I have introduced in Chapter 4 as one of the key actors in making holism interesting to a new generation of scientists. In his book, Capra argues that physics and the "unity of all things" (a Chinese Daoism concept) agree in the idea that all things in the universe are interconnected and there are no fundamental parts in it, which Capra calls the "ecological worldview" (Capra, 1975, p. 291). Prof Frank underlines this ecological worldview by saying that he looks for relationships in patterns of nature, which indicates that nature and life cannot be deducted from a DNA sequence. In his words:

> "I was doing analytical research and trying to understand systems since the 1980... and I was very much into nature, I like to study nature. When I see nature from an ecological perspective, I look at connections and patterns of relationships. That is how I look at nature. That's why I try to understand why nature is doing things as it does because after all everything is linked together. So, from that perspective, I stepped more and more out of reductionist framework." (Prof Frank, 2015, Leiden)

To overcome the reductionist limitations and the genomic hype of the 2000s, Prof Frank and some other researchers founded a systems biology company. They aimed to conduct research that went beyond the HGP and the increasing number of genomic studies by focussing on systems theory and using a holistic approach. However, the mind of funders and researchers was not open to holistic studies or Chinese medicine research, as the focus was on biotechnological research and genomics, which I have shown in Chapter 4. In Prof Frank's case, this was evidenced by showing the difference in the funding budget between his company which had five million dollars and Leroy Hood's Systems biology Institute which was funded by Bill Gates with one hundred million dollars. In contrast to Prof Frank, Hood followed the genomics research trend focusing on functional genomics, which might have influenced the higher funding than Prof Frank obtained.

Strong genomic and reductionistic interest also prevented Prof Frank from conducting holistic and Chinese medicine studies. Hence, he decided to divide his research interests into conducting profitable pharmaceutical research with his company, and Chinese medicine studies at his second research institution. Prof Frank argues that the research interests and funding for drugs and drugs modification studies increased. Wiechers, Perin, and Cook-Deegan (2013) confirm that this was an unintended side effect of the HGP, which was designed as an intergovernmental public funded project. They found that besides the public funding twice as much money was sponsored by private firms in genomics research and development (R&D). This also related to the expansion to DNA patent rights by 2000. Thus, biotechnology and genetic research developed to a business for private R&D and academic research market (ibid). Academics and governmental research institutions recognised this market and increased their research activities in pharmaceutical studies. As a result, Prof Frank supported financially his company with pharmaceutical studies and in his second workplace, in the food and nutrition department, he conducted holistic and Chinese medicine research. Prof Frank claims that:

> "When we started a company in 2000, nobody wanted to do anything else than to work for the Western pharmaceutical industry because that was where the money was. So, we had to make a contract with the other institution at a point in time. The investors and I said, well, because I was on both sides, the most logical was that only the pharmaceutical applications of our knowledge went into the company. That's how we were rewarded, but everything else related to food and Chinese medicine was not part of the company." (Prof Frank, 2015, Leiden)

The above-mentioned paragraph talks about Prof Frank's second involvement in Chinese medicine research. Before, this project he came into contract with Chinese medicine because of a health problem.[24] He underwent a treatment in Chinese medicine as biomedical doctors could not treat him. During his treatment, he learned about Chinese medicine, in particular, the idea of the interrelationship between humans and nature, which resonated with his ecological worldview. Moreover, Prof Frank experienced for the first time in his life, since he had suffered from the disease, that a doctor addressed his strengths and not his weaknesses. The optimism of the practitioner towards Prof Frank's condition and his strength despite his disease was a unique whole body and mind experience. This experience confirmed Prof Frank's perception of Chinese medicine as an integrated body and mind medicine. In addition, the positive attitude of the practitioner influenced Prof Frank's thinking to accept his condition and to work on his whole body and not only on the diseased parts. Hence, against the prediction of biomedical doctors, Prof Frank did not die or become disabled because Chinese medicine aided his recovery. His experience with Chinese medicine demonstrated the capacity of Chinese medicine to him and sparked his interest to learn more about it. As a result, he scientifically studied the efficacy of Chinese medicine, which he had perceived as a higher-level understanding of systems view and holistic view, with technologies (mass spectrometry and gas chromatography), which he had been using since the 1980s.

In the 2000s, Prof Frank started his research on Chinese medicine and confirmed his first observation that Chinese medicine thinking corresponded to his ecological worldview. In addition to his previous perception of the Chinese medicine human and nature relationship, Prof Frank interpreted the ecological worldview of Chinese medicine by stating that everything alive has a rhythm even diseases and ailments. He claims that Chinese medicine had used this perspective for a long time while in Western medicine it had not yet been addressed.

[24] Due to ethical reasons the diagnosis is not mentioned here.

> "I was really interested in Chinese medicine because it has rhythm; it has symptom relationship; it has a holistic view of not only a person living within an environment and a certain climate. So, the person relates to the universe. That is what you see in Chinese medicine. That is why I was interested and it. So, if you look at your own diseases or ailments, you see there is always a rhythm in it because all life has rhythm. So, Western medicine has almost no clue about rhythm, so it always measures one-time-point." (Prof Frank, 2015, Leiden)

Prof Frank's interest in Chinese medicine extended from a private interest to a professional reorientation. However, he found it difficult to cross the border between biomedicine and Chinese medicine, as it was a change between two professional worlds and from reductionism to holism. Although Prof Frank described himself as an audacious man with much experience in science and publications, he did not publish anything about Chinese medicine in a biomedical field until the 2000s. His first publication demanded much courage, as scientists in his field were depreciative towards Chinese medicine, in particular in a biomedical institution. This refers to the connotation that Chinese medicine is something alien or is a pseudoscience, in the sense that it is clearly not biomedicine, and not acknowledged as its equal to be studied at a biomedical institution. This is evinced by research on the integration of East Asian medicines in contemporary healthcare systems that document a power imbalance between biomedicine and other medicines in clinics and research (Cassidy, 2013). Consequently, Prof Frank decided to show the relationship between Western methods and concepts and Chinese medicine with the use of Western measurements:

> "We first had to collect the courage to publish. That is also something I need to explain because you cannot publish things in a Western world without much aggression against what you publish because Chinese medicine is not accepted in Holland as such and I am here also in a faculty with a lot of medical people. So, they are not in favour of this. The steps we took were that we do Western measurements and all time we show their Western and Chinese concepts, which are telling or guiding us to do new things." (Prof Frank, 2015, Leiden)

According to Prof Frank, a problem that frequently arises for those trying to understand Chinese medicine is that people cannot connect Chinese medicine to something they know, or they can benefit from it. Thus, he suggests the prediction of a disease can be made through the pattern recognition in Chinese medicine diagnosis and the technological support of metabolomic profiling and biomarkers, that signify certain conditions and biochemical processes. By using these techniques, Prof Frank believed that he could gain data to present Chinese medicine to biomedical doctors and Western scientists in their scientific language. The bridge between Chinese medicine and Western measurements, as he clearly states, is biochemistry that allows the prediction of a condition. Thus, it offers scientists a new interpretation technique of biomarkers and a biochemical translation of Chinese medicine, which could resolve the ignorance of scientists and their bias against Chinese medicine as an alien system. Prof Frank hoped that it would help them change their attitude to this medicine and become aware of the insights that can be gained through the different perspectives of this medicine. As Prof Frank argues:

> "People don't want to read about the meridian theory because it is too far out. If they see that biochemistry fits with meridian theory, they say that's strange and if you say but look, we can even predict what you don't know and can test it... That's how we did our research. Like, you have patients with the same disease, Chinese doctors say there are two groups, then we measure those two groups and we figure out what the biochemistry behind the disease is. Then we have the bridge... [and when they ask] why haven't we found it? That's very simple because you have never looked at it from this perspective." (Prof Frank, 2015, Leiden)

Prof Frank's professional involvement in Chinese medicine was also influenced by Dr Huang, who is his partner and a Chinese medicine researcher and molecular biologist, whom I will introduce below. She played an essential role in Prof Frank's involvement in Chinese medicine research as she proposed a co-operative research project to study Chinese medicine. Prof Frank's description of Dr Huang's role in this co-operation denotes the function of a gatekeeper, as someone who gained access to key people in China, such as the vice president of the Chinese Academy of Science (the function of a gatekeeper and a list of gatekeepers can be found in Table 3). According to him, the vice president shared her ideas of systems biology as a tool to measure Chinese medicine and to bridge Chinese medicine with biomedicine. Thus, the vice president supported Prof Frank and Dr Huang by connecting them to Chinese collaborators who in fact helped them realise their project on the investigation of Chinese medicine diagnosis with systems biology.

Prof Frank's involvement in Chinese medicine research was in his words something good that happened to him, to quote him: "That's how the universe made it happened". Several events happened in his life that led to his study of Chinese medicine. These events were connected with the development of technology to study systems and his eagerness to conduct systems biology research after Kitano coined the term in 1996 (see Chapter 4) as well as his interest in Chinese medicine as the source of knowledge and the meeting with Dr Huang.

5.1.1 Reflections on the technological and health problem involvement

Prof Frank's involvement takes more space in this chapter as it establishes the type of involvement for the actors in this chapter, the inner circle of the research on Chinese medicine and systems biology. Prof Frank's involvement demonstrates his interest in bridging technology and medical systems, his personal therapeutic experience with Chinese medicine and his risk of losing his reputation as a scientist. Prof Frank used the notion bridge as a rhetorical device and as a technological tool. On a rhetoric level, Prof Frank uses the term "bridge" to define his function in connecting various technologies, as well as bridging systems biology and Chinese medicine with systems thinking and holism. He understands that life and nature are complex, and he discovered that Chinese medicine was a medical system that shared both his perceptions and his ecological worldview. The Chinese medicine worldview recognises life as rhythm, as holistic and complex. Prof Frank experienced this having undergone a Chinese medicine treatment after a fatal biomedical diagnosis. This experience urged Prof Frank to regain the control over his body after the recovery of this disease. Thus, Chinese medicine led him to realise the limitation of biomedicine and science and consequently, he reconsidered his scientific approach to health and diseases. Prof Frank's notion of "bridge" also includes the interpretation that he bridged his experience with his professional life by engaging with Chinese medicine research.

The second definition of the term "bridge", which Prof Frank describes, is with regards to the use of technology in systems biology which translates Chinese medicine into Western science. His first involvement in systems biology equipped him with the technology and methods needed for the study of complex systems and for establishing connections between technologies, scientific fields (i.e., biology and chemistry, computation, mathematics) and Chinese medicine and its tenets. Through the use of technology, he connected the two practices of Chinese medicine and systems biology and was able to translate Chinese medicine concepts with Western measurements into biochemistry. With this translation, he drew the attention of Western scientists to his research and gained their favour by applying this technique to the investigation of individual diagnosis in Chinese medicine to calculate and predict diseases with systems biology. Thus, Prof Frank's endeavours and his capacity to act in this way were attached to and emerged from his previous interactions with omics techniques and systems theory.

Prof Frank's involvement in systems biology and Chinese medicine research contained risks of failures. These risks were apparent in his experiment on several technologies for the analysis of an unknown substance, i.e., the identification of the gender in urine samples. As well as the challenge he faced when engaging with a pseudoscientific medicine without losing his reputation as a scientist. In his involvement with systems biology, he controlled multiple variables in this experiment which depended on his ability to interpret the capacity of multiple technologies that he joined together with the data he collected. In later studies on big data set, theories and philosophy, he achieved with this method a successful study in Chinese medicine diagnosis with metabolomics. However, there was no guarantee that biomedical and Chinese medicine scientists would accept his approach. With systems biology and technology, he bypassed the debates surrounding Chinese medicine as scientific and holistic through his translation of Chinese medicine into big data and his analysis of multiple compounds in Chinese medicine. Consequently, Prof Frank performed an involvement that was not dominated by his need to publish or improve his scientific ranking, but because he felt the need to personalise medicine. Zhang and Wang (2017) found that Chinese researchers suffer from the pressure to publish, which impacts their research performance. This pressure was not seen in Prof Frank's involvement. In contrast, he and Dr Huang had to collect their courage to publish the first research article on systems biology and Chinese medicine.

In the early 2000s, funding and research interest was not open for holism and Chinese medicine studies, consequently, Prof Frank and Dr Huang had to consider their publication. The debates on holism and Chinese medicine research in his company and the lack of funding for genomics, demonstrated the narrow research support. Due to this research environment, the articulation of Prof Frank's and Dr Huang's interest to his scientific community was challenging. This also happened at a time when molecular biology was integrated as a fundamental method in biology (see Chapter 4). Likewise, Lei (2014) argues that in the early twentieth century, “practitioners of Western medicine were simply unable to trust Chinese medicine drugs unless they had successfully been ‘translated’ into the socio-technical network of biomedicine” (2014, p. 201). Thus, Lei indicates a similar tension to today’s situation between Chinese medicine, biomedicine and science as they do not receive a non-biomedicine system openly, but rather see it as a pseudoscientific medicine. From Lei’s example, it is evident that an attempt was made to align Chinese medicine research to Western science which was then pursued throughout the twentieth century. The main difference between the 1920s and the 2000s is that Western scientists are involved in producing evidence for the translation of Chinese medicine into a Western scientific context.

The next code presents an involvement from Chinese medicine to Western science and back to Chinese medicine entangled with both mathematics and systems science.

5.2 Involvement through complexity

Kevin's involvement in Chinese medicine and systems biology was inspired by "complexity" (this is connected to the Chinese philosophy of Daoism). Kevin is a Chinese medicine practitioner, biochemist and AI scientist who is keen on Chaos Theory. Kevin's involvement in Chinese medicine research and systems biology started with his interest to find a Western scientific field that embraces complexity similar to the Daoist representation. In doing so, his involvement presents a detour from Daoism, Western science, Daoist implementations in Chinese medicine to systems biology study that led him the connection between complexity represented as *qi* and systems biology through dynamic self-organising systems.

Kevin's first contact with Chinese medicine happened at the age of 11 through stories about Daoism and *qi*. These stories were told to him by his neighbour and a Chinese restaurant owner Mr La[25]. Informed by those stories and some knowledge of Chinese medicine, he became interested in Daoism and the consciousness as both have been, and still are, examples of complexity for him. Following this, Kevin then studied biochemistry, but he questioned the reductionist method and its capability to study the complexity neurons and neurotransmitter, but not the complexity of the consciousness. Interestingly, he did, however, think that Western science simplified and reduced complex matters, which in the end did not reflect reality as a complex phenomenon. It was evident that he distanced himself from the counterculture movement, i.e., the Hippies, on the West coast of the United States as complexity is often associated with holism and this movement. In Section 4.4.3, I elaborated on the connection between complexity as a holist approach and the counterculture movement. Kevin explicitly avoided a connection to this movement as he claims that Western science and scientific aspirations grasp complexity only with Chaos theory.

[25] This name is a pseudonym.

Due to the reduction of complex issues in biochemistry, Kevin decided to study mathematics and Chaos Theory and he found out that they were the closest to the complexity of Daoism. Following on from this, he realised that to understand complex thinking, he needed to study Daoism and Chinese medicine. For this, he attended several acupuncture classes and moved to China to study Chinese medicine from 1985 to 1990. He believed by studying Chinese medicine, he would experience the central aspect in Daoism, the *qi* and the *dao* 道. Then, with a deeper practical-based understanding of *qi* and *dao,* he could bring together the two ways of thinking systems science and Chinese Daoism. He utters:

> "The dynamic self-organisation of nature is similar to the stories of Chinese Daoist philosophy, so I thought I have to do this course. So, I did a course in acupuncture then I went to China for a small course, three months on Chinese philosophy. And in Chinese philosophy, they said you have to do Daoist philosophy. I had to choose between martial arts or Chinese medicine to learn Daoist philosophy and to experience it and not to study it from the book. You cannot read Laozi, or Zhuangzi in the way you read Socrates, Plato, or Nietzsche, and you have to experience *qi* and the rhythm of *dao*. So, I thought Chinese medicine is maybe the thing which is closest to my biochemistry. So, this is why I choose Chinese medicine, and actually, I stayed there for four years to study Chinese medicine." (Kevin, 2015, Zeist)

At the end of his studies, Kevin wanted to continue with his research on complexity. He believed that Chinese medicine with its holistic approach was the ideal field to do so. However, the studies of Chinese medicine in China employed a Western medicine framework. Kevin found it distracting and misleading that Chinese medicine researchers at his university did not want to investigate Chinese medicine based on its own conceptual framework of *qi* and the interconnection with the human body. In contrast, he felt that they were only interested in modern science, and they radically evaluated the theories and practices of their medicine with Western scientific methods to make it appropriate for biomedicine. He claims their approach "violates" Chinese medicine, as they apply more and more Western science into the teaching and research practice of Chinese medicine. As an explanation for this radical approach, he believes that this approach was caused by the transition from Chinese medicine to TCM, which the CCP and Chinese medicine researchers created during the integration and standardisation phase. However, in Chapter 2, I showed that the transformations of Chinese medicine were not only caused by something they were effects of the political agenda and the interpretation and realisation of Chinese medicine practitioners and scholars. I demonstrated this with the example of acupuncture neuropathology and anatomy and in Chapter 4 and the explanation of *qi*, *yin/yang* or *wuxing* with dialectic materialism and cybernetics. Kevin explains this with the metaphor of a ball being squeezed into a cube:

> "Western research is like a cube, and everything I do as a researcher within the cube is science but at the moment I walk out of the cube it is not science anymore. So, now I have this rubber ball, which is Chinese medicine, and I have to prove to the world that this ball is a ball by showing it can roll and it can bounce, but I have a cube, so I take this rubber ball and press it, squeeze it into my cube. Because it is a rubber ball it fits in but by fitting it in it takes it out of shape now, it cannot bounce anymore, and it cannot roll, so I prove that this ball is not a ball, and this is continually happening when we start researching Chinese medicine with the Western methodology." (Kevin, 2015, Zeist)

When Kevin realised that the shift to modern medicine had taken place, he tried to find answers from practitioners in the countryside. This happened after he finished his Chinese medicine studies and he was confronted with the fact that Chinese medicine researchers were not interested in questions concerning the complexity of the *qi* and its pathway of meridians. In contrast, the practitioners in the countryside were not referring to Western science, physiology and pathology, which pleased him. The practitioners and their energetic pictures disclosed to Kevin that *qi* is the overall concept that explains the whole human body and the system of acupuncture. It shocked him that his teachers at the university taught him a concept of meridians that practitioners in the countryside told him did not exist. When he shared his discovery with his teacher at the university, the teacher was unimpressed and claimed to have known that. Kevin had to accept that the concept of meridians is unnecessary as *qi* is everywhere in the body and does not need a passageway to move in the body. This explanation of *qi* activated a reconsideration of the theory of meridians for Kevin:

> "And he said you have to see it as a concept and then I started to think that channels are the lines on which an organism organises itself around. An acupuncture point is an attractor on which tissues and functions are arranging themselves in relationship to other parts of the body, which have their own attractors, and so you get a very complicated picture. And then I saw that acupoints and channels are actually the connection between skin, muscle, bones, nerves and the physiological system, all the things we separated from each other, the meridians are the connections between them all. So, I was convinced that we can cut up as much as we want but we will never find channels. In that way, because everything is a channel, everything is *qi*, because it is all about relationships, thus, it starts slowly to emerge from itself." (Kevin, 2015, Zeist)

Once Kevin understood that *qi* was complex, and it was not restricted to or followed channels in the body, he returned to Western science. Kevin realised that *qi* is everywhere and does not need channels. Following that he started to relate *qi* to Western science, even though he first criticised Chinese medicine researchers for their eagerness to practice Western science. Kevin related *qi* and the acupuncture point theory to systems thinking. This evoked his understanding of the human body and its cells as a dynamic self-organising system, which was grounded in systems thinking and directed him to systems biology. Hence, systems thinking was a bridge between complexity and systems biology.

The idea of dynamic self-organising systems connected Kevin and Prof Frank. In the early 2000s, Prof Frank and Kevin met at a conference where they presented their ideas on living organisms as dynamic self-organising systems and systems biology. Their shared idea of systems facilitated a research co-operation between them. According to Kevin, the idea of dynamic self-organising systems derived from von Bertalanffy's systems theory. Von Bertalanffy (1968) claims that cybernetics is the theory that controls and regulates, as it is based on information and feedback theory that show that systems are self-regulating. Originally Ashby (1958) formulated the theory of dynamic systems which von Bertalanffy employed. In Ashby view, "dynamic" describes the changes in correlation between the high and the low surroundings state of a system. Hence, a self-organising system is a system that evolves from a lower to a higher complexity by progressively differentiating between the states of the organisation. Based on this theory, Prof Frank stresses the relationship and interaction between different levels and the dualities within an object. While Kevin refers to the opposite inside an object, which are changing the states of their organisation. For example, the day is *yang* which changes at dusk into the night, which is *yin*. The number of relationships between the cells organised on a cell level, tissue level and organ level in the human body represents the complexity of the cell organisation in his comparison of dynamic self-organising systems. Kevin sums up his theoretical exploration by arguing that Chinese medicine research needs systems thinking approach:

> "So, we need to find another way of understanding this whole system of components to develop multi-target pharmacology, which can approach complex and chronic diseases as we are encountering it now in our time. So, this is why we are forced to systems thinking." (Kevin, 2015, Zeist)

Systems thinking approach accomplishes his idea of complexity in Chinese medicine and in the methods used to investigate it, namely systems biology. Systems biology and dynamic self-organising systems theory are grounded in systems thinking and they embrace complexity. Hence, Kevin views research between Chinese medicine and systems biology as being technical, philosophically and culturally attractive and links it to Daoism as an integral part of Chinese medicine.

5.2.1 REFLECTIONS ON THE INVOLVEMENT THROUGH COMPLEXITY

In Prof Frank's involvement, we saw an expected way of experiencing Chinese medicine and its effects first hand and, how he became curious and interested in studying it. Unlike Prof Frank, health issues or technology did not spark Kevin's involvement, but the desire to learn about complex thinking, which he could not find in bioscience. Prof Frank focused on biochemistry and changed very late in his career to actively research Chinese medicine. Kevin, however, took a detour as he was involved in Western science and Chinese medicine but his interest in complexity, drove him to research systems biology and Chinese medicine. Another contrast with Prof Frank, is that Kevin does neither view himself as a bridge builder nor does he use the notion of "bridge" to describe his involvement in Chinese medicine or systems biology. The use of systems thinking in systems biology and the dynamic self-organising system appears as a bridge which inevitably links Kevin's approach to Prof Frank's systems biology.

Kevin's interest in complexity not only triggered his involvement, but it also controlled his involvement in Chinese medicine and systems biology. Law and Mol (2002) describe complexity as a matter, multiple realities, an interest of researchers or a status. He presented an organic but cyclical progress from the question of complexity to his professional status as a Chinese medicine practitioner. During this process, he changed from Western science to Chinese medicine and then he explained the Chinese medicine concept of *qi* with a systems theory. Complexity is a crucial topic for him, and this guided him from Daoism to biochemistry and mathematics. What is more, his involvement represents a process from his understanding of complexity in Daoism and Chaos theory to dynamics self-organising systems. By studying Chinese medicine, he refined complexity in Daoism into the two concepts *qi* and *dao*. Only by gaining this experience, he was convinced that he would understand complexity. In Chapter 2, I mentioned that *jingyan* 经验 has two meanings of either the experience as in prescribing drugs or the experience in the practice of Chinese medicine (see Lei, 2014; Farquhar, 1994). Thus, *jingyan* can define both experience and practice. Following on from his experience with Chinese medicine, Kevin understood that the matter of *qi* was the representation of complexity and to study its movements he returned to Western science, in particular, to systems biology. Thus, *qi*, as well as complexity, are the centre of his involvement and which controlled his development from childhood until now. This interpretation directed him into another involvement, namely his Chinese medicine and systems biology research with Prof Frank.

5.3 FAMILY AND THE EXPLOITATION OF CHINESE MEDICINE INVOLVEMENT

Dr Huang demonstrates her involvement through family and exploitation concerns. She is a molecular plant biologist who studied molecular biology for her undergraduate degree in Beijing at a TCM university and specialised in herbal plant biology. Dr Huang and Prof Frank were co-operation partners in their first Chinese medicine and systems biology study. For Dr Huang, the study of Chinese medicine appears as a realisation of the profession of her family and a way to protect Chinese medicine from exploitation.

Dr Huang's involvement in Chinese medicine started with her grandfather who was a Chinese medicine practitioner and introduced her to his profession. Her interest, however, was more in the scientific evidence production of Chinese medicine herbal drugs. This rhetoric is similar to the CCP's policies of scientificising and the increasing production of Chinese medicine propriety medicines, which are Chinese herbal drugs that were transformed into biomedical drugs. A discussion on this can be found in Chapter 2 on the globalisation phase and Deng Xiaoping's economic reforms during the 1980s and 1990s (see also Hsu, 2008, 2009). Concurrently, in China, a new infrastructure was introduced. This included Chinese medicine pharmaceutical research at Chinese universities and at Chinese medicine pharmaceutical industries together with new research on active compounds to produce Chinese propriety medicine and exchange program with other countries (see, for example, Hsu, 2009; Evans, 1997). In this context, her decision to study Chinese medicine pharmaceuticals rather than Chinese medicine might have been informed by these policies and emerging job opportunities for Chinese students at home and abroad. The new exchange agreements aided Dr Huang in particular to gain a scholarship from China for her cell biology and genetics doctoral study in the Netherlands. She describes the structure of the scholarship as an intergovernmental exchange agreement between China and the Netherlands. A report on fifteen years of co-operation between the Netherlands and China shows that an exchange agreement was signed in the early 1980s and is presented in Chapter 6 (see Ariën and van Genugten, 2012).

Dr Huang's involvement in active Chinese medicine research started after she achieved a high-level position in her field. Her career took a conventional career route in academia as she started as an assistant professor at the University and as a research leader in a governmental research centre. In the research centre, she headed a division for plant biotechnology and with a small group she started to investigate the therapeutic effect of Chinese plant metabolites. She explains this change through her work in food, nutrition and plants that directed her to study Chinese medicine in the 1990s. Once she had performed research on Chinese medicine plants, such as the harvesting time differences on a Chinese medicine plant *ginkgo biloba* she started co-operation with pharmaceutical research centres.

In her research centre and that of her collaborators, Dr Huang had the technological equipment for genetics, proteomics, and metabolomics studies. This technology is what she describes as the "newer technology", and which became widely available after the international HGP and the growth of biotechnology (see Chapter 4; see also Wiechers, Perin, and Cook-Deegan, 2013; Chee and Clancey, 2013). This technology facilitated Dr Huang to conduct her research in Chinese herbal medicine, as well as her research team to study plant metabolites. When she discovered that her colleague, Prof Frank, used omics technology and was interested in Chinese medicine, she approached him to discuss a co-operation on Chinese medicine with systems biology research. Prof Frank agreed to the collaboration:

> "In 2000, I met Prof Frank, and I told him that I was interested in working on the traditional Chinese medicine. Moreover, at that time he was also interested in it and then we started within the research centre an internal project on the Chinese medicine and the biological effects with a successful result. It demonstrated that all animal models that worked for Western medicine have for sure the same therapeutic effect as Chinese herbal medicine and Chinese herbal medicine worked even better with fewer side effects." (Dr Huang, 2015, Leiden)

For Dr Huang, Chinese medicine and systems biology were a perfect match, as they both used systems thinking. Hence, she views systems biology as an equal partner for the holistic studies of Chinese medicine. However, in this combination, Dr Huang first expects that systems biology will prevent the repetition of past exploitation of Chinese medicine in the 1990s in the course of the commercialisation of Chinese medicine. Secondly, she mentions that Chinese medicine and its concepts are used to understand biology. Dr Huang believes that Chinese medicine is already advanced enough to help biologists in their research and to aid them understand what life is and to discover how to diagnose better and treat diseases. Dr Huang's collaborative work with Prof Frank focussed on these issues. As more and more systems biologists adopt the viewpoint of Chinese medicine and she assumes that this change will stop the exploitation. Hence, she views the research interest in systems biology and Chinese medicine as a positive change.

> "Some of them have quite good interactions between Chinese medicine and systems biology, and others just use Western technology with the hope to get the target. Then you have different peoples who interact with Chinese medicine. Some of them think Chinese medicine concepts can guide some to understand the biology. Others are trying to get the component of Chinese medicine and use Chinese medicine as a sort of pool to fish out what they want. Both of them are quite interesting; both of them can get the results they want." (Dr Huang, 2015, Leiden)

In her view, it is important for researchers of Chinese medicine to deal with the complexity of multiple compounds in one *fufang* or individual prescriptions and other influences, e.g., differences in harvesting condition, preparations, storage and decoction of Chinese medicine drugs. Thus, systems biology with the use of omics technology equips her and other researchers, with a holistic approach to study changing life cycles (i.e., the effect of environmental conditions and cycles) of Chinese medicinal plants and the effect of the *fufang* in the human body. However, Chinese medicine should, in her view, not be used as a kind of pool where pharmacologists can fish out what they want. This problem was noted by many traditional medicine researchers over the past decades (see for example, Adams, Dhondup and Phuoc, 2010; van der Valk, 2017; Baer, Singer and Susse, 2003). This concern drove her to participate in further research projects on Chinese medicine drug safety, research practice and drug regulation and control, as we will see in more detail in Chapter 7. She hopes that a shared ground in complexity and systems thinking between systems biology and Chinese medicine will stop or prevent the further exploitation of Chinese propriety medicine commercialisation as was witnessed in the 1990s. As a result, she argues that a holistic investigation needs to respect Chinese medicine as a system, and not as a new drug development source. In this point, Dr Huang acknowledges that Chinese medicine and biomedicine have something in common.

5.3.1 Reflections on the family and the exploitation of Chinese medicine involvement

Dr Huang's involvement in systems biology appears as an organic development as she has already used omics technology in her plant research projects. Systems biology was neither a technological nor a conceptual bridge for Dr Huang as she thinks of both fields are the same. Her perception that both are the same derives from the integration of systems thinking in the Chinese medicine theoretical and educational system in the 1980s and 1990s (see Hsu, 1999). When she studied at the Chinese medicine university, she learned those theories as an integral part of Chinese medicine, thus, her education in molecular biology, systems thinking, and Chinese medicine make it easy for her to draw connections between systems biology and Chinese medicine and to view them both as the same. Nonetheless, technology was a bridge between Chinese medicine and biology, which was intensively used in her research. As a molecular biologist and experienced with Chinese medicine, it suggests itself that biology had to learn from Chinese medicine to surpass the limitation of understanding life and to apply more systems thinking in biological approaches.

Overall, Dr Huang's involvement was not driven by her desire to understand complexity or what life is in biological terms, which was the case for Prof Frank or Kevin, instead it was the desire to prevent exploitation and regulate Chinese medicine drugs production and commercialisation. Similar to Kevin's involvement, at a young age, Dr Huang was introduced to Chinese medicine and returned to it after she achieved a good position at the university in a research centre.

5.4 Discontent in the reductionist presentation of medicine and health involvement

The student George is another gatekeeper (Prof Carl, Dr Huang, Lingma) and he supported this thesis with crucial information on the networks in Chinese medicine and systems biology research (for more information on George, see Table 3, gatekeeper 4). He was a medical biologist before he joined Prof Frank and Dr Huang's PhD program. His involvement demonstrates a discontentment in the reductionist presentation of medicine and health in biomedical studies. He criticises the limited attention to the complex issues of life and social disparities that increase inadequate healthcare for poor people. His vision was a holistic approach to medicine and science; hence, he changed from biomedicine to alternative approaches:

> "I first realised the limitations of the reductionist view of biology and science as a whole when I was still at University around 1995… I studied medical biology, and at the time I had the idea that the way it was taught in university was too reductionist and too many details and didn't have real connection what is going on your life." (George, 2015, Leiden)

George was frustrated with the issue that social and psychological problems were not reflected in the curriculum of life sciences and medical studies. His definition of health, however, is similar to the definition of health given by the World Health Organisation (WHO) from 1946, which states: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 2016). The WHO's defines health not as a status in the absence of any ailment, psychological or social influences. Consequently, the attention to psychological and social factors as influences on health, was lacking in education and was not considered general knowledge, while it was a stated issue in the WHO definition. Therefore, George criticises the disconnection between theoretical and educational understanding of medicine and health. In his view, medical education and practice do not teach or work with the complexity of life and health. Mainly he observes the effects of this problem in healthcare systems that are affected by policies that undoubtedly do not address a holistic approach. Thus, he suggests changing the political system, which, in his opinion, eradicates the problems in society.

His frustration with the reduction of knowledge and information in medical studies caused him to leave academia and to find a job where he could contribute to healthcare. While he worked for different organisations on complementary and alternative treatments, he also learnt *Taijiquan* 太极拳, a physical practice of Chinese medicine that works on *qi* as energy in his body and is also a martial art. Through *Taijiquan*, he learned about Chinese medicine. The practice of *Taijiquan* helped him to understand health as being more than a medical intervention, but as an awareness of the body to cultivate and maintain a healthy condition. When George realised the effectiveness of *Taijiquan,* he wanted to share his findings to help the people and so he contacted Prof Frank. He asserts that:

> "So, I practised *Taijiquan*, and I noticed that I could use it actually to monitor my own body for things that are stiff or stuck. I can use it as a tool to help myself and also later all of us. So, that got me interested and then I met someone who worked at an organisation and is still working there. He founded a kind of collaboration between China and the Netherlands, and he wanted to study Chinese diagnosis and using systems biology techniques to do that. Yeah, I got in contact with him, and that got me kind of into this scientific field at that time." (George, 2015, Leiden)

The learning of *Taijiquan* and the insights he gained, resonate with Prof Frank's idea of health. Prof Frank was familiar with George's publication on CAM systems, and he was keen on his expertise and thinking and to have him on his team. Therefore, Prof Frank invited George to join his Chinese medicine diagnosis project as a PhD student.

5.4.1 Reflections on the discontentment involvement

George's involvement with Chinese medicine research arose from his discontent with the reductionist approach in medical practices and education, the limited perspective of what is and the struggle with social disparities. Hence, he presented a similar path to Kevin's search for complexity in medicine. He is also similar to Prof Frank in that he had the desire to change medicine and healthcare.

George's viewpoint on capitalism in medicine is comparable with Dr Huang's argument on the commercialisation of medicine and herbal drugs. They recognised that the commercialisation of drugs benefited rich people. National and international pharmaceutical companies stole from poor people through overharvesting natural resources, which are valuable supplies for indigenous people as they are used for medical treatments. This phenomenon is described as biocapitalism by Helman (2007) and discussed in more detail in Chapter 2. Thus, George strongly presents the problem of the impact of reductionistic view in medicine and on health. He views alternative medical systems and their holistic view on health, as well as their emphasis on the self-maintenance and self-regulation of the organism, as essential knowledge that needs to be integrated into medical healthcare. This should happen together with the integration of social and psychological factors on health. Thus, his drive was to change the healthcare system by starting with the transmission of knowledge on alternative treatments to perceive health through a biopsychosocial construct.

5.5 Conclusion

The identified actors Prof Frank, Kevin, Dr Huang and George revealed both personal and active involvement in Chinese medicine and systems biology. Their involvement is characterised by personal contact with Chinese medicine before they professionally engaged with Chinese medicine and systems biology research. They experienced through many different ways such as *Taijiquan*, family members or a disease the first contact with this medicine. Consequently, this personal experience informed their decision to change their professional research area to Chinese medicine research. In general, their involvement was inspired by the desire for a change in the dominating reductionist paradigm found in science and medicine to a more holistic approach. As a result, they found that Chinese medicine and its acknowledgement of complexity and holistic thinking, could establish new approaches to research diseases and also to cease the exploitation of Chinese medicine. They also believed that by understanding Chinese medicine, a new approach to medicine and life could be gained and this, in turn, could aid the reduction of costs in healthcare.

The actors were fascinated by the understanding of life in Chinese medicine and its practice which accepted complexity within its concepts. Chinese medicine concepts appeared as worthwhile, to be implemented into modern scientific practice and to change healthcare systems. The question they asked over ten years later was how they could gain more information from experiments and then interpret them in relation to the whole system of the organism. The idea to learn from Chinese medicine and philosophy inspired systems scientists in the 1970s when they started to integrate Eastern philosophies in the early brain research as I elaborated on in Chapter 4.

In the early 2000s, the inner circle hesitated to publish a Chinese medicine article in bioscientific journals and through a biomedical research institution. The main reason for their hesitation was because Chinese medicine was not a topical field for bioscientists to research, nor was it widely recognised as a research or publication area in the West. For example, a high-quality journal *Science* had only published six articles on Chinese medicine since 2003. Thus, it was evident that the motivation for the inner circle's involvement in Chinese medicine research was not related to publications, as argued by Zhang and Wang (2017). Zhang and Wang affirm that professional success is often assessed through research performance, citation indexes, industrial co-operation, together with research and economic performance in competitions for funding and positions. Subsequently, a person's personality and interests can play a secondary role in the struggle of "selling" his or her research through publications and patents. Zhang and Wang's research concluded that scientists only undertook research that was economically profitable, which, interestingly was not detected at the beginning of the involvement of the inner circle.

Technology in contrast did support the achievement and performance of a scientific study. While omics technology was not a driver for their motivation to study Chinese medicine, it was a tool to convey their ideas to the Western scientific community and to perform a scientific study on Chinese medicine. Systems biology with systems thinking, metabolomics and pattern recognition facilitated them to scientifically research Chinese medicine by interpreting patterns in personalised Chinese medicine diagnosis. This combination revolutionised the profiling of metabolites in *zhengs*. Due to the past studies of the inner circle in biochemistry, molecular plant biology and medical biology, they were familiar with the technology used in systems biology and they were convinced that it would facilitate them achieve their aims.

The recognition of Chinese medicine in the Western scientific community was also apparent in the terminology the actors used. Terms like "holism", "Daoism", "rhythm", "body and mind unity" or "complexity" appeared in many of my interviews with systems biologists. They used these terms to describe their personal involvement in Chinese medicine research. According to Asprem (2015, p. 549) these terms were frequently connected to pseudoscience or esotericism and were seen as a return to "a deeper, spiritual understanding of the cosmos". The use of terms like "holism" by systems biologists indicated a wish for a more holistic research approach to understand the human body and nature. The actors also described Chinese medicine as an ancient medicine that preserved its practices and wisdom despite rapid political, economic, scientific and technological development during the last century. Their vision was to discover a holistic approach to health and diseases for developing new research and clinical methods based on the personalised diagnosis and treatments of Chinese medicine. This, then, should aid the recovery of healthcare systems, the protection of

Chinese herbal drugs and the establishment of a personalised medicine. For the actors or the inner circle, their involvement in Chinese medicine and systems biology changed their approach to medicine and their way of practising science in the long-term to more holistic research.

The next chapter will demonstrate the involvement of the actors and the development of their research on Chinese medicine and systems biology through laboratory practice and industrial ties.

6. LABORATORY PRACTICE AND INDUSTRIAL TIES

In Chapter 5, we saw how the actors became involved in Chinese medicine and systems biology research. I described four involvement (Prof Frank, Kevin, Dr Huang and George) in Chinese medicine and systems biology research. They were the first actors who proposed the research of Chinese medicine with systems biology, and who laid the groundwork for this research which included the use of omics technologies, research proposals, and types of co-operation.

This chapter will answer the research question of how the human and nonhuman actors participated in Chinese medicine and systems biology research and influenced the development of the relationship between Chinese medicine and systems biology. The data includes material from participant observations and interviews conducted in Dalian and Harbin in China and Tokyo, Japan during a four months period in 2016 (see Table 1 for fieldwork schedule and Figures 2 and 3 for connections between the sites). This chapter focuses on the involvement of the actors and has been divided into three codes: (i) the co-operation projects between Dalian and Leiden, (ii) laboratory practice and technology in the Harbin site, and (iii) funding and industrial ties of both the Dalian and the Harbin groups.

This chapter describes the involvement of Prof Yu, the Leiden collaborator in Dalian, his PhD student Lingma and a post-doctoral student Long (for more information on Prof Yu, Lingma and Long's project on Lipidomics research, see Table 2). In Chapter 5, I presented the involvement of George, Prof Frank's and Dr Huang's PhD student, in Chinese medicine and systems biology. This chapter demonstrates George's participation as a PhD student in the Chinese medicine diagnosis research project of the Leiden group. The actors from the Harbin site were Prof Xiong, the head of the department of the metabolomics centre, his assistant professors Ang and Xing, his PhD student Ruili and an undergraduate student Yuxi (see Table 2 for more information concerning the Chinese metabolomics project).

Additionally, the two systems biology experts Prof Musashi and Prof Meng will provide insights into the technological limitations of conducting systems biology studies. Following the ethical regulation, all names of the actors are anonymised with pseudonyms that only reveal their academic position, e.g., Professor.

6.1 CO-OPERATION PROJECTS

This section demonstrates the involvement of the collaborators in a research co-operation between the Netherlands and China. The Dalian institute is part of the Chinese Academy of Sciences (CAS) and due to its high reputation in new material research, it frequently conducts highly confidential military research. Its relationship with the military derives from its location in Dalian, a province in the Northeast of China. In the history of Chinese medicine, Dalian is known for its anti-plague efforts during the Manchurian plague epidemic of 1911/12 (see Rogaski, 2004; Lei, 2014).

The institute in Dalian was a collaborative partner with the Leiden group in the Netherlands. The contact between the partners started in China, in 2003 when Prof Frank and Dr Huang introduced the research project. During their trip, Dr Huang and Prof Frank first contacted the vice president of the CAS who suggested Prof Yu and his metabolomics team in Dalian as a co-operation partner. Prof Yu was a molecular biologist who focused on metabolomics research in biomedicine. Dr Huang knew Prof Yu from their time at the university in Beijing and from his publications. Thus, she was convinced that Prof Yu would meet the research criteria for the investigation of diagnostic methods in Chinese medicine. Accordingly, Dr Huang functioned as a gatekeeper 2 in this network (see Table 3 for more information concerning her role) with ties to influential people in China through her upbringing in China, as she claims:

> "In fact, I have my colleagues, I have my classmates, who are in different functions in China and who are all in the field of biology and medicine. So, I kept in contact with them. They are in influential positions within China. That also helped to build up my own network in China. That was the reason why I also know the Minister of Health so well, and I also know the Minister of International Co-operation from the Chinese State Administration of TCM." (Dr Huang, 2015, Leiden)

In 2005, Prof Frank and Dr Huang set up the co-operation under the CAS-Royal Netherlands Academy of Arts and Sciences (KNAW) Joint PhD Training Programme. Dr Huang said that she built this co-operation on, I quote "The research quality and also the trust between each other on a human basis". Her trust on a human basis was built on the fact that the partners in China were her acquaintances, see in the above-cited quote. Secondly, her trust in Prof Yu's research quality derived from the time they studied together period and her attention to his research publications. Interestingly, the term “trust” was in the title “Based on Science, Built on Trust” of the fifteenth anniversary report of the CAS-KNAW agreement (Ariën and van Genugten, 2012). The title suggest that trust was important ever since the first co-operation between the Netherlands and China occurred in the 1970s, at a time when China’s political and economic situation was unstable due to the Cultural Revolution and Mao’s death (see Chapter 2 and Scheid, 2002a). According to Ariën and van Genugten (2012), the CAS and KNAW funded several collaborations between China and the Netherlands, including the Leiden-Dalian research projects between 2007 and 2013 (see Table 2 for project details). Other sponsors were the Chinese and the Dutch governments, the Chinese and the Leiden University, a governmental organisation and Prof Frank’s and Dr Huang’s life sciences company. This indicates that trust was not a unique criterion for the Leiden-Dalian co-operation but for all KNAW and CAS funded projects.

Notably, Prof Yu had no prior experience in Chinese medicine studies. According to Prof Yu’s PhD student Lingma[26] and Prof Yu’s curriculum vitae, Chinese medicine research was an unfamiliar research topic for Prof Yu. Prof Yu’s expertise was in chromatography. In the 1990s, Prof Yu conducted his PhD project on chromatography at the Dalian institute. During the co-operation with Leiden, he obtained funding from the NSFC for six years of research (see Appendix A for details about the NSFC funding). With this funding, he invested in technology and its advancement. For example, Prof Yu’s labs were equipped with liquid chromatography machines, such as gas chromatography, Capillary Electrophoresis Systems, and diagnostic instruments for Cancer research. The lab purchased machines from global omics suppliers, for example, as the US companies Thermo Fisher Scientific, ABI Applied Biosystems Inc., Waters Corporation, Agilent, Leco, Micro-Tech Scientific, Beckham and the Japanese company Shimadzu. The amount of technology in the laboratory indicated a strong focus on the application of technology in his metabolomics research.

[26] Lingma was among the first PhD students in the joint research program between Leiden and Dalian from 2007 to 2013. She recommended further actors and fieldwork sites for this research (see Table 3 under gatekeeper 3).

George, the Leiden PhD student, was involved in this joint research program and made a similar observation about Prof Yu's technological equipment and the funding:

> "They had the most advanced and brand-new machines in the lab. They had much better and more advanced equipment than we had in Leiden. The machines were good. I think they also had more experience in keeping the machines or let's say running the machines so the technical aspect in getting the thing working. It is interesting because it seemed that the government wanted to spend a lot of money on research in China. And the professor that we had contact with he just got a really huge grant and they kept buying stuff. So, it is maybe easy to buy machines, but then experience and knowledge are hard to get. That takes time." (George, 2015, Leiden)

Lingma explained that Prof Yu's lab with all its technological equipment was sponsored by the Chinese government's "Hundred Talent Project". The Hundred Talent Project was founded by the Chinese government with the purpose of recruiting distinguished Chinese scholars overseas and getting them to return to China and to develop China's economic and scientific infrastructure (Yao, Li and Pei, 2013). According to Yao, Li and Pei (2013), 81% of the members of the CAS were funded by the Hundred Talent Project (ibid). They argue that since 1994, the Chinese government offered incentives that included laboratory space, start-up packages and positions as Principal Investigators for their return to China. In Prof Yu's case, he obtained a fellowship from the Max Planck Society, which was one of the partners of the Hundred Talent Project. For that reason, he was identified as a distinguished researcher, which led in 1997 to his recruitment as a professor at the Dalian institute. With the Hundred Talent funding, Prof Yu established and equipped his lab with the technology needed to conduct the research with Leiden, as they had less money and equipment than the Dalian institute.

6.1.1 Employing PhD students in systems biology and Chinese medicine projects

The Leiden and Dalian students were employed for the Chinese medicine diagnosis research project. The students presented in this chapter are George from Leiden and Long and Lingma from Dalian. They had an academic background in analytical chemistry, biochemistry, medical biology. As part of the PhD exchange co-operation agreement between Dalian and Leiden, the Leiden students had to provide training and workshops in analytical tools to the Dalian team. Thus, the Dalian team sent two of their PhD students and one post-doc for training to Leiden. All of the students had to learn systems and network data analysis and some Chinese medicine theories.

The PhD student George was one of the first students who conducted Chinese medicine research within a biomedical department. As presented in Chapter 5, George became involved through a personal interest in Chinese medicine and discontentment with reductionism in medicine and science. He participated in the collaborative research project on Chinese medicine and systems biology through the offer of a PhD position by Prof Frank. Due to the unconventional topic for a biomedical institution at that time in Holland, which I discussed in Chapter 5, George experienced difficulties in being accepted by his colleagues at university. Thus, he had to debate with his biomedical colleagues, the benefits of Chinese medicine and his research. The situation changed after he finished his PhD, and new students who also carried out research on Chinese medicine, joined the program. They were "more accepted" as he says:

> "When I started there [in Leiden] as a PhD student this Chinese medicine thinking was kind of weird, so I was always, at least in the beginning, I was kind of a weird guy there who was studying Chinese medicine. So, it really took a long time to get kind of accepted in this way of looking at health, and why should we bother with Chinese medicine. So, we had a lot of discussions with the group, and now it is the next generation. They are three now, so it's more accepted now." (George, 2015, Leiden)

At the beginning, George's research project encountered a few issues. As George's project was one of the first projects in the co-operation (another PhD student worked on diabetes) of a series of research projects on Chinese medicine and systems biology, the team in Leiden was confronted by many challenges. One such problem was, for example, the question of how to design the study to make Chinese medicine more accessible and acceptable to Western scientists and doctors. This problem reveals another tension between biomedicine and Chinese medicine with the bias of an unscientific but a very complex medicine. Thus, the team struggled with questions about large data sets and how to follow a pathway of drugs by revealing the relationships between various molecules, cells and different levels of organisms. Large datasets were necessary to prove the connections between Chinese medicine patterns;

hence, they decided that systems biology with multivariate data analysis and the chemical analysis of biofluids was a feasible method to establish a metabolite pattern and was acceptable for Western scientists.

> "We had a discussion on how we can do this, how can we make this more acceptable to Western doctors, and Western clinicians and that's why we thought that systems biology might be a nice approach to bridge, let's say, the Chinese view and something that is also explainable to Western doctors and clinicians. Then, we thought, we should start with the diagnosis because that is actually the foundation of Chinese medicine. Our thought was also to do another type of research from what all the other scientists did, no herbal medicine but diagnostics and starting from the base!" (George, 2015, Leiden)

In contrast to George, the post-doc student Long refers to his study of Chinese medicine as "just a project" that did not reveal any profound change in his life. Long, who was Prof Yu's post-doctoral student who studied first geography, biology and chemistry before he gained his PhD in biochemistry. Through the Leiden-Dalian collaboration, he received a post-doctoral position for the quality control of Chinese medicine. According to Long, Chinese medicine was not new to him and not difficult to research due to his Chinese background. He considered Chinese medicine as a familiar practice and theory. However, it was different with systems biology. His interest in systems biology came as a result of his interest in the use of omics technology.

Lingma explained a similar involvement in Chinese medicine and systems biology studies to Long. She studied quantum chemistry and joined the Chinese medicine diagnosis project as a PhD student. To be more precise, Lingma's involvement happened after her application for a PhD position in chemistry at the Dalian Institute. Her application focused on chemical analysis but did not mention that she would examine Chinese medicine with it. Once Prof Yu agreed to the co-operation with Leiden, he needed a researcher to investigate the effects of Western and Chinese medicine drugs on lipids. Consequently, he assigned Lingma to conduct a lipidomics analysis on the intervention of drugs on plasma lipid metabolisms. In particular, she generated lipidomics profiles to investigate whether biomedical drugs or Chinese medicine drugs affected different metabolic syndromes such as diabetes mellitus. For this, she used liquid chromatography combined with mass spectrometry and statistical analysis. She concluded that a Chinese medicine multi-herbal *fufang* offered treatment for metabolic syndrome, and that systems biology can bridge Chinese and Western medicine. As part of the co-operation agreement, Lingma stayed for three years in Leiden and the post-doctoral student Long stayed for one year. Both, Lingma and Long were supervised by Prof Frank and Dr Huang during their research in Leiden. Prof Yu took over the supervision once they returned to Dalian.

The three students' involvement demonstrate that they did not have to create a new project or methods to study Chinese medicine and systems biology as their supervisors did. However, they were the ones who conducted the first research on Chinese medicine and systems biology and had to make sense of it. Only George had some experience in Chinese medicine and showed interest in gaining insights from Chinese medicine diagnosis, and not from its drugs to implement this knowledge in European healthcare systems. The other students were employed in the co-operation project with little or no experience in Chinese medicine or systems biology. Compared to George, Long and Lingma experienced a career-oriented involvement as they took on the project in order to enhance their academic career. They agreed with the technological aspect of systems biology without addressing the philosophical aspect of systems biology. Long and Lingma were employed for these projects in the joint research program with Leiden because they had experience with omics technology and chemistry. Overall, the participation of George, Long and Lingma in this co-operation showed that knowledge concerning the two disciplines of systems biology and Chinese medicine was already established.

6.1.2 Tensions in the co-operation

During the collaboration, those involved had to gather biofluid samples, i.e., blood and urine samples, from Chinese medicine hospitals with the aim of gaining insights into Chinese medicine. The Dalian and Leiden groups hoped to establish a personalised medicine based on the gained insights of the Chinese medicine diagnosis study. To this end, the Dalian group collected patients' blood and urine samples and analysed them with quantitative methods. The task of the Leiden team was to undertake the second analysis with systems and network analysis for the identification of biomarkers and metabolomic profiles of different *zhengs* in Chinese medicine diagnosis. However, George stated that, I quote: "I think it was more about the data analysis and the processing part that kind of knowledge, which was less developed in Dalian than in Leiden". The technological focus of the Dalian institute changed the dynamics of the agreed project on researching Chinese medicine with systems biology because the systems biologists from Leiden had to find new co-operation partners in China to aid them collect new samples. Hence, the co-operation suffered from three problems: (i) research protocols and the quality of samples, (ii) the reliability of the patients, and (iii) a breach in publication.

The first problem emerged from the study design. The Leiden team designed the study with instructions for the students in Dalian to undertake the collection, preparation and measurements of the samples. However, as the Dalian students collected the samples and conducted the experiments before the co-operation with Leiden started, their protocols showed variations. When the Leiden group received the data, it was unclear when the students collected and handled the samples, i.e., storage, preparation and analysis. Finding the right student who was responsible for each step in the process was challenging for the students in Leiden. As a result, the team in Leiden was not sure where the data was collected and struggled to analyse it as Dr Huang recalls:

> "I think they conducted the clinical study partly in the university [and partly at the hospital] and they did not completely follow the instruction, the research plan. So, therefore, the result was scientifically not successful. We did a nice experiment design but in the actual experiment they didn't follow the design." (Dr Huang, 2015, Leiden)

The second problem was the patients' reliability. As patients voluntarily took part in the study, it was uncertain if they would come every day to deliver their blood and urine samples. In particular, if patients did not complete the full cycle of the study, their samples were useless to the researchers. The researchers needed samples from each patient every day throughout a period of fourteen days. The reliability of patients was beyond the control of the researchers and this was therefore another challenge that the study faced. However, the sample collection and handling were controlled by the students in Dalian, which was not satisfactory for the Leiden team. Dr Huang mentions a lack quality of the collected samples. Huang et al. (2011) state that the quality of samples can be influenced by the slightest delay in transportation or the wrong temperature, which changes enzymes in the sample and causes inferior quality. As Dr Huang says:

> "So, we had a joint design for the experiment that said which time they have to take the samples and which kind of patient we needed. But patients were volunteers in this study, so, the patients didn't show up or they gave us the first sample and they didn't come for the second collection. We cannot blame the hospital for this. However, in the collected samples, I think we had some samples with good plasma quality, but the collection of the samples was not high end." (Dr Huang, 2015, Leiden)

Another key problem was the "trust" with which Dr Huang built this collaboration, as stated above. It was essential to her that the collaborative partners abided by the co-operation agreement, but this was not always the case. Before George could publish the findings of his research, a member of the group in Dalian published some data in a Chinese journal without informing and acknowledging the Leiden group:

> "One thing, for instance, was that the data that we got from them, they also worked or downloaded the data and eventually we found out that they got some parts of it published in a kind of Chinese journal and we didn't know about it. In the West, to publish the same result twice is a kind of no go. But for them, it was more common." (George, 2015, Leiden)

Overall, the co-operation started with the aim to gain insights into Chinese medicine diagnosis, but the collaborator's intentions crystallised a division of the interests during the process. The Dalian team focused on technological advancements, rather than the conceptual interest of a holistic study on Chinese medicine. They followed the reductionistic paradigm within the framework of biomedicine, which was a significant setback for the Leiden team. Prof Frank believes that Prof Yu's return to reductionism was for an economic reason. Prof Frank recalls the moment when he realised the research focus of his partners in Dalian had changed to technology and bioscientific methods:

> "…and that was a time when I learned a lot about China, sometimes being less holistic than I thought. Some Chinese people are more Western thinking than we are. What I thought was the treasure, is sometimes not so easy to find. People were more interested in extracting, extracting and extracting and then make a drug. Everybody was in the Western mode of wanting to earn a lot of money by making Western drugs and Chinese medicine. You cannot earn so much money with holistic Chinese medicine studies because there are patterns, they say this and this. So, it was very economic driven, and I thought that is not what I want." (Prof Frank, 2015, Leiden)

In addition, George believes that the Dalian students showed a lack of enthusiasm for a novel research method for systems biology to investigate Chinese medicine. This highlights the fact that the Dalian students were employed for a job and not for the sake of Chinese medicine research:

> "It didn't feel like a collaboration. For them also, it was more a kind of duty and do what the professor says, and you don't feel really the enthusiasm for the study or something. We were all very enthusiastic in the Netherlands, but it almost felt like we are giving them more work to do for us to figure things out." (George, 2015, Leiden)

The different interests emerged during the co-operation process and influenced the decision to end the co-operation once the Leiden institute had received the samples. Nevertheless, the experience with Dalian brought a better understanding of the scientific interest of the partners of the Leiden team, which was as modernised and competitive as Western scientists.

6.2 Laboratory practice and technology

This section introduces the dual-trained Chinese medicine and systems biology researchers. The actors in this code are the Harbin team. Harbin is located in the province of Heilongjiang, China and in the team there was Prof Xiong, his two assistant professors Xing and Ang and 20 students. I will refer to the PhD student Ruili and the post-graduate student Yuxi in this chapter. All members of the team were trained in Chinese medicine pharmaceutical sciences, systems biology and the use of omics technologies. Prof Xiong founded the Chinese medicine pharmacology post-graduate program in 2005 and since the 2010s, he has run a PhD program in Chinese medicine metabolomics in which Chinese medicine pharmaceutical students are trained in systems biology. Thus, they represent the group of dual-trained Chinese medicine and systems biology researchers in my study. In the following section, I will describe the involvement of Prof Xiong and his students in Harbin with extracts from field notes.

The head of the department in Harbin, Prof Xiong, studied Chinese medicine serum pharmacochemistry, which focuses on the development of drugs, in Harbin. Following this, he gained his PhD in pharmacokinetics in Japan and worked for a pharmaceutical company in Germany. On Prof Xiong's return to China, he received a position at a university in Harbin in the good agriculture research unit for investigating and setting standards for medicinal plant cultivation and harvest. According to the assistant professor Xing, shortly after his return, Prof Xiong received funding under the "973"[27] program for basic research in 2005 and established a post-graduate course in metabolomics. The Chinese government largely invested in various research and development programs and the 973 program was one of these investments was shown

[27] The "973" program was a MOST funding that aimed to develop collaborative basic and translational research, innovations and technologies aligned with the "national priorities in economic and social development". Since 2006, it was extended to the "National Key Basic Research Programme" for specialised disciplines such as protein sciences, stem cell research, reproductive biology and developmental biology (Yao, Li and Pei, 2013).

by Zhou and Leydesdorff (2006) with the increase of the Chinese Gross Expenditure in Research and Development (GERD) ratio to 1.31% by 2003, which was almost one half of the 2010 agreed ratio aim of 3% by the European Commission (ibid). The next achievement of Prof Xiong was, in 2012, with the establishment of the centre for metabolomics studies of Chinese medicine as a combination of pharmacognosy[28] and systems biology.

My first meeting with Prof Xiong was at the International Conference on Health, Healthcare and Eco-civilisation at the London South Bank University on September 5-6, 2015. The conference hosted scientists in Chinese medicine, biotechnology, life sciences, sinology and acupuncture from China and Europe to discuss the latest developments in Chinese medicine research. Prof Xiong presented his latest results of metabolomics studies on a Chinese medicine *fufang* which aimed to find the appropriate pattern or *zheng* for its use. After a conversation with him, he allowed me to conduct fieldwork in his department from April - June 2016 (see Table 1 for observation details from my fieldwork). I observed Prof Xiong's students in wet laboratory experiments on human blood serum and urine samples. The observations took place in the metabolomics laboratory and the department of internal medicine in the affiliated Chinese medicine hospital of the university.

In the department of metabolomics research, I followed Ruili who was conducting, as part of her PhD project, an *in vivo* study on metabolites of blood serum and urine samples on patients that suffered from jaundice, in particular the *yang* jaundice (*yang huangdan zheng* 阳黄疸证).[29] Chinese medicine distinguishes two types of jaundice, a *yin* and a *yang* type. The *Yang* type presents a yellow pigmentation, and symptoms include damp heat such as fatigue, fever, a heaviness of head and body, no appetite, a thin tongue with a greasy coating and a floating, wiry or rapid pulse. The *yin* type (*yin huangdan zheng* 阴黄疸证) presents a poor appetite, bloating, aversion to cold, soft

---

[28] Pharmacognosy is a branch of pharmacology that deals with natural substances and especially medicinal substances obtained from plants, animal, fungi, molds and yeast (see Orhan, 2014).

[29] Jaundice is a liver dysfunction that hinders or completely disrupts the resorption of old blood cells, which causes aggregation of a chemical in haemoglobin namely the bilirubin in the body. This leads to a yellow pigmentation of the face, sclera and urine (see Tewari et al., 2017).

stools, a swollen pale tongue with a greasy white coating and a deep, thin, or retarded pulse. This is the *zheng* of a damp cold in the body (Wang, Zhang and Sun, 2012). The *Yinchenhao tang* 茵陈蒿汤 (*Virgate Wormwood* Decoction) is a standard prescription in the Chinese medicine pharmacology to treat yang jaundice. Unschuld (2005, p. 446) states that in Chinese, the word *tang* 汤, as in *Yinchenhao tang*, means “hot liquid” or “decoction” and is a standard description for liquid Chinese medicine drugs.

Three groups in the metabolomics department in Harbin studied the *Yinchenhao tang*. The first group examined the chemical compounds in the *tang,* which is the decocted formula. The second group tested the *tang* on animal models to determine biomarkers, efficacy, and safety. The third group assessed the decocted *tang* in clinical trials for the verification of the effect on human metabolism, proteins and genes. In the first group, students bought ingredients from an authorised Chinese medicine drug seller and prepared the complex prescription of various herbs, *fufang,* as a decoction, which is then called the *tang*. Prof Xiong was the only authorised person in the department to verify every single herb used in the studies. After the verification process, students decocted and examined the prepared *tang* in the laboratory. Then, they stored the packages in the fridge for the second project. In the following, I will focus on Ruili’s project with the third group.

The third project was Ruili’s *in vivo* project. Ruili’s was introduced to the project by Prof Xiong. Prof Xiong arranged a co-operation with the leading doctor (*laozhongyi* 老中医) of the department of internal medicine (*neike* 内科) in the affiliated TCM hospital. According to Farquhar (1994), *laozhongyi* was a term used to call Chinese medicine doctors in the 1950s. The *laozhongyi* allowed her to conduct her study in his department. In the next extract, I will describe a ward round in the hospital to identify participants for Ruili’s study.

> On Monday mornings in the ward round, the *laozhongyi* selected the patients who were appropriate for Ruili's study. Among two dozen doctors and other students, Ruili and I visited every patient room and listened to the doctors' presentation of the patient's records and the *laozhongyi's* prescriptions. When the *laozhongyi* found a suitable patient for Ruili's study, he introduced the study briefly to the patient and instructed Ruili to collect the consent and the data of the patient from the doctor in charge. Then, he continued with his ward round. After he finished the ward round, Ruili informed the doctor in charge of the selected patients about her study. The doctor told the patient about the procedure and that Ruili would collect two blood samples and urine samples for 14 days from the patient. Then, Ruili asked quickly for the patient's medical history, demographic data including telephone number and his or her signature on the consent form. She had to add all the participants' data into a national database for scientific studies. Then, Ruili's study started with collecting the blood serum one day before the first administration of the *tang* and one day after a fourteen-day period of taking the *tang*. The urine samples were collected throughout the fourteen-days period. As a part of the study design, the doctors had to prescribe all participants in the study the same formula without making any amendments to the recipe. This contrasted the usual practice Chinese medicine as usually doctors modify the prescription to the specific condition of the patient. (Fieldnote, 2016, Harbin)

Ruili had several mechanisms to collect information and prevent failures in the study. Compared to the above presented Leiden team, she knew the doctors in charge of her participants, and she had the telephone numbers to contact patients if they did not show up for the daily sample collection. Nevertheless, it often happened that patients signed up for the study and then they did not drop off their samples, or they forgot to hand in the blood or the urine sample as they were not inpatients. Although she had the patients' numbers and called them, most of the patients had already eaten their breakfast, which made their sample useless for the experiment. In addition to this, sometimes it was difficult to get the samples from patients in an advanced state of the disease, as they needed the help of relatives to provide the sample.

Due to the fact that not all the patients followed the instruction of not eating before the nurse took their blood or their urine sample, Ruili also faced the issue that many patients were transferred to biomedical hospitals because they felt that Chinese medicine was not helping them, or that their condition was becoming more severe. In more severe cases, Chinese medicine was sometimes difficult to consume as some of the patients could not intake any food or fluids; thus, it was not possible for them to drink the *tang* for 14 days. Others for example, developed liver cancer and needed chemotherapy for which the *Yinchenhao tang* was not applicable. Patients with advanced diseases were sent home because they wanted to die surrounded by their family. Practitioners often commented that I quote one practitioner "we do whatever is the best for the patient".

Back in the laboratory, Ruili prepared the samples for centrifugation. She separated the blood serum from the red blood cells and the pellet, i.e., dirt, from the clean blood serum with the centrifuge (*lixinji* 离心机). The serum is essential for the analysis of the proteins, as they carry the metabolised Chinese medicine.

> Ruili filled the urine from the 10-millilitre tubes with blue threaded fasteners in five two millilitre tubes with a click fastener. Then she put the test tubes in the centrifugal machine with 13000 round per minutes (rpm) for 10 minutes. When the program started, the tubes were cooled down to about eight degrees Celsius. In the next step, the machine sped up from 1 to 100 within a second, and after a few more seconds, it reached its full speed. The centrifuge worked like a washing machine, which was placed on a table. Once it had finished, she filled the numbered test tubes with urine. The test tubes were numbered with continuing numbers for each patient and the day of collection, such as 1-1 (first patient and first day after the first drug administration) and froze them in a fridge. She needed to freeze the samples at minus 80 degrees. A full analysis was done with a minimum batch of 10 patients (10 x 14 days=140 urine samples + 10 x 2 blood serum samples = 160 samples a batch). (Fieldnote, 2016, Harbin)

Throughout the data collection and handling of the samples, the pattern *zheng* was only visible to Ruili in the form of urine or blood serum samples. Ruili and the other students did not know in advance how and in which metabolites, proteins or genes, the *zheng* would be manifested. Only in the analysis of the metabolites, by comparing all urine samples analysed in the fourteen day period the two blood serum samples, Ruili was able to see the *zheng* through a change in the metabolites as a reaction to the *Yinchenhao tang*. To analyse the samples and to identify metabolites, Ruili used mass spectrometry and the ultra-performance liquid chromatography (UPLC). The identification happened through a mass determination by consulting free accessible databases such as the Kyoto Encyclopaedia of Genes and Genomes (KEGG) or the METLIN Metabolomics Database. The databases were connected with software that evaluated mass spectrometry and chromatography data.

> In the metabolomics lab, Ruili analysed her samples with the UPCL. Every day she prepared a new batch of samples for which she took the urine for seven days and mixed it with a solvent. To mix the liquids, she put them in the mini centrifuge, which was a tiny version of a centrifuge in the size of a box for four eggs. Then she filled the liquids in small glasses, which she placed afterwards in the liquid chromatography-mass spectrometry (LC-MS) and the rest of the urine she froze. After ten minutes in the machine, the machine delivered her the first data set file. The analysis file showed a graph with hundreds of mini-peaks like a topographical map of the Alps. Every peak could be determined with special software with different functions like metabolite analysis that delivered her mass information. With the connection to databases such as Scripps, METLIN and KEGG, she found the name and the masses of chemical compounds. Ruili said that sometimes the metabolites are unknown. Hence, she needed to check in several other databases the number of the metabolites and their chemical compounds to find the mass information. (Field note, 2016, Harbin)

Technology was vital when combining Chinese medicine and systems biology research for the evaluation of the metabolism of a *fufang*. Technology like mass spectrometry, gas chromatography, thin layer chromatography, high-speed counter-current chromatography, and capillary electrophoresis was used for the Chinese medicine metabolomics studies, but not exclusively. Many scientists in Harbin did not relate themselves to systems biology research, but applied systems biology technology in their studies. The definition of "systems biology" according to the assistant professor Ang (later only Ang) shows that the Harbin team often defined systems biology on its four types of high-throughput measurements: genomics, proteomics, metabolomics, and transcriptomics. The method was a many-to-many approach (多对多 *duo dui duo*) to investigate what Ang called the "different levels and properties". This had the advantage of using technology as an analytical tool for large-scale and complex systems in a short period. The results disclosed, according to Ang, "the mystery of Chinese medicine" by screening its effect on genomes, proteomes, and metabolomes.

Despite the optimism of Chinese metabolomics researchers, systems biology experts and promoters, for instance, Prof Musashi and Prof Meng (the observers of the research of Chinese medicine with systems biology as illustrated in Figure 3 the purple network) argue that omics technology is still too limited to conduct systems-level research in terms of systems biology. As a result of this, omics technology is also not advanced enough to grasp the complexity of Chinese medicine. Prof Musashi is a systems biologist and AI scientist and, in his opinion, systems biology is a holistic method which has two limitations for Chinese medicine research: technology and its theoretical aspect of systems research.[30] The various omics technologies systems biologists use are still inadequate to scan all the compounds in a complex Chinese medicine *fufang*. Through the identification of all the compounds, they are however able to determine the relationship and the change of behaviour of the whole *fufang* in metabolism. Prof Musashi, however, argues that omics technology is too limited to adequately study a whole system. This theoretical limitation also includes the fact that systems theory does not fully grasp the complexity of Chinese medicine. Thereby, he refers to *qi* and its all-encompassing status in an organism as not traceable in specific layers, but which moves freely between them. The complexity issue is described in Kevin's involvement in Chapter 5. Nonetheless, Prof Musashi is convinced that systems biologists in the future will improve technology and their approach and will go from being able to identify only a small number of identified compounds to all compounds in a *fufang* and their interactions within a metabolism. Consequently, this also increases the amount of data beyond the present technological capacity used to study these changes.

Prof Musashi believes AI will overcome the technological and theoretical limitations for big data problems. Big data is too complex, too fast-moving and the arrangement of the data is too unstructured, thus, traditional data processing software applications are unable to manage them. Hence, Prof Musashi believes that in the future AI systems and robotic systems will support the conduction of experiments, the analysis of systems biology and the diagnosis of traditional medicines. The benefits are as he says:

> "I think in particularly in the diagnosis with the AI system we can give a much more precise certification of the patient. We actually could have a robotic system to do the experiments. The AI system generates the diagnosis. So, we can classify the patient much more precise. We can diagnose specific subcategories we haven't thought about yet. That could be possible so if we can find a biomarker and especially create an intervention that is a little bit fuzzy now… I think the goal is actually to build a system by 30 or 40 years from now, and I think that would completely revolutionise the way how we do things in biology." (Prof Musashi, 2016, Tokyo)

[30] Prof Musashi's systems biology project started in 2002 and was funded by the Japanese government. See Table 2 for more information about his systems biology project and the intended AI/Kampo research.

Prof Musashi assumes that AI will help overcome the big data of medical publications that include medical knowledge from all scientifically examined medicines. However, this would mean that only published studies will be integrated into an AI diagnostic calculation and evaluation. AI will use an algorithm to match the results of the biomedical tests doctors run on patients with the clinical data from databanks to find an appropriate treatment based on biomarkers and phenotypes [31] for individual diagnosis. The scientific evaluation of Chinese medicine and its integration into a big data medical database administrated by AI, indicates the inclusion of only selected knowledge, which relates to the standardisation process under Mao Zedong. Mao wished for a modern scientific medicine in the 1950s and 1960s and he only included standardised Chinese medicine theories and formulae into new Chinese medicine textbooks (see Chapter 2, see also Taylor, 2005). However, the difference is that Prof Musashi's AI system aims to develop a worldwide medical system and a personalised treatment, which requires more information on existing drugs and their efficacy on the proposed disease.

AI, according to Prof Musashi, will be soon essential in every leading institution of the world, in the same way omics technologies have become indispensable in laboratories over the past twenty years. Without AI, research would be old-fashioned, and doctors would not be able to cope with the increasing body of medical knowledge and have the ability to apply new findings to their daily practice. Prof Musashi estimates that by 2051 all acknowledged institutions will have a very well-built AI system for performing research. If they do not, the institutions will not be deemed internationally competitive.

Similar to Prof Musashi, Prof Meng deems there are technological limitations when it comes to conducting systems biology and Chinese medicine research (see Table 2 for his diagnostic kit project data). Prof Meng is a geneticist and a systems biologist. He helped establish a systems biology research centre in 2000 and founded the first systems biology platform in China in 2006. Concerning systems biology and Chinese

[31] Phenotypes are representations of individual characteristics that result from the interaction between the genetic constitution of an individual organism (the genotype) and the environment (see John Hopkins School of Medicine, 2018).

medicine research, he considers that systems biology research is not yet thoroughly performed, and that people underestimate the complexity of systems biology research, which aims to understand the whole system and not only its parts. This undertaking requires more advanced technology to gather larger data sets in less time to present the whole system. Therefore, the problem with systems biology is its technological limitations. Most systems biology institutes have limited capacity, as they are too small to conduct a systems level study in its full extent. He explains in detail the challenge of a "truly" systems biology study:

> "Systems biology basically understands systems at different levels like on the level of protein and dissects each component. Then you need to use the most advanced technology to understand each component. We call them the pathways. If you don't have the technology, the pathway is not complete. Then you cannot do systems biology. I think in a way we still do systems biology not in a complete sense. We are doing these studies with the technology we can get, for example, with mass spectrometry. We can analyse a couple of thousands of proteins at one time but not the whole human protein. Because of all the limitations in technology systems biology has not lived up to its expectations yet." (Prof Meng, 2016, Hangzhou)

Prof Meng believes that Chinese medicine studies with systems biology are an attempt to perform systems biology research without any outcome. He asserts that, "We are waiting for the results". In contrast, the Harbin researchers are not concerned about the technology limitations, they are more interested in gaining results with the available technology for their Chinese medicine studies which evaluate drugs. They are not focused on performing a systems biology research in its complete theoretical understanding. The Harbin team's approach is similar to the Dalian researchers. They both use the available technology to investigate their metabolomics studies and they were less interested in the theoretical components of systems biology. Systems biology was no more than a story writing tool or technology (see Section 4.3.2 on the definition of systems biology). However, both usages of systems biology differed from the Leiden team approach. The Leiden researchers were interested in systems and their whole function and relationships, thus, for them, the exploration of a technological application was only interesting when regarding the understanding of the system in Chinese medicine.

6.3 FUNDING AND INDUSTRIAL TIES

Similar to Dalian, Harbin used the technological equipment from the American company Waters Corporation. The purchase of the ultra-performance liquid chromatography (UPLC) machine from the American company in 2005 was a strategic plan to aid them publish more and to attract future sponsors. Prof Xiong gained the attention of the Waters Corp. by mentioning the UPLC machine in 200 publications. Due to the high publication rate, the company established a co-operation with the department. The team views this co-operation as a link to the industry and to a scientific co-operation between China and foreign companies and institutions.

Industrial co-operation was necessary for the Harbin department as they gained research funding from national and international research institutions. For example, Prof Xiong's paper on the application of Waters UPLC machine for Chinese medicine drug examinations in 2005 established a co-operation with the Hokkaido College of Pharmacy in Tokyo and initiated study exchanges for students and participation at conferences. Several students and associate professors from Harbin, such as Prof Xiong and assistant professor Xing, studied at Hokkaido University for at least half a year during their program. Every year Prof Xiong joins the conferences in Japan. In addition, technological connections between Chinese metabolomics and other universities were established. These included connections with Amur State University in Blagoveshchensk, which undertook several analyses of Russian folk remedies. Further study exchanges and technological co-operation were set up with Macao, Hong Kong, and Taiwan.

Most of the funding for the Harbin studies came initially from the Chinese government, then the provincial government and from pharmaceutical companies. The funding from the pharmaceutical industry was only five per cent of the entire funding. For example, industrial funding was connected to patenting drugs, which stands for long-term studies and thus was not very common. Moreover, the industrial funding depended on the region and revealed a North-South disparity, as Southern universities such as Jiangxi TCM University or Shanghai TCM University receive more industrial funding due to the better economy, as claimed by the undergraduate student Yuxi.

It is more complicated to gain funding for systems biology projects in China than to gain Chinese medicine funding. Prof Meng emphasises two issues in the struggle with funding in China. First, Chinese funding is disease focussed, funding is gained for the investigation into epidemic diseases, HIV, hepatitis-C virus diseases or other special problems. The second problem is the lengthy design and realisation process of systems biology studies, which is outside the normal funding timeframe of two years, and beyond the budgets of the funders. Prof Meng claims that China does not offer any "big systems type of funding". Hence, systems biologists in China depend on funding from Chinese government funding bodies such as the National Science Foundation of China (NSFC, see Appendix A) and the Ministry of Science and Technology.

> "Two-thirds come from the public funding, and one third comes from the NSFC. The NSFC used to fund programmes on a much broader level of each project, but now it focusses on much smaller projects but many of them. Initially, the Ministry of Science and Technology used to fund big projects as well and they have called for a research proposal. You can have some money if the Central Government says this is what we ask everyone to go into, and then they ask professors in China to submit a proposal... And there is another funding from the Ministry of Health." (Prof Meng, 2016, Hangzhou)

Due to the change and the limited funding for long-term studies, which is needed for systems biology research, Prof Meng established his own company with start-up funds. However, those funds were not continuous either. Hence, to overcome the budget gap, his company focussed on the commercialisation of personalised medical ideas, for example, a liver diagnostic kit for blood serum diagnosis in the laboratory (see Table 2 for project details).

The change to short-term studies in China depended on the political agenda, which aimed after 2006 to increase innovations in China with the National Key Basic Research Programme funding (see, for example, Yao, Li and Pei, 2013). This program addressed protein research, which included any metabolomic drug study. As many of the projects in Harbin and Dalian were funded by this program, their study design prioritised the completion of a project within the time of a postgraduate or PhD research program of two to six years. This tendency restricted the conduction of long-term projects and moved towards the evaluation of Chinese medicine *fufang* to discover active compounds.

With the aim of gaining funding, the Harbin and Dalian research centres offered services to other universities or companies. For example, the Harbin group began scanning products from other traditional medicines or the Dalian team analysed lipid in food products for local companies. It therefore appears that with the increased use of omics technology research in drug discovery and development, co-operation was essential with the pharmaceutical industry in China.

6.4 CONCLUSION

This chapter demonstrated that PhD and post-doc students became involved in Chinese medicine and systems biology research projects in the course of their training and career. The outer circle did not intend to develop new methods to research Chinese medicine or learn from it; they developed their expertise in technology and analysis tools and were invited to take research positions. I identified the codes of: co-operation projects, technology and industry, for causes of their participation.

The students in Dalian became involved through the research projects of their supervisors. They had to learn Chinese medicine from scratch or had limited knowledge due to their upbringing. They also had to learn systems biology, as their field of research was chemistry. As a result, the Dalian-Leiden co-operation showed that research in Chinese medicine and systems biology started with the idea of learning Chinese medicine from its very core complex of understanding the human body, diseases and life in harmony with nature. The research co-operation was built on trust and relationships between the supervisors and politicians. The intention of the Leiden team to conduct a study with a holistic approach on health and Chinese medicine with Chinese partners, remained partly unsuccessful due to their strong dependency on technology, as well as, the poor results of the samples combined with the breach of publication etiquette. These tensions caused the end of the co-operation between Dalian and Leiden.

The involvement of the Harbin students was different from the involvement of the Dalian-Leiden students. The involvement differs in two aspects: first, the Harbin students were trained in systems biology and Chinese medicine and, secondly, they evaluated *fufangs* on specific *zhengs* rather than identifying biomarkers that determine a *zheng*. The first difference between the students in Harbin and Dalian was that the Harbin students were trained in Chinese medicine pharmacology and started with systems biology or omics techniques during their post-graduate studies. Thus, they combined their knowledge from previous studies on Chinese medicine and integrated systems biology to conduct basic research on Chinese medicine and examine drug efficacy. While, the Dalian researchers were neither trained in Chinese medicine nor systems biology before they were employed as doctoral and post-doctoral students, the Harbin researchers were trained in Chinese medicine and systems biology. The Harbin researchers tailored the study to identify the effects of a Chinese medicine *fufang* for a specific *zheng* on animal models or humans. The scientists in Harbin studied the drug first and then tested it on various *zheng* to determine on which *zheng* it was most efficacious. Thus, they verified the use of the drug and discovered active compounds for patents and new drug developments. This was a different approach to the Dalian case, as they studied the *zheng* first in order to develop a new drug.

The Harbin team demonstrated that for Chinese medicine and omics studies, only one scientist, who integrated the knowledge of both, was needed. They highlighted that the development of a comprehensive study of understanding Chinese medicine as a foundation and the scientific methods of systems biology, were tools for discovering active compounds and developing new drugs. The *zheng* was a parameter to design studies and to assess the efficacy of Chinese medicine *fufang*. With this approach, the group created several links to the industry with drug patents to recap a small percentage of their funding.

Similarities between the students from field sites, Harbin and Dalian, were that they referred to omics technology in their studies rather than systems biology and its complexity at systems-level understanding. They were interested in the application of technology for the evaluation of drugs or the identification of biomarkers in their studies. Another similarity was that they were challenged with the compliance of patients in clinical studies. This challenge caused incomplete samples collections of participants or an inferior quality of samples.

The technological motivation affected the co-operation between Dalian and Leiden. Although at first both aimed to research Chinese medicine diagnosis with systems biology in order to understand Chinese medicine as a holistic system and practice the objective later changed to the technological development for metabolomics studies. The divergence of the initial aim, the incomplete and inferior quality of samples and the publication of results without agreement of the Leiden partner caused the end of the Dalian-Leiden co-operation.

It is possible to conclude this chapter by stating that the students in Harbin and Dalian were employed as researchers to conduct the studies designed by their supervisors, who were trained in Chinese medicine and metabolomics studies. Consequently, it can be said that the inner circle was involved because of their interest in Chinese medicine and systems biology. Whilst, the students in this chapter (the outer circle) were only involved because they were invited and employed to conduct the studies.

7. NETWORKS AND POLITICAL TIES

This chapter will answer the question of how did the human and nonhuman actors participate in Chinese medicine and systems biology research and influence the development of this “interface”? The theme “Networks and political ties” was identified through thematic coding of episodic interviews and a literature survey, which I discussed in Chapter 3. I conducted the interviews with pharmaceutical scientists, humanists, systems biologists, Chinese medicine practitioners. I collected data from organisations such as the WHO, a university network organisation, ERC and the European Pharmacopoeia Commission (EPC). The theme revealed three codes: (i) political networking, (ii) how they joined Chinese medicine studies and (iii) funding and regulations. These codes demonstrate that the actors formed and participated in networks and organisations or were invited by organisation to participate in Chinese medicine and systems biology research. This is different from the involvement in individual projects of the inner circle scientists (see Chapter 5) or co-operation projects (see Chapter 6).

In this chapter, I will first present the data from a university network and how it is linked to politicians that generated an exchange platform for discussions on Chinese medicine between China and Austria. Then, I will demonstrate how the actors (including organisations and networks as nonhuman actors) were invited to participate as experts in a joint Chinese medicine research consortium. The last section of this chapter will elaborate on various research organisations and the specific funding that financed and supported the research on Chinese medicine and systems biology.

7.1 POLITICAL NETWORKING

The political networking code arose from interview data with Prof Vera. Prof Vera is a humanist, the founder of a university network organisation and the head of the International Relations Department at an Austrian university. In her function, as a connector between China and Austria, she successfully established a network of politicians, scientists and Chinese medicine researchers in China which started in the 1990s. This code demonstrates that in 2005, the research which explored Chinese medicine for prevention and research co-operation gained momentum and pushed the Austrian government to release funding for this research. This presents an intertwined relationship between academia and politics and Austrian political strategies which looked to increase co-operation with China.

Prof Vera's involvement in Chinese medicine started in the 1990s, with the university network organisation project. The university network had the main focus on student exchange programs between Austria and Asian countries. With this university network organisation, Prof Vera claims that she addressed the poorly developed relationships between her affiliated university and Asian universities. A statistic on the enrolment numbers disclosed that no Asian student was enrolled, for example, at the University of Salzburg in the academic year of 2000 and 2001 (see statistics in Appendix E). Thus, Prof Vera aimed to improve student exchange and research relationships with Asian countries. To this end, in 2000, she founded the university network organisation to shift the focus from the university relationships with the USA, Canada, Africa and Australia to Asian countries. With this organisation, Prof Vera developed a multidisciplinary student exchange program for a network of eligible scientists, researcher, students and politicians of Eurasian countries.

Prof Vera recalls the initiation of Chinese medicine research in Austria as a link between political and academic interests. Since 2005, Prof Vera signed with Chinese universities and politicians various Memoranda of Understanding (MOUs) that agreed to promote and develop Chinese medicine through conferences and training programs. Thus, she organised the first experts' workshops and conferences on quality standards in Chinese medicine in 2005, Chinese medicine as a successful concept for East and

West in 2006, and the prevention of age-related diseases such as dementia, neurodegenerative diseases, cardiovascular and metabolomic diseases in 2008. These conferences provided a discussion platform for Chinese medicine, which was the interest of the Austrian Ministry of Health. Compared to the Austrian interest in Chinese medicine, Prof Vera explains China's research interest as a political strategy to improve Chinese medicine research:

> "There were ten researchers in a cluster in 2005, then our Ministry of Health showed an interest in traditional medicine so that the Austrian Ministry of Health signed an agreement with the Academy of Traditional Chinese Medicine and the Ministry of Science funded the research… On the other hand, the Chinese Ministry of Health and then also the Ministry of Science and Technology were charged with the task to advance the research on traditional Chinese medicine." (Prof Vera, 2018, Vienna)

Prof Vera's university network organisation was funded by the Austrian Ministry of Education and the Ministry of Health. Her connections with Austrian politicians helped her to obtain funding from the Austrian government for her student exchange programs, which helped attract Asian students to study in Austria. Prof Vera argues that her relationships with politicians were crucial as in the early 2000s, the Federal Minister of Education, Science and Research, under minister Elisabeth Gehrer (2002-2007), reduced the funding for students' and researchers' mobility programs. However, Prof Vera managed to maintain her funding by addressing the governments interest. The interest of minster Gehrer included increasing the competitiveness of Austria's universities by connecting them on a "multidisciplinary" level with China. Prof Vera argued that, in the early 2000s, China was a top investing country in research and development, and the exchange programs with its top universities secured her funding. She believes that due to Austria's small size of the country and the fact it has twenty-two or twenty-three private and public universities, China was attracted to the country and eager to collaborate with them. Hence, she secured her student exchange program and extended her network to Chinese medicine practitioners, researchers and policy-makers.

Prof Vera reaffirmed the fact that in the late 2000s, China's interest grew in both fields of science and technology (see Zhou and Leydesdorff, 2006). She observed that in the course of this interest, Chinese medicine became commercialised and globalised for the development of new drugs. Hsu (2009) discusses this issue with the example of

Chinese propriety medicine that aimed to prove commercial fitness of Chinese medicine in biomedical fields and offered alternatives to biomedicine by adapting to biomedical drug production. The same applied to TCM hospitals in China. The government advanced TCM; thus, Prof Vera claims: "when you look at the hospital or medical universities in China, they all have TCM departments to promote and sell their TCM". China increased their investment in Chinese medicine; however, the distribution depended on the interest of politicians that supported Chinese medicine funding and equal distribution among universities:

> "There is already a lot of interest in the marketing of Chinese medicine, which means the sale and the globalisation. Thus, the individual universities will receive less money, but the special universities will get enough money and promote the academy as a figurehead. And then they can dispose of their own resources. But it will always depend on who on a state's level, in China and in Europe, is interested in it and after that, it will be supported or not." (Prof Vera, 2018, Vienna)

Since the 2010s, the Austrian government's funding for academia has been reduced, which has caused a decrease in investments for technological equipment and research development. Prof Vera's interpretation of this development is that Austria needs visionaries to bring the issue of Chinese medicine forward and to generate new funding for this kind of research. While researchers in Austria struggle to gain funding, China increased their investment in research and with Prof Vera's program, the interest of Austrian scientists to study in China became attractive due to the better technological equipment (see Zhou and Leydesdorff, 2006).

The code political networking presented Prof Vera's contribution to the establishment of political and scientific discussions and conferences on Chinese medicine research in Austria. Prof Vera's participation in Chinese medicine research and conference correlated with the socio-political urgency and interest to research disease prevention and treatments of age-related diseases together with the interest of China to invest and promote in Chinese medicine research collaborations. Hence, she built scientific and medical exchange relationships between Austria and China, as well as Chinese medicine institutions. She encouraged through her conferences and workshops the government to release funding for Chinese medicine research in Austria. Therefore, her participation in Chinese medicine and systems biology research derived from her vast network, her function to improve international relations, and the urgent need for treatments and the prevention of diseases.

The next code will demonstrate how actors were invited to research projects and to a Chinese medicine and systems biology research consortium.

7.2 Joining Chinese medicine studies

This code of joining Chinese medicine studies exemplifies two different reasons for the need of Chinese medicine research in Europe: the foundation of a TCM clinic in Germany and two renal failure cases caused through the use of a Chinese medicine slimming product in Belgium. These two causes evoked an interest in studying Chinese medicine during the 1990s. At that time, the first research on Chinese medicine was conducted by pharmaceutical scientists. Following this the first local and monograph studies developed during the 2000s to global projects that combined Chinese medicine *fufang* or practice examinations with systems biology methods. The code of joining Chinese medicine studies reveals an increasing interest in Chinese herbal product research in the late 1990s and early 2000s which developed an exchange between Chinese medicine and European pharmacologists, biomedical scientists and Chinese medicine researchers. The code consists of four participations in Chinese medicine research and the ERC TCM consortium (see Figure 3 which depicts their relationships). I will first present one participant in early Chinese medicine monograph studies, then, I will demonstrate how this research enlisted other scientists in ethnopharmacology research and to the ERC TCM consortium.

Prof Carl's participation in Chinese medicine research shows that Germany and China co-operated in the first Chinese herbal monographs carried out in Europe. In the early 2000s, funding emerged for Chinese medicine and CAM studies, the ERC TCM consortium and Cambrella projects. Prof Carl had studied Chinese medicine remedies for 30 years. During his PhD in the 1990s, he was asked to investigate the quality of Chinese medicinal herbs by studying a species of the *Echinacea* plant genus that was used in Chinese medicine. The plant was one of 250 herbs that the Chinese medicine collaborators in Beijing suggested for the use in a TCM clinic in Germany. Prof Carl and his fellow students ensured the quality and safety of all 250 plants for the import to Germany and the use in the TCM clinic.

The circumstance that led to Prof Carl's PhD research project started in 1975 when the Prime Minister of the Free State of Bavaria, Franz Josef Strauß led a delegation to China. Strauß met Mao at the end of the Cultural Revolution (1966-1976) when the country was severely devastated and Mao Zedong was ill (Erling, 2015). One of Strauß' delegates was the entrepreneur Anton Staudinger. He suffered a severe cardiac problem during the journey which required emergency treatment in a Chinese medicine hospital where practitioners treated him successfully. A Chinese medicine treatment in Chinese hospitals was not uncommon during the 1970s. This was because of the Chinese state policy that aimed to integrate Chinese medicine in Western medicine settings such as hospitals (see Karchmer, 2010; see also Taylor, 2005). According to Karchmer (2010), during the Cultural revolution only a small number of Western medicine doctors were available in hospitals who supervised a larger number of Chinese medicine practitioners in learning Western medicine and practicing herbal medicine, acupuncture and massages. The high number of Chinese medicine practitioners was the result of the previous political measurement to reduce costs in pharmaceutical and medical supply in rural areas by barefoot doctors during the revolution.[32] These barefoot doctors were integrated in the hospital setting during the 1970s. The number eclipsed the integration of Chinese medicine practitioners in Western medicine hospitals in the 1970s (Kiely, Goossaert and Lagerwey, 2015).

After this experience and Staudinger's return to Germany, Staudinger was convinced of the efficacy of Chinese medicine and wanted to set up a TCM clinic in order to provide all Germans with this medicine. However, the Bavarian Ministry of the Interior, under Strauß, imposed this from happening and would only allow it on the condition that the medicine practice and drugs would be scientifically evaluated under a scientific advisory board. This aimed to guarantee the safety of all applied Chinese medicine drugs for the patients. Staudinger met the condition by establishing a committee that included Prof Carl's PhD supervisor, as well as other scientists and physicians from universities in Munich, Frankfurt and Witten-Herdecke.

Prof Carl performed his first Chinese medicine research in the course of the newly established co-operation between his university and the new project of a TCM hospital in Bavaria. For the supply and evaluation of the herbs, the TCM hospital and the

---

[32] Barefoot doctors (*chijiao yisheng* 赤脚医生) were people trained in Chinese and Western medicine as mobile doctors with the aim to reduce pharmaceutical costs and bring them to the countryside (Kiely et al., 2015).

university co-operated with a TCM hospital in Beijing. The co-operator in Beijing delivered the clinic with selected and verified herbs and sent Chinese medicine practitioners for a specified period to Munich. Prof Carl and other PhD students evaluated the 250 selected herbs and compiled the results into single plant monographs. For this evaluation, they used thin layer chromatography and high-performance liquid chromatography, which were standard technologies for chemical analysis of the herbs. With these technologies, they critically evaluated and demonstrated through quality controls, the efficacy and safety of Chinese herbal drugs that set the first standards for legal requirements in this field. Those monographs were later employed in the Chinese medicine pharmacopoeia. Overall, Prof Carl and his supervisor worked for ten years on the evaluation of Chinese medicinal herbs.

Prof Carl's link to Chinese medicine research describes an early and political requirement for the scientific evaluation of Chinese medicinal herbs in order to set up of a TCM clinic in Germany. His supervisor, who was a co-operator of the TCM hospital, assigned Prof Carl to scientifically evaluate the *Echinacea* plant in 1991. His work in Chinese medicine research demonstrates the same employment type as the students in the research projects code in Chapter 6. This type reveals a participation through a supervisor who acquired a research project and recruited students in order to conduct experiments. Hence, Prof Carl decided to take on the job as a doctoral researcher in pharmaceutical science and examined a Chinese herbal plant according to the standards of European medicinal plant research. Through his PhD project, he established a vast network of Chinese medicine practitioners and researchers in China and Germany.

Prof Jakob is another pharmacological scientist and ethnopharmacologist, who studies the use of medicinal substances using traditional knowledge and customs. Compared to Prof Carl, Prof Jakob does not present an early participation in Chinese medicine. According to his observation, the interest of Western scientists in Chinese medicine and other alternative medicine studies emerged in the mid-1990s. Prof Jakob claims that this was related to the foundation of the new journal *Phytomedicine* in 1994 by the scientific board member of the TCM clinic in Germany, which I elaborated on in Prof Carl's participation above. This correlates with the commercialisation and globalisation phase of Chinese medicine propriety medicine, which I described in

Chapter 2. The journal *Phytomedicine* provided a platform for a scientific investigation of medicinal plants beyond the conventional biomedical paradigm (see, for example, Phytomedicine, 2015).

Similar to Prof Carl, Prof Jakob argues that the two fatal renal failure cases in Belgium in the 1990s caused the demand of scientists to evaluate Chinese medicine. In Belgium, two young women died of kidney failure after the uncontrolled intake of a Chinese herbal slimming product. The slimming product included the toxic plant *Aristolochia fangchi* (*fen fang ji* 粉防己) as a replacement for the initially used and safe herb *Stephania tetrandra* (*han fang ji* 汉防己)[33], which in most cases causes nephropathy. Nephropathy is a disease or dysfunction of the kidneys. Prof Carl argues that the fault for the nephrotoxic cases was the lack of regulation on Chinese medicine drugs in Belgium. Belgium regulated Chinese medicine drugs under the food supplements law which permitted the purchase of Chinese medicine slimming products over the counter without restrictions or instructions about their intake. Thus, the Belgium case, or also called the "Chinese Herb Nephrotoxy", evoked public concerns about the safe use of Chinese medicinal products and the urgency to ensure the safe use of Chinese medicine remedies (see, for example, Heinrich et al., 1998; Dobos et al., 2005). In contrast, other countries such as Austria controlled all kinds of drugs under the Medicines Act.

In the 1990s, another interest group emerged beside Chinese medicine, the CAM researchers. Prof Jakob argues that the Chinese medicine project Konstrukta started with clinical research in the TCM clinic in Germany and investigated both Chinese medicine, and other natural medicines. With the establishment of the TCM clinic, came the first evaluation of Chinese medicine. Thus, it was logical for the associated scientists to continue with this research by starting the journal *Phytomedicine*. Slowly after the journal was founded, funding structures for Chinese medicine research unfolded in Europe which also simulated projects in other CAM research fields. For example, Cambrella was the counterpart to the ERC TCM project and investigated

[33] The *Aristolochia* case in Belgium was discussed widely in the scientific field such as Heinrich et al. (1998) flagged the problem in the species *Aristolochia* and not especially the medicine which uses the plant. Dobos et al. (2005) discussed the control and regulation of Chinese medicine herbal drugs. Leung and Xue (2005) suggested to transform Chinese medicine into an evidence-based medicine because a medicine can only be measured by its efficacy.

CAM practices and legal regulations in the EU member states. In 2007, the ERC awarded Cambrella researchers a EUR 1 million grant from Framework Program 7 (FP7). According to Prof Jakob, unfortunately, the Cambrella project did not continue after producing the final report for the ERC. As he says: "That [Cambrella] never really took off. Like many of these projects, the output was rather modest." In contrast, the ERC TCM consortium continued with the Traditional Chinese medicine research association (TCM RA).

According to both Prof Carl and Prof Jakob, the ERC TCM funding was the first European Union-wide funding for Chinese medicine in combination with cutting-edge technology (see Table 2 for a detailed account on ERC TCM projects). Prof Jakob remembers that the ERC TCM consortium funding was introduced at the conference of "TCM in Europe and International Cooperation TCM in Post-Genomic Era" in 2007. At the conference in Italy, European Ministers of Health and well-known scientists gathered to discuss Chinese medicine in Europe. The ERC initiated discussions about the best method to study Chinese medicine. Thus, the following ERC funding call in the FP7 program in 2007 aimed to coordinate interested researchers in Chinese medicine and systems biology in Europe and other countries.

The ERC TCM consortium's structure was divided into a core group of the management, the members of the consortium and the called-in experts. With the ERC FP7 funding, the consortium constructed a network of 200 scientists and gave them a three year timeframe. The consortium decided that omics technologies, as well as systems biology, were deemed the most appropriate methods to research Chinese medicine.

Prof Carl functions as a gatekeeper (see Table 3 for more information on the gatekeepers) in this research due to his membership at the consortium, his relationship with other actors in the Chinese medicine and systems biology research field, and his PhD project. With the start of an ERC TCM research project, Prof Carl became a non-beneficiary member. However, after the completion of the ERC TCM project he wanted to verify with omics and systems biology the effect of Chinese medicine; thus, he participated in the following project the TCM RA.

Simultaneously, to the conference in Italy, Prof Vera arranged conferences and co-operation between Austria and China to discuss quality standards in Chinese medicine and its use as preventive medicine in the Austrian healthcare system (see the code on political networking above). Prof Carl recognises her work and claims that co-operation with China, such as the Academy of Chinese Medical Science were built due to Prof Vera's contacts and conferences. Prof Vera's efforts initiated Chinese medicine research in Austria. Consequently, in 2007, her university network contacts, such as Prof Carl, participated in the ERC TCM consortium.

Prof Jakob became an expert in the ERC TCM due to his study on *Aristolochia* plants, which was a toxic plant in the Chinese slimming product, as above-mentioned. He was called-in as an expert and a non-beneficiary member for in general phytopharmacology to find active substances in plants, although he was not a specialist in Chinese Materia Medica. Prof Jakob investigated indigenous herbal treatments with the *Aristolochia* plant in Mexico. The results of his research showed that 99% of *Aristolochia* plants contained substances that cause nephropathy. The species of this genus were widely used in traditional medicines except in those countries where the plant is not indigenous, such as South Australia or South Africa. Through the case in Belgium, as above-mentioned, the plant became known as "Chinese herb nephrotoxin". Hence, Prof Jakob argued that nephropathies were linked to certain substances in the genus of *Aristolochia* plants, which aroused among Chinese medicine expert's criticism. They claimed that his argument was, I quote him: "nonsense", "unfair", or "it was an example of the inability of Europeans to use Chinese medicine drugs properly". However, some recognised that the toxicity of the plant was a global problem that required more research. The reaction to Prof Jakob's argument attracted the attention of the ERC TCM members who invited him into the consortium as a non-beneficiary member focussing on the safety, quality assurance and analytics of Chinese medicine research.

Another called-in expert in the ERC TCM consortium was the systems biologists Prof Frank, whom I introduced in Chapter 5. Prof Frank attracted the attention of the consortium with his success in Chinese medicine diagnosis research, which started in 2005. He supported the consortium with his expertise in systems biology and Chinese medicine and hosted the concluding conference of the ERC TCM consortium in the

Netherlands at which some members, such as Prof Carl, transformed the ERC TCM into the TCM RA. Prof Frank distanced himself from both, as he did not want to, I quote him, “talk 90% of my time to people who are reductionist”. He considered that the consortium continued with a reductionist research paradigm, which would not address the complexity of Chinese medicine. Rather, the members of the ERC TCM would only aim to reconfigure Chinese medicine drugs to “manage” diseases. By doing so, the consortium would “isolate Chinese medicine again” by repeating reductionist studies the members have undertaken many times before in their pharmaceutical careers. The reductionist pattern did not meet Prof Frank’s definition of satisfactory development. Thus, he decided to only present his findings at the ERC TCM conferences.

Dr Huang, a Chinese medicine scientist mentioned in Chapter 5, refused to take on “active” status as a member of the consortium because she committed her time to other projects. However, she was, in her words, “contracted” for the contribution of “some ideas”. In contrast to Prof Frank, Dr Huang joined the consortium without any concerns about the reductionist paradigm. She gave presentations and advice in the work groups of the consortium. In the subsequent TCM RA, which was founded in 2012 as I mentioned above, Dr Huang took over the co-chair of the regulation of Chinese medicine interest group. She also participated in the European Pharmacopoeia research project with other members of the ERC TCM consortium and TCM RA which aimed to add Chinese medicinal drugs in the European Pharmacopoeia. Hence, her status as a called-in expert extended to related projects of the ERC TCM such as the European Pharmacopoeia and the TCM RA. This shows that Prof Frank and Dr Huang were linked to the ERC TCM (see Figure 3 for the link between the ERC TCM and the Chinese medicine diagnosis project). However, their participation was mainly representative as it did not affect their Chinese medicine diagnosis project.

The aim of the ERC TCM consortium provoked discussions among participants. Prof Carl’s interest was to control the use of Chinese medicine through the Medicines Act that regulated the scientific evaluation and the distribution only through pharmacies, as pointed out above. The integration of Chinese medicine under the drug law would be necessary to avoid the marginalisation of Chinese medicine. Prof Carl argued that it is important to regulate Chinese medicine as medicine alongside biomedical drugs which are regulated and controlled in order to prevent them being sold without professional (i.e., medical doctor or pharmacist) advice. Additionally, the regulation of good practice in Chinese medicine research is necessary to avoid the unjustified prohibition of these drugs or plants. Prof Carl believes that Chinese medicine can help healthcare systems in treating many chronic diseases that lack appropriate treatment in biomedicine. Thus, Chinese medicine should experience a similar development as Traditional European medicine (TEM)[34]. Compared to Chinese medicine, many European nations recognise TEM products as drugs, as many biomedical drugs derive from TEM phytopharmaceuticals. Thus, the examination of TEM products is more advanced than Chinese medicine in Europe. Hence, Prof Carl stresses the need for more research on Chinese herbal medicine to accomplish the recognition of Chinese medicinal products as drugs.

In contrast, Prof Jakob believed that Chinese stakeholders aimed to integrate Chinese herbal medicine in the European Pharmacopoeia. He said that Chinese scientists thought that the integration would achieve the approval for the import and marketisation of Chinese medicinal products, and the practice of Chinese medicine by EU member states rather than the control for its sale and protection of the consumer. However, the European Pharmacopoeia is unrelated to the import, the market laws and the acceptance of Chinese medicine practice in EU countries (EDQM, 2010). The consortium was in Prof Jakob's perception, a project for the "modernisation and globalisation of Chinese medicine". He compared this project with a "new silk road"[35], which is a trading route for TCM into Europe. A group of engaged scientists supported this undertaking as they wanted to show their skills to integrate Chinese medicine into European healthcare services. Prof Jakob criticises the optimism of scientists from the outset of this consortium and agrees with Prof Meng's opinion concerning the lack of results in Chinese medicine and systems biology research. According to Prof Jakob,

[34] TEM refers to the history of medical practice in Europe that experiences a renaissance since the early 2000s (Uehleke, 2007). The practice with European plants is often referred to as Western herbal medicine (Waddell, 2016).

[35] The term "Silk Route" refers to a trading route from Europe to Northern China in the second century BC (see Barnes, 2005).

better coordination of the efforts of individual scientists would have increased the likelihood of the acceptance of Chinese medicine in Europe:

> "… the Chinese wanted to try somehow to show how great they are. That's where modernisation and globalisation come in. One was more of a roadmap and the other was more of a New Silk Road to Europe… because that has such an amoeba structure, when such a group of single prima ballerina get together with TCM researchers, everyone wants to do something amazing. A lot happens but, in the end, nothing happens. And of course, there was a lot of efforts here, how can we drive this project, how can we ensure that traditional Chinese medicine is accepted in Europe?" (Prof Jakob, 2018, London)

The consortium announced the successive project at the April 2011 conference in the Netherlands. At this conference, the management of the ERC TCM consortium declared the project complete. This TCM RA project was organised by some members and applicants who lost the funding for the ERC TCM consortium in 2009 (i.e., the Shanghai University). Consequently, they transformed the consortium into an industrial supported scientific TCM RA that linked Europe with China. The RA enlisted sponsors for meetings and devices for metabolomics studies, in return for selling the devices to the members of the consortium and RA. The development of the consortium into the RA continues with the attempt to push the integration of Chinese medicine as a drug, alternative or preventive medicine into healthcare systems in European countries.

The code of joining Chinese medicine studies showed the development and participation of scientists in networks like the university network or a large-scale project on Chinese medicine research and systems biology. Interview data revealed that the interest in studying Chinese medicine appeared first in the 1990s with the establishment of the TCM clinic in Germany and the journal *Phytomedicine.* These establishments attracted the interested of many pharmacologists in traditional medicinal plants and drugs, such as Prof Carl.

Specific plant studies engaged other scientists such as Prof Jakob with his study on widely traditional medicines used and the most toxic plant *Aristolochia*. For those scientists, the safety, quality and efficacy of Chinese medicinal drugs became crucial for the regulation, control and integration of Chinese medicine as a medicine in the European Pharmacopoeia or the Medicinal Act. Prof Jakob and Prof Vera claimed that the project was an attempt to modernise Chinese medicine and to enter the EU pharmaceutical market.

This code demonstrated that a technological and ideological exchange connected Chinese medicine with European pharmacologists, biomedical scientists and Chinese medicine researchers in the late 2000s. This was financed by the ERC network funding which identified 200 scientists and decided that omics technology and systems biology were the best methods to research Chinese medicine.

7.3 Funding and regulations

The code "Funding and regulations" draws on data from the literature survey of scientific publications to complement the data in Chapters 6 and 7. The data is presented in three codes: (i) social demands for changes in the healthcare system, (ii) the European Research Council funding, and (iii) Chinese medicine in the European Pharmacopoeia. First, a series of social movements and political changes enforced European social and scientific interest in Chinese medicine. Secondly, the WHO and the EU requested research and policy strategies for Chinese medicine in Europe. In the last part of this chapter, I will elaborate on the function of the European Pharmacopoeia for Chinese medicine research and regulation.

7.3.1 Social demands for changes in the healthcare system

From the 1980s onwards, European healthcare systems were confronted with structural and monetary challenges (van der Greef et al., 2015). Social movements in the USA demanded the recognition of CAM as a profession, as well as a better quality in healthcare and less expensive caring costs (Hess et al., 2008). The WHO (2002) reported a tendency in developed and developing countries towards the use of traditional medicine. In their article, Baer, Singer and Susser (2003) argue that in developed countries, the shift to traditional medicines increased due to the lack of the right chemical drug treatments for chronic diseases, idiopathic and many autoimmune disorders in biomedicine. Hence, traditional medicines were for many patients a cheap alternative to biomedicine and offered for many chronic diseases, a more appropriate treatment that biomedicine could offer for their ailment. For instance, 70% of the people in Canada, 49% in France and 31% in Belgium used traditional medicine (WHO, 2002). The media in Austria reported in 2005 that pain management therapies with acupuncture were popular among the Austrians. Austrians either tried acupuncture for once out of curiosity or as a frequent alternative treatment to allopathic medicine and chemical drugs with side-effects ("*Schmerz: Therapieaussicht kann bereits helfen"*, 2005). Due to the rising use of traditional medicines, the WHO (2002) formulated working strategies for its member states to integrate policies, safety and efficacy, access and rational use of traditional medicines. The WHO (2002) wanted to research the claim of less or no side-effects of traditional medicine drugs and to establish policies for traditional medicines to integrate them as moderate approaches to chronic or debilitating diseases.

In developing countries, due to the lack of biomedical drugs available for AIDS, malaria or SARS and access problems, economic reasons and belief systems contributed to the growing usage of traditional medicine. The population in developing countries such as 80% of the African population and 40% of the Asian people relied on traditional medicines as a stable source of healthcare rather than biomedicine (WHO, 2002, p. 2). For example, a problem with biomedicine in developing countries was the non-existing or bad developed technological infrastructure on which biomedicine depended on to establish healthcare services and to deliver a diagnosis. Another problem was the high ratio between doctor and patients. The WHO (2002) reported that in Africa one medical doctor served 40,000 citizens, while the ratio between a traditional health practitioner and citizen was 1:500. Consequently, the geographical access problems and diagnostic challenges, traditional medicine, such as Chinese medicine was favoured over biomedicine. Reflecting on these circumstances in the early 2000s, it can be said that biomedicine arrived globally at a critical point that challenged to address health issues and lacked effective and cost-efficient therapeutic treatments.

Though in many countries people opt for traditional medicines, only 25 WHO member states have implemented regulations for the application and the quality assessment of traditional medicines or included herbal products in their pharmacopoeia (WHO, 2002). To increase the attention on traditional medicine, the WHO published a strategy for the implication of good practice in traditional Chinese medicine research in 2002 (ibid). The Good Practice strategy stressed the need for policies and regulations on quality, safety, efficacy, access and rational use of traditional medicines and CAM. The WHO (2002) expected the member states to integrate traditional medicines as a healthcare package into their healthcare systems, which guaranteed the access to medicine independent from financial resources of people or cities where the medical infrastructure was better developed.

Following the request for research and policies by the WHO, in 2002 the ERC funded a project on CAM practices, the Cambrella project. According to the Cambrella report by Wiesener and colleagues (2010), all twenty-seven member countries of the EU adjusted their national legislation to the EU regulations on CAM practice, but a unified regulation was missing. In the EU member states, the adaption of the law is a national decision. As a result, the degree of adjustment varied immensely between the member states and increased a disparity in research on effective therapies in CAM and individual practices and practitioners across EU countries. The challenge was to find a standard for studies on the safety and efficacy of CAM practices (ibid). For instance, Wiesner et al. (2010) reported that Austria legally recognises acupuncture as a scientific treatment for pain. However, according to Austria's Law on Physicians of 1984, only medical doctors are allowed to practice acupuncture. This law applies to any medical practice that requires medico-scientific knowledge or involves any therapeutic work on patients. The legislation includes any CAM specialisation, which is regulated by the Austrian Medical Chamber diploma (*Ärztekammerdiplom*). Hence, the diploma limits the practice of CAM treatments by medical doctors.

The regulation of Chinese herbal drugs is a further problem between EU member states. The application of the Medicines Act (*Arzneimittelgesetz*) on Chinese herbal products requires the recognition of Chinese medicine as a drug extracted from a natural product (ibid). Comparable to medical practice, EU member states have individually strict Medicines Acts. For example, Belgium regulates Chinese herbal medicine under the food supplements law. Whereas, in Austria, Chinese herbal medicines are drugs, and they are only available on prescription in pharmacies (Wiesener et al., 2010). Thus, every country in Europe has its definition of whether Chinese medicinal products are food supplements or drugs. The demand for regulation and research on Chinese medicine by the WHO (2002) and the fragmented laws on CAM in the EU, were addressed in other EU funded projects on the control and regulation of Chinese medicine, which will be discussed next.

7.3.2 The European Research Council funding

The European Research Council (ERC) is a pan-European structure of scientific research programs. It founded the ERC TCM consortium. The funding was introduced at the first "Sino-European Conference on Traditional Chinese Medicine (TCM) - International Cooperation and Perspective in Science and Technology" (short Sino-European Conference) in 2007. From 27 to 28 July 2007, European Ministers of Health and well-known scientists gathered in Rome to discuss Chinese medicine in Europe under the title "TCM in Europe & International Cooperation TCM in Post-Genomic Era". According to the conference program, Chinese medicine was at its core and seen as the political engagement of Chinese medicine between China, Italy and other EU states (Sino-European Conference, 2007). The China Academy of Chinese Medical Sciences (CACMS) and the Italian National Institute of Health (INIH) organised the conference (ibid). The focus of the conference was to bring members of the government and European organisations, universities, scientific institutes and enterprises together to discuss the policies and regulations for Chinese medicine development and products, collaborations for medical product development and clinical research for disease treatment with Chinese medicine.

Interviewees found that the Sino-European Conference was the first attempt to push Chinese medicine research and drug marketisation in the EU on a political exchange platform (Prof Jakob, 2018, London). This statement can be supported by the list of chairs, sponsors and co-sponsors that indicates that the Chinese government and Chinese organisations used the conference to push Chinese medicine in the EU. The chair was the deputy director from the International Cooperation Department of the Ministry of Science and Technology from the People's Republic of China (PRC) Ma Linying. The vice chairs were Zhang Qi from the State Administration of Traditional Chinese Medicine (SATCM) and Xu Youjun from the State Food and Drug Administration (SFDA) of the PRC. Maria Paola Di Martino from the Ministry of Health of the Republic of Italy was the only Italian co-chair in this conference. The main sponsor was the Directorate-General for Research in European Commission and the co-sponsors were predominantly from China and included the Ministry of Health (MOH), the SATCM, the SFDA and the State Intellectual Property Office. Participants were from organisations, such as the Ministry of Economic Affairs of The Netherlands, the WHO and the United Kingdom Trade and Investment (Sino-European Conference, 2007). Chinese organisations and political players took a central role in the conference, which strengthened the argument of China's plan to marketize Chinese medicine drugs in the EU.

The list of speakers at the conference in Bologna 2007, included members from European Commission, health ministers from the Italian, Austrian, German, Danish and Chinese governments. Important researchers for the creation of further research projects in systems biology and Chinese medicine research were the systems biologists Jan van der Greef and Jeremy Nicholson; the pharmaceutical scientist Rudolf Bauer; metabolomic researcher Xu Guowang; Chinese medicine researchers Guo Dean, Lu Aiping, Fan Taiping, Luo Guoan and the entrepreneur Anton Staudinger. They all gave talks about Chinese medicine policies and regulations, pharmaceutical products, treatments and cures. All these speakers were selected for this conference due to their expertise and participation in Chinese medicine practice and research. For example, Nicholson was one of the most cited systems biologists in Chinese research papers (see, for example, Zschocke et al., 2005; Luo et al., 2012a; van der Greef et al., 2013; Lu et al., 2012; Xu et al., 2013). Luo and his colleagues worked on their book their book *System Biology for Traditional Chinese Medicine* (2012) that discussed systems biology as a new way to study Chinese medicine, while also continuing the development of Chinese medicine as well as systems biology through experiments designs and strategies.

The highlight of the conference was the introduction of a Chinese medicine research project funded by the ERC. On 27th June 2007, Andrzej Rys, the director for Public Health and Risk Assessment of the European Commission, introduced a new ERC funding for Chinese medicine and systems biology at the conference (Sino-European Conference, 2007). This funding supported for the first time in the EU a Chinese medicine research project from 2009 to 2011. The FP7-HEALTH-2007-2.1.2-7 - "Traditional Chinese Medicine in the post-genomic era" was one of the grants introduced for health-related research under the ERC FP7 (EC, 2006).[36] This funding

[36] Initially, the title of the funding covered complementary and alternative medicines (CAM). However, in the last report, it shifted to "Systems biology and Traditional Chinese Medicine" (EC, 2007b).

was a “Coordination and Action plan” between EU and China and provided a fund to “promote and support networking and the coordination of research activities by applying functional genomics in the context of Traditional Chinese Medicine” in co-operation with China (EC, 2007, p. 23).

The FP7 aimed to promote the ERC as a research area and inaugurated a total budget of EUR 50.5 billion (GBP 44.55 billion).[37] The ERC invested more than half of it in the co-operation and action program (EUR 32 million, GBP 29 million) and EUR 1.1 million (GBP 968.194) in the ERC TCM consortium (EC, 2012). With a “Specific International Coordination Action” (SICA) program, the ERC aided the “International Cooperation Partner Country” (ICPC) between the EU and non-European countries such as China.[38] The reason for China’s status as a special partner was that the EU signed an agreement with China as a scientific and technological co-operation partner (EC, 2006).[39] With the funding decision in 2009, the ERC changed the name of the FP7 to the topic “Translational research” in human health by gathering large data including systems biology (ibid).

The SICA funded applications that addressed the networking aspect between various institutions to research large datasets of Chinese medicine with systems biology. That followed the political aim of the EU to explore good practice with a systematic literature review for evidence on the safety and efficacy of Chinese medicine with omics technology. Consequently, the project aimed to fund multidisciplinary research

---

[37] The FP7 program started in 2007 and ended in 2013 (EC, 2007a). The first FP1 started in 1984, and FP6 terminated at the end of 2006. The current framework program is the Horizon 2020 began in 2014 and will run until 2020, with a funding budget of nearly EUR 80 billion (ERC, n.d.).

[38] The and allocated the SICA as a third country co-operation program to contribute to turning the Union into “the” world’s leading research area. The EU FP7 has to ensure three points: coherence with EU policies, complementary programs and the achievement of the Millennium Development Goals (MDGs). Thus, the EU invested in world-class state-of-the art research with the principle of excellent research. The program included four categories: (i) Co-operation program for transnational and policy defined themes; (ii) Ideas program for the research community and investigator-driven research; (iii) People program to support individual researcher; and (iv) Capacities program to support research capacities (EC, 2006). The ERC TCM gained funding under the co-operation program.

[39] In 2007, the EU provided funding to the International Cooperation Partner Country (ICPC), in this case China, so that organisations from third industrialised countries can carry out research. Such programs aimed to support global health issues like malaria, tuberculosis, and other epidemics or mutual benefit of bi-regional co-operation, e.g., healthcare systems. The combination of EU and Chinese scientists fulfilled the SICA project requirements of two participants from two different Member States and an ICPC country (EC, 2006).

for developing new knowledge and methods that addressed European healthcare problems, as well as those in developing countries (EC, 2006). Concurrently, some members of the ERC TCM project examined Chinese medicine drugs for the integration in the European Pharmacopoeia as presented next.

7.3.3 Chinese medicine in the European Pharmacopoeia

The European Pharmacopoeia Commission (EPC) addressed the growing demand for Chinese medicine by organising a conference in 2010. In this conference, stakeholders like the Chinese Pharmacopoeia Commission, the SATCM of the People's Republic of China and the National Key Laboratory of TCM Quality Control discussed safety issues of Chinese medicine. They signed a Memorandum of Understanding in 2011 with the European Pharmacopoeia to reinforce their co-operation for the protection of public health (EDQM, 2010).

Gerhard Franz, a member of the ERC TCM, formed and chaired the TCM working party of the European Pharmacopoeia research team, which was the Consortium for the Globalisation. The members aimed to reinforce monograph research on Chinese medicine for the integration of Chinese herbal drugs into the European Pharmacopoeia (EDQM, 2011, p. 38). However, the EPC, as part of the Council of Europe, regulates the development, production and marketing process of drugs. The EPC accepted several Chinese herbal products based on the standards of biomedical drugs, for example, the quality of medicinal drugs, the safe use for patients and the free movement of drugs in Europe (EDQM, 2011).

Nevertheless, the approval of Chinese medicine practice is part of the general CAM legislation, which each EU member states individually regulate (see Section 7.3.1). According to the legislation and Prof Jakob's assumption about the EPC regulations, the EPC does not regulate the implementation or the practice and use of Chinese medicine. Consequently, the integration of Chinese medicine drugs in the European Pharmacopoeia does not permit the sale and practice of Chinese medicine in EU states.

7.4 Conclusion

This chapter showed from interview material and the results from a literature survey, three codes of political networking, joining Chinese medicine studies and funding and regulations. The scientists in this chapter participated in the ERC TCM consortium due to their experience in previous projects. They were members of the Dalian-Leiden collaboration, political networking with the university network organisation, specific plant research or the TCM clinic research on Chinese medicine in Germany. They all became part of the ERC TCM after they were invited to join the consortium as advisors. The expertise of the five scientists (Prof Vera, Prof Carl, Prof Jakob, Prof Frank and Dr Huang) was valuable to the ERC TCM to identify and enlist 200 scientists in the first ERC funded co-operation and networking project.

This chapter presented the results to the question how the participation of human and nonhuman actors influences the development of this “interface”? The data showed that a series of action between organisations such as the WHO, and individuals such as scientists or researcher established research projects that developed to international consortium and co-operation in Chinese medicine and systems biology. This was shown with three main reasons why the ERC funded the ERC TCM project. First, the WHO addressed the problem of the increased use of traditional medicine by publishing a report with the research and policies in this field internationally. Second, the specific legislation across European countries showed a lack of consistent regulation and control of drugs. Thirdly, European scientists expected to decrease healthcare costs by discovering new single active compounds in Chinese herbal drugs for the development of new drugs. Some smaller projects continued with either the continuous intention of the twentieth century to globalise and modernise Chinese medicine or the efforts to integrate Chinese medicine drugs in the European Pharmacopoeia.

In the codes of political networking, the process of generating networks and enlisting scientists and politicians in the research in first Chinese medicine then in Chinese medicine with systems biology. Thus, the code of political networking revealed how Prof Vera connected politicians and universities in China and Austria and her network became an organisation platform for Chinese medicine conferences in Austria and the main political and academic contact source for the ERC TCM consortium.

The joining Chinese medicine studies code revealed the scientific aspect of the participation in Chinese medicine studies in the 1990s. The interest in Chinese medicine research in Europe emerged from the co-operation between the TCM hospital and universities in Germany as well as the new journal of Phytomedicine. This stimulated a broader interest in Chinese medicinal products and other traditional medicines research. One of the presented actors was Prof Carl. His participation in Chinese medicine research stemmed from his PhD research which supported the establishment of a TCM clinic in Germany. The other actor was Prof Jakob who was invited to join the ERC TCM studies through his work on the plant *Aristolochia*. Prof Frank and Dr Huang were invited to the ERC TCM consortium as they conducted the first studies on Chinese medicine and systems biology. Additionally, Dr Huang contributed to the integration of Chinese medicine drugs in the European Pharmacopoeia, while Prof Frank not only contributed as a presenter, but also as an organiser of the final ERC TCM conference in Leiden in 2011. With the finalised projects, the actors published their findings in 2011 and 2012, which explains the high number of publications in these years (see Figure 1), as presented in Chapter 3.

The focus of the ERC TCM was the assessment of research methods and standards for Chinese medicine drugs and their efficacious use. Simultaneously, the question of the best method for the evaluation of Chinese medicine drugs generated networks that connected universities, politicians and the industry to the ERC TCM consortium. Some of the identified scientists, such as Prof Carl and Dr Huang, continued in the successive association of the consortium, which intended to globalise Chinese medicine.

The participation of the five actors was often regarded as a professional obligation and implied a degree of apprehension with regards to the aims of the ERC TCM management team. Prof Jakob and Prof Vera expressed their concerns about the aspirations to globalise and to marketize Chinese medicine. This aim was made evident by the successor of the consortium, the TCM RA that continued with the use of Chinese medicine as an export product to the European market. In their viewpoint, Chinese medicine developed in the direction of commercialisation of Chinese medicine drugs. Within a decade Chinese medicine research developed from a marginal interest in sciences into a European and Chinese co-operation project that established network, organisations and departments of Chinese medicine research.

The results from this chapter and Chapters 4, 5, and 6 will be analysed together and presented in the next chapter.

8. ANALYSIS

In this chapter, I will analyse the life stories descripted by the codes presented in Chapters 4, 5, 6 and 7 in modes of a heterogeneous network, vision and vocation, to address the following research questions:

1. Is there an "interface" and if so, can this latest contact between Chinese medicine and systems biology be referred to as an "interface" and what is its nature?
2. How does this "interface" differ from previous encounters between Chinese medicine and modern science and Western medicine?
3. How did the actors become involved in Chinese medicine and systems biology research?
4. How did the participation of the human and nonhuman actors in Chinese medicine and systems biology research influence the development of the relationship between Chinese medicine and systems biology?

Research Question 3 which examines how actors became involved in this "interface" is intertwined with the questions about the emergence and development of this "interface" (Questions 1 and 4) and the nature of it. I use Law's (1994) "modes of ordering" approach to investigate the meanings (perceptions) and frames (codes) gained from thematic coding of ethnographic data (see Chapter 3). The modes of a heterogeneous network, vision and vocation explore how the ordering of the emergent relationship between systems biology and Chinese medicine is achieved.

TABLE 4: QUESTIONS AND MODE OF ORDERING ORIENTATION

Table 4 presents the mode in which each research questions will be answered.

Question 1:	Mode of a heterogeneous network: description and nature of the "interface"
Question 2:	Mode of a heterogeneous network: nature of previous encounters compared to the current "interface"
Question 3:	Mode of vision: emergence and nature of Chinese medicine and systems biology research through personal involvement
Question 4:	Mode of vocation: nature, emergence and development of Chinese medicine and systems biology research through co-operation

"Modes of ordering" are strategies used to organise meanings and effects (i.e., agency, orders, networks, organisations) or collected "bits and pieces" that describe a process of how actors and networks emerged into the form they have taken and the place where they currently are (Law, 1994, p. 21). The ordering is a way to arrange empirical data into patterns, which emerge through various processes and transformations that are associated with and performed by "heterogeneous materials". I will use Law's (1994, p. 23) definition of "heterogeneous materials", which are, for example, people, machines, architecture, texts, talks, decisions, computers or organisations. In the line of other ANT theorists (Callon, 1986; Latour, 1987, Law, 1994), Law (1994) argues that these materials perform as actors if they transform due to an interaction with other materials. For example, a computer is an actor as it consists of various elements and devices that process data through the interaction of these parts. Hence, in summing up Law's (1994) definition, this means that various actors belong to different classes of things (humans or non-humans) that co-evolve to new things.

In this chapter, I will first describe the concepts I use to carry out the analysis. I will then show how I apply these concepts to structure my analysis. Following this, I will present my modes of (i) a heterogeneous network, (ii) vision, and (iii) vocation. In the first mode of a heterogeneous network, I analyse the perceptions, descriptions and aims of the systems biologists and Chinese medicine researchers (the actors) and their relationship between Chinese medicine and systems biology. My argument is that multiple and different relationships between various sites performed co-operation, which describes the nature of this "interface". Secondly, the mode of vision reveals the involvement of the actors after a change from their comfort zone in their research area in science and biomedicine, to a traditional medicine or an enhancement of their academic career. Finally, in the last mode of vocation, I analyse how the participation of various actors and their co-operation with various field sites (see Table 2 for partner institutions and Figure 3 for linkages between sites) influenced the development of their relationship between Chinese medicine and systems biology.

To understand "modes of ordering", stories that describe and explain the relationships between Chinese medicine and systems biology and their context are needed in order to gain a "thick description".[40] Law (1994) argues that stories indicate patterns and relationships that order sociotechnical networks through relational materialism. With regards to relational materialism, Law (ibid) refers to Foucault's discourse analysis, which in his opinion is concerned with the question of how materials perform themselves and generate effects, such as strategic arranging. Law (ibid. p. 95) uses relational materialism to perform a discourse analysis by taking "the notion of discourse and cut[ting] it down to size". This means: "first, we should treat it [the story] as a set of patterns that might be imputed to the networks of the social; second, we should look for discourses in the plural, not discourse in the singular; third, we should treat discourses as ordering attempts, not orders; fourth we should explore how they are performed, embodied and told in different materials; and fifth, we should consider the ways in which they interact, change, or indeed face extinction". This means that patterns are "imputed" to his stories as a way to identify and determine his mode. However, as my aim is to stay close to the material, I use the thematic codes described in Chapters 4, 5, 6 and 7 to generate patterns for modes, and develop from those, a detailed analysis of the involvement and process involved in developing a relationship between Chinese medicine and systems biology.

40 Thick description describes and explains actions, such as, human behaviour and in which context these actions occur. Context information can be biographies, historical information on the cause of the action, including situational, relational and interactional (about meanings and relationships) details (see Geertz, 1988).

Following Law's (1994) stories approach, I employed multi-sited ethnography to detect multiple discourses that form "modes of ordering" and materials, which are performing relationships and associations. I collected stories including life stories and narratives about how research interests, projects and funding were generated and how relationships between the actors of Chinese medicine and systems biology, academia, industry and politics and nonhumans in the form of fluids, solvents, machines, organisations, governments and funding play into the creation of scientific and technological achievements in Chinese medicine and systems biology research. As a result, the "modes of ordering" present in-depth descriptions of the various processes of ordering of the relationship between Chinese medicine and systems biology. However, as ordering is a process; it has to be viewed as a verb that continually enacts, performs and generates (Law, 1994). This means that modes are never complete and can be interpreted in many other ways than, for instance, I present them in this thesis.

The process of ordering generates a "centre of translations" (Law, 1994, p. 104). According to Law (1994), a "centre of translation" is a place where representations of actors and actions are generated and gathered. The "centre of translations" strains for reflexivity and self-reflexivity by monitoring the situation and happenings and makes calculations to act upon those observations. Thus, the "centre of translation" gathers, monitors, makes, simplifies, calculates and acts upon the flow of "immutable mobiles" (ibid) that are transported from and to the periphery. "Immutable mobiles" are materials that are easy to transport for dissemination and communication, and always maintain their shape (Law, 1994, p. 104; see also Latour, 2011). These can be seen in the forms of research papers, print material, money, a postal system, cartography, navigation, ocean-going vessels, cannons, gun powder or telephony (Law, 1994). In Law's (1994) discourses, he differentiates materials between more and less durable materials and those various materials represent and control the actions within a mode. Accordingly, the periphery is the place where the actor is seen outside the network and is the place which is not involved in the reflexive activities.

The two modes I adapt from Law (1994) in this thesis are: the "mode of ordering vision" and "the mode of ordering vocation". First, the "mode of ordering vision" talks about a scientific vision of the future which concerns dreams, order and the practicability of ordering. This mode is characterised by an actor who is gifted, elite, a visionary, a genius, a workaholic, a charismatic leader or a decision maker, and who is attractive, inspirational, funny, single-minded, and committed to science. The actor has research organisations and the public behind his/her actions. Vision is elitist as only a few people perform scientific visions which distinguishes them from others. By using his "mode of ordering vision", I analyse the involvement of systems biologists in Chinese medicine research as a change from their comfort zone in their discipline - science and biomedicine - to a traditional medicine. This mode reveals the scientific visions of actors that guided their involvement in Chinese medicine and systems biology studies and shows how they attracted with their vision, other scientists and funders. This mode demonstrates first how systems biologists decided to change from science to Chinese medicine, which is often referred to as a "non-scientific field" (Ward, 2011, p. 69), and then how they engaged with Chinese medicine practitioners, researchers, theories and materials.

The "mode of ordering vocation" orders the stories of the scientists' dedication to their job and the value they associate with it (Law, 1994). People in the vocation mode embody skills, expertise and importance, character and the required knowledge and training needed for a certain position. This mode portrays a person with the necessary qualifications or a person who has access to a research position and is able to creatively solve puzzles, is a self-starter and approaches ranking challenges such as publishing. I will use Law's (1994) "mode of ordering vocation" to analyse the participation of actors in systems biology and Chinese medicine research projects or in the ERC TCM consortium. Visions, beliefs, and aspirations of the inner circle such as complexity or holistic research methods were not in the foreground of their participation in research projects. In contrast, what I call the actors in the mode of vocation, the outer circle, were either interested in a research position, or they were invited into Chinese medicine and systems biology projects due to their expertise in technology or biochemistry. Scientific activities and presentations of the inner circle's work attracted the actors of the outer circle and recruited them in a variety of ways. Therefore, the mode of vocation analyses participations, job positions, funding and networks as a motivation to participate in the research projects between Chinese medicine and systems biology. Both modes of vision and vocation inform us about the involvement of the actors in Chinese medicine and systems biology. The difference between them is that actors in the mode of vision talk about their inspirations, individual aims and creative ways to find solutions to their professional and private lives. Vision is more personal as it describes aims beyond the current or the next research project and it is about changing approaches in medical research and medicine in the long run.

The mode of a "heterogeneous network" describes the perceptions and nature of the "interface" between Chinese medicine and systems biology through translations and "immutable mobiles" to establish co-operation (see Table 4 for modes of heterogeneous network). I use Law's (1994, p. 23) definition of "heterogeneous" to mean different kinds of materials (omics technology, computers), organisations, and people for example agents, which are effects of a network of various materials (i.e., machines) or people. According to Law (1994), the word "network" describes associations between various human and nonhuman actors that create patterns. Hence, a heterogenous network denotes the kind of actors and their ways to generate and perform relationships. Consequently, a homogenous network consists of associations between either humans or nonhumans.

The mode of a heterogeneous network is informed by the work of Moser (2005) who applied the "modes of ordering" to study disability with analytical tools outside the conventional approaches of disability studies and its focus on dualism of normal and not-normal. She collected life stories of disabled people in multiple sites in Norway and ordered them according to the perception of the actors and their interaction with technology that defined modes of normal, lack, fate and passion. I want to analyse various perceptions and descriptions of the relationships between Chinese medicine and systems biology in ethnographic data and life stories of various actors in multiple sites in Europe, China and Japan. Thus, this mode of a heterogeneous network aims to preserve the perceptions of the actors and the network character of a multi-sited research in Chinese medicine and systems biology, and also "cut down in size" the discourse of research projects and co-operation by showing "how ordering is done and how it enacts itself in different material forms" (Moser, 2005, p. 671).

This chapter will first analyse the mode of a heterogeneous network. It will then examine the mode of vision and finally the mode of vocation.

8.1 THE MODE OF A HETEROGENEOUS NETWORK

The mode of a heterogeneous network will be used to answer Question 1. It investigates which actors such as materials, machines or people are associated with this "interface" and how they generated and performed in relationships while researching Chinese medicine with systems biology. This mode orders the various perceptions and description of the actors I have interviewed in (i) co-operation, (ii) biochemistry and (iii) omics technology as a bridge of what the nature of this "interface" is and how it was built between Chinese medicine and systems biology. The projects, I refer to, are the Dalian-Leiden co-operation, the ERC TCM consortium, the Harbin research group, and the systems biology expert and AI scientists. I will first focus on the description of the co-operation or bridge. Biochemistry and technology will be discussed later in this section.

8.1.1 CO-OPERATION AS NETWORKS OF EXCHANGE

Most of the interviewed actors in Dalian and Leiden did not refer to the research relationship between Chinese medicine and systems biology as an "interface", they referred to it as a "co-operation". Co-operation was described as an exchange of materials. Some referred to technology and biochemistry to describe the connection and the translation between Chinese medicine and systems biology (George, Harbin team, Prof Carl). The materials in this mode of a heterogeneous network were: systems biologists, pharmaceutical scientists, biochemists, Chinese medicine researchers, politicians, molecules, omics technology, samples, *zhengs*, publications, reports, funding, organisations, patents, drugs and concepts. "Centres of translation" (Law, 1994) were the Leiden team, omics technology, principal investigators and supervisors, AI, the ERC TCM management team and collaborators. "Immutable mobiles" connected materials between the different human and nonhuman actors and products of omics and biochemistry analysis, research papers, experiment protocols, biofluids, and drugs.

According to the description given by the actors, co-operation refers to two things: the exchange of materials and students. I argue that co-operation generated "centres of translation" (Law, 1994) that were constituted through the interaction between scientist and materials, which are listed below. First, the Dalian-Leiden groups consisted of systems biologists and molecular biologists who described their co-operation as the exchange of materials and distribution of conceptual ideas for their studies on Chinese medicine and systems biology. Materials were omics technology, analysis results, experiment protocols, research papers, funding, concepts, samples and protocols. The Dalian team co-operated because they had a special interest in omics technology and the different ways it could be used to apply analytical tools in pharmaceutical research by trading materials for technological knowledge. Thus, it is evident that omics technology played a fundamental role in the establishment of this co-operation. The use of omics technology as the latest technology with its multivariate analysis attracted and convinced the Dalian group to agree to this co-operation (as described in the mode of vocation). Omics technology represented for the Dalian group, a new way to interpret data for their metabolomics studies, which meant technological advancement and new funding resources from Chinese medicine sponsors.

The second exchange was the exchange of students. According to Law (1994), bodies are "immutable mobiles", which transport and disseminate information between the periphery and the centre. As above-mentioned, the Leiden group acted as a "centre of translation" in the exchange of students. This means, the students (Lingma and Long) performed a transmission of information by moving to and conducting their research in Leiden. They absorbed the concepts and analytical methods of systems biology to investigate Chinese medicine from professors and the research team in Leiden, which they then transmitted to the Dalian group. In return, the Dalian students shared their knowledge of the usage and maintenance of technology with the Leiden group. In contrast, the Leiden students (George and his fellow students) learned from materials, such as samples and wet experimental data. As a result of this co-operation, the Dalian students benefited in terms of learning support and by sending three students to Leiden for a period of one to three years. While the Leiden students acquired samples, technological support and they visited the Dalian institution only for a couple of days.

In “modes of ordering” terms, the Leiden team represented the “centre of translation” due to their expertise in systems biology and analytical knowledge.

Another type of “immutable mobiles” were experiment protocols that represented problems during the co-operation between Dalian and Leiden. Experiment protocols should have distributed experimental data. The research design depicted every step in the experiment so as to prevent mistakes. However, the students did not follow the design, thus, the experiment protocols lacked information on the exact experiment procedure including sample handling and preparation. Against the common assumption that communication suffered as a result of a language barrier between English or Dutch and Chinese, or the technical language of chemistry, there was the added issue of documentation and not following the research design. Consequently, the details were not transmitted to the Leiden group, which they needed to perform the analysis. Based on the results of the research and relationship performance, they calculated the value of this co-operation and ended it once the research had finished. The lack of data distribution was not a problem in any other co-operation; therefore, it was not calculated as a risk in the study design of the Leiden team. Hence, it was the issue of storing and sharing information between human actors that influenced the achievement of the Leiden and Dalian project and future co-operation.

To sum up, Chinese medicine researchers and systems biologists co-operated through concepts and biofluids, which generated a platform for the exchange of expertise in analysis and technology. In addition, this co-operation aided the exchange of students, samples and data between the teams in Leiden and Dalian. This platform provided the students with workshops and training in Dalian and a distribution channel for data sets and batches of blood and urine samples from patients in Dalian to the laboratory in Leiden. Thus, the co-operation between Dalian and Leiden was an exchange of biochemical data and analytical and technical knowledge, and revealed ways on how these materials were disseminated and transmitted.

8.1.2 BIOCHEMISTRY AS THE CENTRE OF INTERACTIONS

Biochemistry appeared a couple of times at the heart of the relationship between Chinese medicine and systems biology. I argue that biochemistry is an “immutable mobile” as it is transportable in the form of samples or as the analysis of a paper, and it does not change its form. In terms of relational materialism, the results of a biochemical analysis are durable and transportable in written form on paper, and also in digital form as a set of chemical elements. The results of a biochemical analysis are not transformed when they are transferred between systems biology and Chinese medicine.

Most of those interviewed argued that biochemistry connects the two fields as molecules at the lowest level in an organism, thus, molecules are the right place to start the investigation into the relationships between Chinese medicine with systems biology. This interpretation was informed by the knowledge that both sides understand biochemistry. It is obvious that systems biology, as a branch of biology and a multidisciplinary field of biologists, chemists, engineers and bioinformaticians comprehends biochemistry and molecules. The understanding of biochemistry in Chinese medicine is not so obvious. Hsu (1999) and Taylor (2005) argue that the integration of natural sciences in Chinese medicine curriculum and research happened in the 1960s. As a result, biochemistry represents data to connect Chinese medicine and systems biology through a common language. Put this way, biochemistry is an “immutable mobiles” because the data is critical for systems biologists and Chinese medicine researchers to prove their relatedness of a holistic and system-level understanding of the human body. Thus, biochemical analysis conveys vital information about both sides and both sides are able to interpret it with their own concepts. Following this, biochemistry performs a relating function between Chinese medicine and systems biology, as without biochemical analysis their communication and interaction is reduced or even inexistent. Therefore, biochemistry is the centre of actions. Based on biochemical information, the actors can calculate and adapt an analysis or the preparation of a sample. However, without a biochemical analysis, the study of any Chinese medicine drug or biofluid analysis would not be possible. Therefore, concerning research Question 1 which asks about the nature of this “interface”, biochemistry embodies the elementary interaction to bridge Chinese medicine with any field that understands biochemistry including systems biology or biomedicine.

As a result, the "interface" is not only represented through human interactions but also as a relationship between humans (for example, systems biologists, pharmaceutical scientists, Chinese medicine researchers) and nonhumans (biochemistry and omics technology). Human and nonhuman actors interacted through biochemical analysis, sample preparation or publications, while the human actors used analysis data and samples for their co-operation. Besides extracting data, biochemistry generated reliable evidence for Chinese medicine through which the projects on Chinese medicine gained more attention from different stakeholders. However, to produce biochemical evidence, omics technology was required, which will be elaborated on in the section on mode of vocation (see Section 8.4).

8.1.3 Omics technology as the centre of orderings

Omics technology takes a central position in the relationship between Chinese medicine and systems biology. Omics technology functions as a "centre of translation" for biochemical analysis and as an actor. Firstly, it is the "centre of translation" as it controls the data of biochemistry as an "immutable mobiles" that moves between omics technology, systems biology and Chinese medicine. Most of the research in Chinese medicine is performed on active compounds research in *fufangs* of a maximum of twelve herbal ingredients, which consist of thousands of chemical components. In order to discover active compounds, omics technology is a crucial technology. In this case, omics technology performs a biochemical analysis. Due to this, omics technology is the "centre of translation" and biochemistry is an "immutable mobile".

Omics technology in its second function is an actor that represents a network of various materials, which are assembled by other machines, constructed by engineers and run by scientists. In the mode of a "heterogeneous network", omics technology interplays with human actors and by doing so decentres them. Law (1994) argues that the agency is not determined by a human actor or by one specific actor, it is rather a process of networking associations that affects an agency. In the case of Chinese medicine and systems biology, omics technology orders the relationship between Chinese medicine and systems biology. This ordering happens through accumulating evidence for Chinese medicine efficacy and safety. It orders the biochemical analysis by determining the sequence of the analysis. As I argued above, biochemical analysis is the central means of communication and co-operation between the two fields. Thus, both fields are linked by omics technology. For systems biologists, omics technology embodies the method to accomplish holistic studies on all levels in a living organism. While for Chinese medicine researchers, it embodies the hope to prove the efficacy and in detail the effect and actions of Chinese medicine drugs and practices. Hence, to identify the molecules and their actions, scientists in this heterogeneous network needed omics technology. To put it in other words, omics technology is the effect of the efforts of systems biologists and Chinese medicine researcher to study the complex system of Chinese medicine in combination with various technologies (as seen in Chapter 5). Consequently, I argue that omics technology is an actor in this mode which orders the production of analysis data and facilitates communication between Chinese medicine and systems biology. It is clear therefore that omics technology and biochemistry are both at the centre of the attention and actions of Chinese medicine researchers and systems biologists.

In conclusion, in the mode of a heterogeneous network I answered Question 1 by demonstrating that the term “interface”, as a description for the relationship and the research activities between Chinese medicine and systems biology, was not used by Chinese medicine researchers or systems biologists who had already conducted research in this area. Instead they referred to the nature of the relationship between Chinese medicine and systems biology as a co-operation or as it being a bridge between biochemistry or technology. Co-operation was described as the exchange of materials. I argue in the example of the Leiden group that they acted as a “centre of translation” in their co-operation with the Dalian group and that the “centre of translation” (the Leiden group) controlled and monitored the exchange and distribution of materials and students.

Concerning the nature of the relationship between Chinese medicine and systems biology, the actors described an interaction based on the shared understanding of biochemistry. Biochemistry described the basic level of the human organism, thus, the actors anticipated that it would deliver information on the changes that occurred in a human organism through medical interventions. Thus, I analysed biochemistry as immutable mobile and omics technology as nonhuman actor as they were essential for the communication and establishment of the interaction between Chinese medicine researchers and systems biologists. Omics technology performed a role as the "centre of translation" between both sides, as well as an agent. This agency was an effect of establishing a research method for systems biology research on Chinese medicine. Omics technology represents a network of biochemical analysis and various machines as cutting-edge technology. Resulting from the various descriptions and performances in multiple locations, I argue that the nature of the relationship between Chinese medicine and systems biology is a heterogeneous network that is constituted by human and nonhuman actors such as biochemistry, omics technology, as well as human actors involved in Chinese medicine and systems biology.

8.2 THE DIFFERENCES AND SIMILARITIES TO PREVIOUS ENCOUNTERS

In order to answer the second research question of "How does this 'interface' differ from previous encounters between Chinese medicine and modern science and Western medicine?" I will compare historical accounts that focus on encounters between Chinese medicine and modern science and which are found in publications on the history of Chinese medicine with publication in Chinese medicine and systems biology after 2005.

In the 2000s, the new effect on the interactions between Western medicine or modern science and Chinese medicine, was that scientists of different nationalities and disciplines interacted on a research platform to study Chinese medicine. This was an effect of the dialogue systems biologists had initiated with Chinese medicine researchers, practitioners and Chinese scientists. Systems biologists looked to the East for new ideas like, for example, what was witnessed in the 1970s when systems scientists such as Bateson and Grey studied Eastern philosophy and practices with their "Western science" approaches (see Section 4.4.3 and Pickering, 2010). Instead systems biologists approached Chinese medicine researchers and conducted Chinese medicine research with them to overcome the bottleneck of reductionism in Western science and medicine. They aimed to learn from Chinese medicine a holistic understanding of medicine and *bianzheng lunzhi* diagnosis for the establishment of personalised medicine and individualised treatments. The difference was that Western systems biologists approached and communicated with Chinese medicine researchers and scientists (see Chapter 2). Their communication was made possible as a result of the integration of modern science and systems theory in Chinese medicine which took place in the late twentieth century.

The nature of the historical encounters was described by Rogaski (2004), as either being co-operative or coercive. Systems biologists and Chinese medicine researchers agreed on the definition of their research as co-operation. Even though this characterisation changed with the advancement of this relationship, it did never become coercive. As I showed with the analysis on co-operation (see Section 8.1.2) systems biologists and Chinese medicine researchers created co-operation and interactions by training students in Chinese medicine and systems biology. The interactions linked various actors and projects to become a heterogeneous network. I illustrated this effect with the example of the ERC TCM (see Section 7.2), which connected various actors and their networks to an international networking and coordination project. As a result, the nature of this “interface” was co-operative. It consisted of a globally distributed network that correlated various interests from 2009 to 2011 in one representational project, the ERC TCM consortium. Hence, I suggest the term “heterogeneous network” for the description of the relationship between systems biology and Chinese medicine, instead of the term encounter or “interface”.

A crucial difference from past encounters is that systems biologists engaged with both Chinese medicine practice and medicine researchers before they first conducted a study on Chinese medicine. This is evident in the Chinese medicine researchers’ interviews, rhetoric and visions (see Chapter 5), which stress the fact that systems thinking and holism are integral parts of Chinese medicine and systems biology. They perceived that both fields match on the common ground of systems thinking and holism, thus, systems biology was adequate to study Chinese medicine on its terms. This contrasts with the political oppression of the political agenda of implementing Western science, standardisation, curriculum and theories in Chinese medicine during the twentieth century. The engagement of systems biologists with Chinese medicine on shared concepts, makes a crucial difference to previous encounters. That is, that the actors established a co-operation and did not enforce the implementation of Western scientific concepts in Chinese medicine (see Section 4.4.4).

Against the perception of those interviewed that believe that systems thinking and holism are integral parts of Chinese medicine, the analysis in Chapter 4 shows that these two concepts were integrated in Chinese medicine in the 1950s. This means that through the concepts of systems thinking and holism in systems biology provided a clear match for Chinese medicine. The historical sources showed that they were first integrated into Chinese medicine in the 1950 and 1980s, in alignment with the political agenda of Mao Zedong and the focus on Engels’ dialectic materialism. As an effect of these integrations, under the political agenda, holism was interpreted in the dualistic way of *yin* and *yang*. Chinese medicine practitioners such as Qin Bowei re-interpreted this concept to show that Chinese medicine was a science (see Qin, 1955). Later in the

1980s, the political agenda for further standardisation and globalisation of Chinese medicine called for the implementation of systems science and cybernetics in Chinese medicine, which was supported by the Chinese medicine practitioner Lü Bingkui and Chinese cybernetician Qian Xuesen. Similarly, systems biology evolved from systems science and cybernetics, which made systems thinking into an integral part of systems biology. Thus, the perceived similarity between Chinese medicine and systems biology was the shared ideology of systems thinking and holism which derives from the same influence of cybernetics.

The relationship between Chinese medicine and systems biology is only seen and understood as being coercive due to the continuous integration of modern science, theories and omics technology by Chinese medicine researchers in Chinese medicine. In the 2000s, Chinese medicine researchers applied omics technology and systems biology to examine Chinese medicine for basic research and evidence production. I refer here in particular to Chinese medicine researchers who chose the language of biochemistry and omics technology to describe the relationship between systems biology and Chinese medicine. I interpret the emphasis on biochemistry and technology as a process of self-colonialization. According to Noordenbos (2008), self-colonization describes intellectuals who make themselves dependent on an alien culture to define the "Self". In the process of self-colonization, Chinese medicine researchers assimilate the thinking and practice of biomedicine and then enact it in Chinese medicine. Karchmer (2010, p. 248) argues that the adaption of a postcolonial form of medicine is a "trend of Chinese medicine doctors to achieve ever-greater competency in Western medicine". Karchmer's (2010) case studies on clinical practices in China demonstrated how Chinese medicine practitioners diagnosed biomedical diseases by relating them to Chinese medicine *bianzheng lunzhi*. This means that these practitioners rely increasingly on biomedical diagnosis. Interestingly, Chinese medicine was affected by several cases of malpractice in China in 2006 when an online petition was started which aimed to remove Chinese medicine from the Chinese National Health Care System (ibid). This happened concurrently as the WHO's 2002 report demanded good research practice and policies (as discussed in Section 7.3.1). Owing to the public discussions on Chinese medicine practice and research, I believe that the integration of systems biology and omics technology in Chinese medicine was partly an effect of these events and also a continuation of the attempt of Chinese medicine researchers to master Western scientific practice, as any other natural science.

To conclude, the difference between past encounters and the relationship between Chinese medicine and systems biology in the 2000s was that in the twentieth century, the encounters were aligned to political agendas. These political agendas caused a self-colonialization by aligning Chinese medicine increasingly to Western medicine to secure its survival as a medicine in China. This happened in particular in the 1920s and 1950s. Also, past encounters were confrontations between Chinese practitioners of Chinese medicine and doctors of Western medicine and politicians. In this relationship between Chinese medicine and systems biology, the aim to enhance scientific practice and to modernise Chinese medicine research continued. However, Western systems biologists changed the interactions mode as they approached Chinese medicine to learn from this medicine based on the shared theories of systems thinking and holism. Nevertheless, the actors did not reflect on the reshaping of Chinese medicine during the twentieth century. In fact, in their articles published after 2005, they did not reveal any awareness of the integration of systems thinking and holism in Chinese medicine. This unawareness, I believe, affected the view of the actors involved in Chinese medicine, as they saw it was a perfect "match", mainly because they assumed that systems theory and holism have always been inherent in Chinese medicine and in the form they were presented to them, they perfectly fit with the holistic and systems thinking in systems biology.

8.3 THE MODE OF VISION

The mode of vision will present the process of the involvement of the actors in Chinese medicine through their ambitions and interest in complexity and holistic approaches. This mode will answer the third research question of how the actors became involved in Chinese medicine and systems biology research. To build the order of involvement, I will elaborate on the involvement of Prof Frank, Dr Huang, Kevin and George. They represent what I call the inner circle of the heterogeneous network of Chinese medicine and systems biology research, as their involvement describes the emergence of the research relationship between Chinese medicine and systems biology mainly because they performed the first studies on systems biology and Chinese medicine.

Their scientific visions included the want for personalised medicine, the aim to improve healthcare systems, acknowledgement and wanting to study its complexity and a desire to avoid the exploitation of Chinese medicine. The difference between these four actors and the rest of the actors I interviewed and observed, is that their involvement in Chinese medicine studies was guided by their aim to fulfil their visions. Visionaries were also mentioned by actors in the mode of vocation. Prof Vera and Prof Carl argued that the healthcare system in Austria does not change very often because of the lack of scientific vision or visionaries. Accordingly, the actors consider visions as crucial for change to take place in science and politics.

The actors involved in the ordering of visions were ambitious, single-minded, highly skilled and thinkers. Their involvement in Chinese medicine research evolved over a long period, between ten and twenty years from their first time they were introduced to their first Chinese medicine study. Notable is that they all were determined and persistent to follow their aims and scientific visions, which was not only seen in the cases of actors with PhD degrees (Prof Frank, Dr Huang and George) who worked in academia, but also in Kevin's case, as he completed a study in biochemistry and worked as a Chinese medicine practitioner. The pattern shows that the codes of involvement were built through technology and health, complexity, family and exploitation and discontentment with reductionism. This involvement was guided by the actors' scientific vision which maintained their interest in Chinese medicine.

Prof Frank's vision of a "personalised medicine" aimed to attain a medicine that established an individual treatment for each patient and that was informed by the individual diagnosis and treatment prescriptions found in Chinese medicine. First, Prof Frank's involvement in Chinese medicine started with his scientific achievement of studying biofluids with multiple variables, which paved the way for complex Chinese medicine drug studies. In the realisation of this aim, Prof Frank combined various machines and analysed his findings with a computer. He controlled the combination and the compatibility of the machine and eliminated electric interferences and other issues. Thus, he was a "centre of translation" between various machines and engineers, bioinformatics, chemists and technicians who supported him for this project. Based on the interferences or information given by his technicians and colleagues, he controlled the configurations, monitored the outputs and adapted his parameter and configurations until he and his team succeeded in combining the machines and run the first sample pattern recognition on biofluids with a computer. The combination of machines and skilled people started with an experiment on urine samples and developed into a method to study biofluids for metabolism studies using Chinese medicine drugs. Thus, the vision of Prof Frank's personalised medicine started with an experiment to measure more variables and to gain more information.

Prof Frank's vision for a personalised medicine co-emerged with his second involvement in Chinese medicine after he experienced a successful treatment with Chinese medicine. This experience represented a change in his mindset, and he developed an interest in investigating Chinese medicine. I interpret his involvement as a re-ordering of his life which enacted a new ordering of his research interest. Prof Frank exhibited this by changing his mind set to positive thinking and to a holistic study biological phenomenon. The re-ordering of his professional life reflected the changes in his private life and these were first characterised by his technological achievements and his skills to apply technology to complex studies. Prof Frank mentions that his access to technology and his ability to use it, made it easy for him to engage first with systems biology and then with Chinese medicine. In addition, this shows that he positioned himself at the centre of a technological field, as he was able to tinker with technology and develop a new method. This development and his interest in systems thinking eased his move from his academic comfort zone in biomedical studies into Chinese medicine research. He changed from being part of the dominating reductionistic research paradigm, to gaining a better understanding of the interactions between nature and humans and to acquiring an ecological worldview which he saw in Chinese medicine. The final step to the realisation of his vision of a personalised medicine happened when he worked with Dr Huang.

Complexity and holism were crucial concepts in the involvement of George and Kevin in Chinese medicine research. Their scientific visions of the acknowledgement and the study of complexity in Western science and the improvement of healthcare systems and medical research by integrating holism, stress the problem of reductionism in science and medical care. George and Kevin's discontentment with the dominant reductionist paradigm in science and medicine affected them both. Firstly, George's changed from a job at the university to researching alternative medicines for a private organisation, and Kevin who had studied biochemistry started to study Chinese medicine. Kevin became involved in Chinese medicine and systems biology through his interest in complexity. Law and Mol (2002) describe complexity as a matter, multiple realities, an interest of researchers or a status. In this case, complexity was Kevin's interest that triggered his involvement, in addition, it performed and controlled his involvement in Chinese medicine and systems biology. Kevin and George's dedication to find alternative systems and their search for complexity and holism led to their involvement first into Chinese medicine practice and *Taijiquan* and then into Chinese medicine and systems biology research. Their return to Western science and academia happened because of the novel approach of dynamic self-organising systems which are used to study Chinese medicine. Interestingly, however, Prof Frank was attracted to Chinese medicine and systems biology, as both used a holistic approach to study life and health. Systems biology and Chinese medicine embodied the vision of complex and holistic research in Western science.

The last ordering demonstrates an involvement in Chinese medicine research with a vision to avoid further exploitation of Chinese medicine with an adequate research method. Dr Huang hoped that a holistic study of Chinese medicine would stop the extensive research for active compounds in Chinese medicine. Additionally, she hoped that systems biology would allow her to evaluate Chinese medicine *fufang* to prove its efficacy and safety as a whole. Her ordering reveals that she was introduced to Chinese medicine by her grandfather in her early childhood. This was followed by a career in molecular biology. However, only with the emergence of systems biology and Prof Frank's interest in Chinese medicine, did she then start to engage with Chinese medicine research. This late engagement shows that her research was centred around her career and an appropriate approach to study Chinese medicine, which would enable her to enhance her academic achievement. Dr Huang was the main collaborator and gatekeeper between China and the Netherlands (see Table 3 for her role as gatekeeper 2). Amongst the four scientists, she had the second highest academic position in this mode and was the one who conveyed the idea about a Chinese medicine and systems biology study. Thus, she was a scientific visionary for this project, while the other actors presented scientific visions about other aspects of this study. It was important to her to investigate Chinese medicine drugs as a whole, which is similar to all of the other actors involved in this mode.

Prof Frank, Kevin, Dr Huang and George's order of vision presents an involvement in Chinese medicine research through their visions, which maintained their passion for Chinese medicine. Their visions were personalised medicine, improving healthcare systems, acknowledgement and study of complexity and a desire to avoid the exploitation of Chinese medicine. The actors had a personal interest in Chinese medicine, and they had had a long and sophisticated engagement with Chinese medicine up until the point they decided to conduct the study. This enactment was influenced by various factors such as disease, method development, family and a desire to study Chinese medicine. The actors were interested in the idea of the human body and nature as interrelated systems in Chinese medicine. It represented to them an alternative to the reductionist paradigm used by science and medicine, as Chinese medicine emphasises the complexity of life and nature, as well as considering the organism as a system. This group consisted of just a few people that represent the initiation of an international research interest in Chinese medicine and systems biology, which seems in comparison to the second mode, as a small number. However, Law (1994) explains that the proportion of scientific visionaries and the profane are generally speaking a small group of elitists and are distinguished people.

8.4 THE MODE OF VOCATION

In the mode of vocation, I address the fourth research question: how did human and nonhuman actors become involved in this emergent "interface" and how did the different modes change this emergent "interface" between Chinese medicine and systems biology? The mode of vocation demonstrates the participation of the actors in the outer circle and their involvement in Chinese medicine and systems biology research through invitation or employment (see Table 4 for research questions and modes). I analysed stories and publications of pharmaceutical scientists, systems biologists and Chinese medicine researchers invited or employed by research projects as experts, doctoral or post-doctoral students. The outer circle included actors from the networks of the Leiden-Dalian co-operation, the Harbin group, the ERC TCM, the network organisation and the systems biology experts. Their enrolments happened through research projects and omics technology. Some actors presented more than one ordering of enrolment.

8.4.1 RESEARCH PROJECTS, PUBLICATIONS AND JOBS

The mode of vocation introduces the actors and illustrates how they became employed or were asked to participate in a research project that dealt with Chinese medicine and systems biology. The aims and intentions of the enrolled actors, the outer circle, was to acquire a degree or a job (PhD, post-doctoral, research fellow) but, however, the study of Chinese medicine was not their principal interest. Their supervisors enrolled them for a specific research topic. In other words, the students did not actively decide to engage in a Chinese medicine research project. The project was monitored by the principal investigator or the individual team leaders (these were in most of the cases the supervisors) who received the funding. Thus, the principal investigators or supervisors represent a "centre of translation" with the task to reflect, self-reflect, monitor and control the collaborators and students who performed the study at the periphery. Accordingly, the principal investigator acted on his or her observations and the representations of the performance of his or her students and collaborators. Based on the observations, he or she calculated the next steps in the project.

Research projects were generated through the visions of the inner circle and their publication on Chinese medicine and systems biology research. Research papers as "immutable mobiles" informed, interested and enrolled actors into the research and funding of Chinese medicine and systems biology. As research papers conveyed the ideas of the inner circle, they co-generated the co-operation between the inner circle and the ERC TCM. Important actors, and interviewees, for example, Prof Vera coordinated the first interactions and co-operation between Austria and China. In her function, she co-ordinated and enacted several Memoranda of Understanding for Chinese medicine research and controlled and managed the exchange between both sides. Through this role, she established contacts with many politicians, scientists and practitioners in this research field. These contacts were essential for establishing research funding for Chinese medicine in Europe during the 2000s. Hence, Prof Vera's network was important for the ERC TCM consortium which enrolled her as an advisor. In comparison, the ERC TCM was enacted by the WHO report and the EU plan to research Chinese medicine and enrolled scientists based on their publications which discussed Chinese medicine as a good practice research plan. The consortium was a "centre of translation" that aided the communication between the EU and China and the interest of the WHO and the EU to scientists and researchers, which is shown by the fact that there were a total of 200 members that participated in the consortium.

The students in the outer circle were enrolled through their applications for a PhD or post-doctoral position in a research project. As the supervisors organised the projects, the students applied for a job in the research project because it used omics technology, and not because it was a Chinese medicine study. Hence, the students did not control their involvement in the Chinese medicine study. Their supervisors controlled, monitored and calculated the student's projects. For example, Prof Carl described his enrolment in Chinese medicine analysis through his supervisor. A political arrangement between an entrepreneur, politicians and his supervisor demanded the evaluation of Chinese medicinal herbs for use in a TCM hospital. In his words, universities were supposed to know everything. Thus, his university had to prove that the consumption of Chinese medicine herbs was safe. Prof Carl's supervisor employed him to generate a plant monograph for a Chinese herb with the chemical analysis by using chromatography. The method was the same method his supervisor used for the examination of European plants, because chromatography was a commonly used method in his sector.

In ordering terms, Prof Carl's supervisor represented another "centre of translation" that acted between Prof Carl and chromatography. The liquid or thin layer chromatography (TLC), which Prof Carl used was cutting-edge technology at that time. TLC and advanced versions are still the most important machines in pharmaceutical studies (see Leung, Fong and Xue, 2006). Pharmaceutical scientists rarely applied systems biology, as they did not need the whole range of omics technology for their studies of plants (see Angelova et al., 2008). Prof Carl's evaluation of a Chinese medicine plant depended on the TLC. For the successful examination of Chinese medicine plants, he needed TLC technology and the set of ordered relations between elements, such as co-operation with other universities, the hospital, the plant, the herbal supplier, the funder and the interaction between scientists, the sample preparation, the machines, the chemicals, the computer, the cables, the electricity network, the software program and the databases to establish a sophisticated analysis of the plant's origin, functions, preparation and dangers. This technology enabled Prof Carl to investigate the properties of the Chinese medicine plant he was studying. By presenting the findings to his supervisor, Prof Carl reported his progression and further steps or adaptions to ensure he finished the project on time. By doing so, his supervisor monitored and controlled the project. The results were "immutable mobiles" that functioned as proof of his findings for the supervisor's co-operator. Thus, the findings were an effect of the interaction between Prof Carl and technology, between him and his supervisor and between his supervisor and the co-operator.

Prof Carl's employment demonstrated a number of associations with people and machines. According to Law (1994), size is an effect, or a product generated by allocation and performances of a phenomenon. Prof Carl decided to participate in the already existing co-operation with the network of human and nonhuman actors and effectively established the research project and his PhD position. Prof Carl's experience is different to those in the inner circle. Both Dr Huang and Prof Frank (from the inner circle) founded the research project themselves. Dr Huang and Prof Frank had the technology, a method and their unique expertise. They generated a network of funders, collaborators, students, peers and publishers whereas in Prof Carl's case, the co-operation between the university, the TCM clinic and the university in Beijing was already established and his supervisor already had a lab, several students and technology. The size of Prof Carl's supervisor's network was the result of the TLC technique which was successfully used to study plants and enticed funders that supported previous research and Prof Carl's project. The Bavarian government was the requestor of this research, as a condition for the establishment of the TCM clinic. Thus, Prof Carl's participation was embedded in an established network of various actors with the task of examining Chinese medicine plants. Consequently, Prof Carl's project represents a pre-established network of machines and humans that were associated with his supervisor's previous projects and university, which proved to be strong and enduring for the Chinese medicine plant study.

Similarly, the doctoral student Lingma and the post-doctoral student Long were enrolled on a PhD and a post-doctoral project. Before their employment in the Chinese medicine projects, they demonstrated neither personal nor professional interest in Chinese medicine research. Their research projects were effects of the relationship and interaction between their supervisor Prof Yu, Prof Frank and Dr Huang (from the inner circle), who established the research co-operation for the Chinese medicine diagnosis study. In the annual enrolment process at the Dalian university, Lingma and Long applied for PhD and post-doctoral research positions in Prof Yu's lab and their engagement in the Chinese medicine project occurred after their acceptance. After the completion of their projects, and thus their co-operation, Prof Yu returned to biomedical research together with Long and Lingma. This demonstrates that their interest was attached to their vocations rather than to the study of Chinese medicine.

A change in the research engagement changed the relationship between the Leiden-Dalian co-operation partners. The principal investigators acted as a "centre of translations", as they calculated the project beforehand and monitored its process and unfortunately, the interactions changed through inadequate performance and communication. For example, besides George's involvement through his vision, he was also enlisted as a PhD student by Prof Frank. George's story showed that once he gained some data on his project, the Chinese partners published them in a Chinese journal without his or his supervisors' consent. The publication affected a rewriting of his study and weakened his relationship with Dalian. A breach of the agreement was a risk that was not included in the calculations of the "centre of translation". According to Law (1994), co-operation and interactions are contingent processes. This means that ordering processes are about local not exhaustive processes that are not determining how things turn out in general. Law (ibid) suggests committing to an ordering inquiry rather than uncovering other root orders. Thus, the co-operation problem could either be ordered as a different ordering or as one consequence of the ordering vocation. In following the latter, in a recursive procedure, the divergence of the co-operation agreement indicates that whatever the calculation of the "centre of translation" was at the beginning, the process of ordering was open, and included the risk that the co-operation partner could counteract their agreement. In the action of the breach of the Dalian partner, the data represented an "immutable mobile" that moved in both ways between the Dalian and Leiden sites. Consequently, both sides could use the data either according to the agreement, and thus just for the co-operation purpose, or for their own publication purposes. As the Dalian team followed the latter, the data caused after the breach, a re-ordering of the research project by changing the focus of George's project, and inevitably forced him to re-write his findings. However, the Dalian team published a paper with data on a novel analysis method.

The presented mode of vocation talks about research projects and their association with technology, collaborators, politicians, funders and the industry. It focuses on an established organisation for projects that needs to be filled with researchers. The researchers in this mode were skilled, motivated and selected to participate in Chinese medicine projects that were controlled and monitored by their supervisors and principal investigators. The students described as actors in this research projects engaged with their individual projects, but not in the organisation of the co-operation, and they were not in control of the topic of their project. Of course, they could have rejected the project, however, they did not do so as they related to the projects with their technological or theoretical skills.

8.4.2 Omics technology, complexity and industry

What was demonstrated in most of the stories of enrolment in this "interface" was the interest in omics technology. Omics technology was intertwined with the research projects. Omics technology and systems biology enabled a new approach to medical studies and initiated most of the research projects between systems biology and Chinese medicine. As argued in the mode of a heterogeneous network, omics technology represents a "centre of translation" between Chinese medicine and systems biology. In detail, it facilitated a translation between molecules and *zheng*. First, omics technology enables the researcher to read biochemical data as scientific evidence for Chinese medicine, while Chinese medicine researchers translate this data back into *zheng*. Secondly, as a "centre of translation", omics technology represents a new large-scale method to study Chinese medicine and to grasp its complexity. Thus, in this section, I will start by demonstrating how omics technology was the "centre of translation" and how it generated a new way to investigate complex phenomena. This is evident in the demonstration of technology as a crucial link for the interaction between scientists and Chinese medicine researchers (I elaborated on this in the mode of a heterogeneous network – see Section 8.1.2). I will then show how omics technology persuaded pharmaceutical scientists and the industry to join the research field of Chinese medicine as the scientists were using omics technology as an analytical tool. This combination generated funding for research. Finally, I will show how omics technology restored the control of Chinese medicine researchers in their efforts to promote Chinese medicine studies.

Omics technology instigated the co-operation between the Leiden-Dalian partners. Although the co-operation was initiated through the friendship between Prof Yu and Dr Huang, the main interest for the co-operation was technology. I strongly believe that the Dalian scientists enrolled in this project because of the technological approach. They wanted to learn about the latest omics technology and the use of metabolomics analysis. In contrast to the students George, Lingma, Long, Prof Carl, who were enrolled through projects, omics technology enlisted higher rank scientists in this "interface" such as supervisors, Prof Yu, Prof Jakob and Prof Carl's supervisor. The Leiden scientists presented Prof Yu with their new approach to systems biology and their holistic analysis of metabolomics, genomics, proteomics and transcriptomics in one study, which immediately attracted Prof Yu. He participated in the hope to extend his technological spectrum from metabolomics to other omics technology and to advance his technology-focused research. In this co-operation, the Dalian scientists performed their first investigation in Chinese medicine and systems biology. Accordingly, omics technology was the "centre of translation" between the Dalian and the Leiden team.

The relationship between Leiden and Dalian represents a hierarchical relationship based on analytical knowledge of systems biology research. This arrangement happened through the design of the research study by the Leiden team. The Leiden team also had the competency to apply systems biology and analytical tools. They were experts in biofluid analysis and understood the included devices and their technical arrangement. Due to this knowledge, they ranked higher than the Dalian team. The co-operation occurred through the interest of the Dalian group in the Leiden group's know-how in the use of biofluid analysis with systems biology. They wanted to learn from the Leiden team. Although Prof Yu's team was not familiar with systems biology and Chinese medicine, they started the co-operation. Following this, the Dalian team wanted to be trained in biofluid analysis through their co-operation with Leiden. Omics technology effectively evolved into a "centre of translation" between them and generated training opportunities and new machines for data collection and sample preparation of their study.

The increased focus of the Dalian team on technology caused tensions and a deviation from their principal objective, which was studying Chinese medicine with systems biology analysis, to omics technology and its application. The deviation was evident when the Dalian group failed to fulfil their tasks – these included collecting and preparing blood and urine samples and handling them according to the study design of the Leiden group. Since the documentation of the investigation was not consistent and accurate, the report the scientists produced was incorrect. This caused problems for the principal investigators as they could not predict this disruption of the project beforehand, but they needed to make new arrangements to solve the issues. The solution was to mention in the research paper that the sample data was incomplete, thus, they needed to acquire replacement data from different collaborators. Therefore, the Leiden team decided to detach from the main co-operation partner and find another one. As a reaction, George reduced his interaction with the Dalian team, and the exchange between the other Leiden students gradually decreased too until the completion of the project in 2013 (see Table 2 for the project timeframe).

In contrast to the Dalian-Leiden co-operation, omics technology generated interactions between scientists and Chinese medicine researchers and practitioners, which had not happened on such a large and global scale before. By using omics technology, actors convinced politicians in the EU and China to establish an international co-operation in Chinese medicine research. The ERC demonstrated its interest in Chinese medicine in 2007. At the centre of their program for Chinese medicine funding was what they called a "Translation research on human health" with systems biology in "Traditional Chinese Medicine in postgenomic era" (EC, 2007a). In this case, Chinese medicine research transformed from understanding Chinese medicine diagnosis with systems biology by the Leiden team, to translating Chinese medicine with systems biology. This was a result of the scientific reliability of systems biology. Systems biology incorporated both, big data and omics technology, and represented to stakeholders, funders and the scientific community an assurance as a scientific method to unravel the complexity of Chinese medicine. By generating visual models of molecular data and comparing them to Chinese medicine *zheng* patterns, the produced results of the first studies confirmed the competence of this method and caused the emergence of co-operation between systems biology and Chinese medicine on a molecular level. This process joins my argument that this relationship is an interaction between systems biology and Chinese medicine on a biochemical level and through omics technology. This was also confirmed in research papers as a bridge between metabolomics and Chinese medicine (see Wang et al., 2005).

The Harbin research institution obtained public and industrial funding through the use of omics technology. In the late 2000s, the team received most of their funding from the Chinese government for their Chinese medicine metabolomics research projects. The government designed the funding for fundamental research in Chinese medicine with omics technology to conduct and to improve scientific understanding of Chinese medicine theories and drugs. This was also an important reason for Prof Yu from the Dalian group, to engage with Chinese medicine as it provided him access to a new public funding source in order to purchase new technology. Therefore, omics technology as a “centre of translation” functioned as a connection between the interest of the Chinese government and scientists, as Chinese medicine research funding was tied to omics technology and the funding related to the industry supplied the institutions with omics technology. The connection to technology was seen in the application of several types of mass spectrometry and gas chromatography purchased and partly sponsored by the company Waters Corporation. Every field site in this heterogeneous network, which I visited, used Waters Corporation machines, which reveals the primacy of the company in this field. The Harbin’s purchase of this machine, as I suggest, was a strategic turn to attract the attention of the producer and the scientific community working with the same omics technology. The Harbin team first secured sponsorship from Water Corporation following numerous publications on Chinese medicine studies which mentioned the application of Waters’ machine in their methods section. As a result of this, the co-operation with Waters affected scientific partnerships, student exchange programs and conferences with researchers working on traditional medicines inside and outside of China.

The second resource of funding in Chinese metabolomics research was the pharmaceutical industry in China. The use of omics technology on the analysis of Chinese medicine drugs generated a co-operation with producers of Chinese medicine pharmaceuticals. The particular interest was in patents. Scientists used omics technology to identify useful therapeutic *fufangs* for issuing patents. The acquired licenses generated a small percentage of their research budget, but more importantly, in the course of their co-operation, patents were a product of a long-term research and co-operation process. Thus, the Harbin group secured a long-term sponsorship from Chinese medicine pharmaceutical industry partners in China. What omics technology represented here was a link to the industry and economy through the commercialisation of Chinese medicine products.

The increasing number of patents raised the awareness of the actors and the scientific community on the exploitation of Chinese medicine and other traditional medicines through commercialisation (see, for example, Helman, 2007; Efferth et al., 2018; Ansari, 2016, Hao and Xiao, 2014). Patenting traditional medicines entails the risk that foreign companies exploit indigenous and traditional knowledge by licensing them as an invention or innovation and ignoring their responsibility to share the generated revenues with the indigenous community, known as biopiracy (see Helman, 2007; Efferth et al., 2018). Against the common purpose of patents to protect innovation or an invention of one person or organisation, the patents on traditional medicines extract indigenous knowledge from folk remedies or customs, extinct plant species and destroy natural resources for the medical supply of the local people (see Efferth et al., 2018). Patents for single Chinese herbs were first issued in 1924 for the herb *Eumenol danggui* (see Andrews, 2014). However, today, pharmaceutical scientists and pharmaceutical companies patent complex Chinese medicine formulae, *fufangs* (Wang and Chan, 2010). For this, only the chemical structures of its major active ingredients need to be identified (ibid). Once the active ingredients are found, pharmaceutical companies patent the *fufang* as a drug and by doing so they use the indigenous knowledge of people who have always used the drug and relied on its supply for their medical needs. Helman (2007) claims that the main issue is that pharmaceutical companies benefit financially from the patented drugs and do not share these benefits with the indigenous people. An increased production of the patented drug requires more resources; thus, it causes the over-harvesting of wild growing medicinal plants and therewith less supply for indigenous people, or even the extinction of those plants (see for example Leung, Fong and Xue, 2006; Efferth et al., 2018). Thus, Bodeker (2006, p. 35) believes that the "interface" (his own word) between Chinese medicine and biomedicine is shaped by the competition for shares from patents between non-indigenous individuals and organisations or indigenous groups.

The third point is the empowerment of Chinese medicine and researchers through omics technology, which translates *zheng*. The Harbin team demonstrated an empowering of Chinese medicine through the interpretation of *zheng* with omics technology. They studied *zheng*s in various models (i.e., *in vitro* and *in vivo* in animal and human models) and tried to translate the *zheng* into molecules, biomarkers, active compounds, genes, proteins or metabolites. To enact power omics technology would have required the performance of actions. However, omics technology did not act in this way as they collected and prepared the samples or operated by themselves. The operation and preparation happened with the help of Chinese medicine researchers and their knowledge. Thereby, the researchers obtained control of the machine by programming and monitoring the crucial functions. Through their interaction, they used biofluids profiling as an analytical tool to find evidence for a manifestation of a

Chinese medicine *zheng*. In other words, the biofluid analysis presented a pattern in the form of graphs and numbers. It translated the *zheng* into another form or language. The researcher reconstructed the *zheng* by analysing the peaks in the charts and determining biomarkers or masses for vitamins, acids, or any other compounds that indicated and confirmed the characteristics of the *zheng*. Another method was metabolite profiling. This approach helped to recognise an inflammatory status, to count lymphocytes and to measure the differences between them. The application of these different methods performed the process of obtaining various representations of the pattern and enacted the empowerment of the Chinese medicine researcher. Hence, the biofluid analysis results became a representation of *zheng*, and the analysis of the researcher reconstructed the *zheng* in scientific terms. Accordingly, omics technology empowered the Chinese medicine researcher to study Chinese medicine, and through interaction with analytical tools and a scientific understanding, the *zheng* emerged.

A biofluid analysis with an omics approach included multiple layers and "heterogeneous materials" (Law, 1994). Conversely, it excluded anything which omics technology cannot yet analyse in a blood or urine sample. Thus, the representation of omics techniques data excludes some aspects of Chinese medicine. Law (1994) argues that the mode of empowering affects the deletion of something, for example, of a low-status work. The exclusion of some aspects in Chinese medicine meant that researchers could not study all layers or perspectives of Chinese medicine at the same time, which caused the reduction of the complexity in Chinese medicine. For example, the Harbin team studied a *fufang* to find out on which *zheng* the *fufang* had the best therapeutic effect. With pharmacognosy methods, the Harbin group investigated the drug mechanism of a standardised drug that was commonly prescribed by Chinese medicine practitioners for more than one *zheng*. The researchers studied the interaction between the drug and the proteins, the genes and the metabolites in a human or animal model to detect how the *fufang* performed on each of these levels. The performance revealed on which *zheng* the medication was the best fit. Another option was that the researcher analysed the drug mechanism by identifying how and what the drug affected. The mechanism study represented a description of transcriptions, repairs, manipulations or influences, which induced the healing process. However, it did not represent the interaction between all levels as they were not represented in the biofluids or the varieties of Chinese medicine drug prescription.

As already indicated in the above-mentioned examples, omics technology had limitations in the study of complex issues and systems. Prof Musashi and Prof Meng were systems biology experts without having an involvement in the ERC TCM, but they became interested in Chinese medicine and Kampo studies. The crucial difference in their enrolment through omics technology was that they both independently demonstrated an enrolment with omics technology in Chinese medicine or Kampo medicine research. They both agreed that omics technology was too limited to undertake systems biology research on Chinese medicine. Thereby, this impasse represented a challenge for them, which they wanted to meet by assisting with their expertise. Both actors visualised systems biology and AI as an advancement in the study of Chinese medicine to generate and handle big data of any reported and evaluated medicine within less time and less errors. To put this into ordering terms, AI is in Prof Musashi's perception, a "centre of translation" through its calculation speed. It controls and monitors any therapy given to the patient considering the symptoms. By evaluating those interventions, it immediately acts on them by prescribing different drugs or treatments. Therefore, AI represents an appropriate example for a "centre of translation" or a control unit that is unbiased in medical evaluation - as long as the AI designer is fair and integrates both medical and scientific knowledge.

The mode of vocation demonstrates that omics technology was an attractor and caused the enrolment of various actors. Omics technology was central to the above-presented stories as it served as the "centre of translation" to attract funders, collaborators, industry and politicians and developed into a requirement for funding applications and the study of Chinese medicine in China and Europe. Consequently, omics technology made Chinese medicine studies credible, trustworthy and scientific to funders. While, this link between Chinese medicine and omics technology created a dependency on omics technology in Chinese medicine studies, it also implied that Chinese medicine was a weak entity without omics technology, and that the use of omics technology empowers Chinese medicine researchers to study their medicine on an equal footing as biomedicine, which consequently dismisses its association to quack medicine. The actors' stories demonstrated that the "centre of translation" between omics technology and researchers and systems biologists was not limited to one location, one actor or one technique as control, calculation and monitoring emerged through various interactions between the actors on the various sides and with omics technology.

8.5 Chapter Conclusion

In this chapter, I analysed the life stories descripted as codes in the Chapters 4, 5, 6 and 7 as modes of a heterogeneous network, vision and vocation. These codes were used to address the research questions on the term and nature of the "interface" between Chinese medicine and systems biology and how it differs from past encounters between Chinese medicine and modern science and how the various involvements changed and influenced the development of the relationship between Chinese medicine and systems biology.

In the first mode of a heterogeneous network, I demonstrated that various actors (practitioners, doctors, physicians, omics technology, concepts, ideas and methods) generated and participated in the research co-operation. These were the Leiden and Dalian co-operation, the Harbin research group, the university network organisation and the international ERC TCM consortium. There were numerous reasons as to why the actors became involved in the research of systems biology and Chinese medicine and these included: a scientific vision, the desire to take part in a research project and wanting to use omics technology. I analysed the involvement in mode of vision that presented the emergence of Chinese medicine and systems biology research through the scientific visions of the research co-operation of the Leiden group.

The mode of vocation demonstrated the employment in the research field of Chinese medicine and systems biology. The projects described in the mode of vocation derived from the initial study of the inner circle and stimulated the participation of actors in the Harbin research group, the university network organisation and the international ERC TCM consortium. The participation of the actors developed through "immutable mobiles" such as research papers, analysis results, biochemistry, experiment protocols, biofluids, drugs and bodies and generated together with the co-operation of partners, principal investigators and supervisors, the consortium and omics technology a "centre of translation", which globally distributed co-operation between Leiden and Dalian, the university network organisation and the ERC TCM.

The crucial finding of this research is that Western scientists initiated the research of Chinese medicine and systems biology and the different involvement of the actors (including omics technology) influenced its development from individual research co-operation to a globally distributed heterogeneous research network on Chinese medicine and systems biology.

9. CONCLUSION

This thesis aimed to explore the emergent "interface" between Chinese medicine and systems biology. In this chapter, I am going to summarise the key findings of my research and address the primary research questions:

1. Is there an "interface" and if so, can this latest contact between Chinese medicine and systems biology be referred to as an "interface" and what is its nature?
2. How does this "interface" differ from previous encounters between Chinese medicine and modern science and Western medicine?
3. How did the actors become involved in Chinese medicine and systems biology research?
4. How did the participation of the human and nonhuman actors in Chinese medicine and systems biology research influence the development of the relationship between Chinese medicine and systems biology?

Following this, I will show how my research contributes to the field of the history of Chinese medicine and STS studies. I will conclude the chapter by outlining the limitations of my research and highlighting some areas for future research.

In Chapter 8, I defined an interface as a heterogeneous network that is composed of human and nonhuman actors. The actors in my research were systems biologists, Chinese medicine researchers, omics technology (including genomics, transcriptomics, proteomics and metabolomics) and biochemistry. All of which were involved in various globally distributed research projects on Chinese medicine and systems biology. I asked whether the various interactions between Chinese medicine and systems biology that have taken place since 2005 constructed an interface. Based on the analysis of my ethnography, I can now ascertain that an interface in the form of a heterogeneous network did indeed emerge after 2005 through personal and socio-political interest in Chinese medicine research, and that the heterogeneous network does differ from pervious encounters due to the engagement of European systems biologists with Chinese medicine and its concepts.

The findings in Chapter 4 clearly show that in 2005, a relationship between Chinese medicine and systems biology emerged. Research articles written by various actors, political discussions and research projects on systems biology in Chinese medicine demonstrated an interest in examining Chinese medicine drugs and practices. An analysis with the concept "mode of ordering" a heterogeneous network showed that the "interface" was a heterogeneous network of human and nonhuman actors working in various research projects. The term "interface" however, was not used by the interviewees. They preferred the notion "co-operation", as a description for the interaction between European and Chinese scientists working with systems biology on Chinese medicine. Co-operation as the nature of this heterogeneous network demonstrated multiple "centres of translations" (Law, 1994) that monitored and regulated the interactions between the co-operation partners: Leiden-Dalian group, the ERC TCM consortium and the university network organisation. Interactions happened through the exchange of students, concepts, omics technology and biochemistry. Omics technology and the common language of biochemistry enabled the co-operation between Chinese medicine and systems biology.

The interactions between European systems biologists and Chinese medicine researchers, as presented in this heterogeneous network, make a significant difference to past encounters. This became apparent when European systems biologists tried to engage with Chinese medicine researchers and practitioners on their own terms and with Chinese medicine researchers and practitioners in a co-operative environment. In contrast, in the encounters of the twentieth century, Chinese medicine scholars either implemented Western medicine and science, or the relationship between Chinese medicine and Western medicine was coercive, not co-operative (as it later became). Subsequently, this heterogeneous network during the 2000s is different from past encounters between Chinese medicine and modern science in the twentieth century.

The findings in Chapter 5 showed that scientific visions of a personalised medicine, an improvement of healthcare, the study of complex systems in Western science with Chinese medicine, and the avoidance of exploitation of Chinese medicine drugs were the main motivations for European systems biologists to engage with Chinese medicine. Four European systems biologists looked to the East, like systems scientists did in the 1970s, to establish a holistic approach to medicine and science that was inspired by the holistic and systems thinking of Chinese medicine. In Chapter 5, I showed that systems biologists and Chinese medicine researchers perceive Chinese medicine and systems biology as the same, due to their shared ideology of holism and systems thinking. However, against the perception of actors, these concepts evolved through the process of continuous integration of Western theories in Chinese medicine during the twentieth century. While systems biology developed from cybernetics and systems science, which were grounded in holistic and systems thinking. As a result, the described match (see, for example, van der Greef et al., 2010; Wang et al., 2005; van Wietmarschen et al., 2011; Zhang et al., 2012; Hu, 2012) of systems biology and Chinese medicine was an effect of these developments.

The perception that systems biology is a match for Chinese medicine through holistic and systems thinking, was one reason for the involvement of European systems biologists in Chinese medicine. I analysed the involvement of European systems biologists, the inner circle in the heterogeneous network, in Chinese medicine through the “mode of ordering vision” (Law, 1994). I demonstrated that systems biologists became involved in Chinese medicine research because of their scientific vision, which they hoped to fulfil by studying Chinese medicine *zhengs* and herbs. Their involvement illustrated a discontentment with the dominating reductionist paradigm in biomedicine and science during the 1990s, which stimulated an interest in Chinese medicine. This inner circle was introduced to Chinese medicine through health problems, *Taijiquan* practice, family members and neighbours. Through their engagement with Chinese medicine the inner circle gradually changed their mind set to holistic and complex thinking, and they changed their research interest from biomedicine to Chinese medicine. Thus, the scientific vision of changing the medical and scientific systems in Europe, stimulated the inner circle’s involvement in Chinese medicine research.

The professional change of the inner circle to Chinese medicine research happened in the context of emerging discussions about the lack of evidence for Chinese medicine drugs and practices and their safety in China (see Karchmer, 2010) and Europe (WHO, 2002). My data showed that socio-political discussions and actions on Chinese medicine started in the 1990s and included the Chinese herb Nephrotoxy in Belgium, the establishment of the TCM clinic in Germany, the WHO report in 2002, and EU networking funding. These discussions and actions provoked systems biologists and European pharmaceutical scientists to conduct studies on Chinese medicine with systems biology.

The inner circle connected systems biologists and Chinese medicine researchers and persuaded politicians to invest in their research on Chinese medicine through the production of biochemical evidence for the evaluation of the safety, efficacy and quality of Chinese medicine drugs with systems biology. Systems biology and omics technology were viewed as a tool to realise their visions, and not as a determining factor for their involvement. The actors of the inner circle saw biochemistry as a bridge between Chinese medicine and biomedicine, and they also believed biochemistry was useful to demonstrate their approach to people from outside systems biology and Chinese medicine fields. The mode of vision of the inner circle presented an active and profound involvement of European systems biologists in Chinese medicine.

The mode of vocation shown in Chapters 6 and 7 investigated how the relationship between Chinese medicine and systems biology developed. The mode demonstrated that the inner circle's research papers on Chinese medicine and systems biology increased the interest of politicians in Europe and China and supported various research projects. The mode of vocation discovered that pharmaceutical scientists, Chinese medicine researchers and biochemists became employed in Chinese medicine and systems biology through their research area and ability to engage with omics technology. Research projects were mostly linked to co-operation and attracted various actors to participate in co-operative Chinese medicine and systems biology research that lasted two to six years. The involvement of these actors, however, was passive and with little knowledge of Chinese medicine before their participation. These actors did not connect Chinese medicine to their private life, as compared to the inner circle. Moreover, their commitment to Chinese medicine or systems biology was with their job and research skills, and this was evident when they returned to biomedical studies or they continued a reductionist paradigm after terminating their projects.

Omics technology empowered Chinese medicine researchers to prove their theories on Chinese medicine (the research on *zheng* is a clear example). While for the funders, industry and politicians, omics technology represented scientific reliability of Chinese medicine research, the increasing number of publications (see Figure 1 for the publication numbers). The co-operation between Chinese medicine and systems biology since Wang and her colleagues' (2005) paper and the ERC TCM funding on Chinese medicine and systems biology in 2009, demonstrated that EU politicians, funders and scientists, accepted systems biology and omics technology together as a Western scientific approach to produce scientific evidence on Chinese medicine. Accordingly, the outer circle showed less interest in creating holistic methods and concepts to approach the complexity of Chinese medicine. Their research projects became a trust-worthy investment for stakeholders to fund Chinese medicine research, and by doing so, they boosted Chinese medicine studies on a global platform of political, economic and medical intertwining.

The modes of vision and vocation showed diverse ways and degrees of involvements in international networks of systems biology and Chinese medicine research. They revealed that scientists engaged differently in the research projects, due to their expertise in systems biology or Chinese medicine. The diverse ways transformed the relationship between Chinese medicine and systems biology until the completion of the ERC TCM project in 2011. The focus of the ERC TCM consortium was on the use of "immutable mobiles" (Law, 1994) such as research papers which determined that omics technology was the best method to evaluate the quality, efficacy and safety of Chinese medicine. In the following project, the assessed methods changed from instruments of evidence and evaluation, to models for the modernisation and globalisation of Chinese medicine (see for example Li and Su, 2008). As a result, the research interest and participation changed increasingly due to these models.

It can, therefore, be said that the heterogeneous network between Chinese medicine and systems biology research is a multi-disciplinary and global network that is composed by omics technology, biochemistry, systems biology, pharmacology scientists, researchers and politicians. Through the different modes of vison and vocation, the development of this heterogeneous network was revealed. For instance, the ideas of the inner circle were grounded on the firm beliefs that systems biology is a crucial concept when studying Chinese medicine, or that Chinese medicine is key to personalised medicine and the reform of healthcare systems. This means that the inner circle strived to find a new research model in science, while the outer circle continued their studies with reductionism once their projects on Chinese medicine and systems biology ended. Moreover, rhetoric and achievements of the outer circle stressed the technological and scientific development in evidence production for the efficacy, safety and quality of Chinese medicine drugs. From my research findings, it was clear that the actors became involved in a variety of ways in this this heterogeneous network and they shaped its development through their engagement in this heterogeneous network.

My work contributes to the history of Chinese medicine by showing that the scientific interaction between the actors from Western science and Chinese medicine changed. Compared to the historical encounters found in the twentieth century, European scientists engaged with Chinese medicine to gain insights to help establish a personalised medicine and to reform the European healthcare systems. Thus, the latest interactions aided the actors once they started to understand Chinese medicine and meant that they could then learn from it, rather than exploiting its herbal remedies for new biomedical drugs. This study answers the call of Chinese medicine researchers for a detailed ethnographic study on the emergent "interface" between Chinese medicine and systems biology in the past years (Scheid, 2014). The need for a better understanding on the ways of how Chinese medicine and technoscience interact, is supported by the widely acknowledged need to study medical anthropology at home to better understand the influence of biotechnology in science and medicine (Lei, 2014; Hadolt, Hörbst, and Müller-Rockstroh, 2012; Chen, 2003; Manderson, Harden and Cartwright, 2016; Helman, 2007).

To answer the call for more detailed research on this "interface", I employed a multi-sited ethnography approach to study a globally distributed and heterogeneous network between Chinese medicine and systems biology in great depth. I explored the emergent heterogeneous network through the involvement of human and nonhuman actors, which has never been looked at before. Studies on traditional medicine have investigated remedies and their transformation into drugs that comply with biomedical and Western market standards (e.g., van der Valk, 2017) or the influence of science in traditional medicines (see, for example, Adams, Dhondup and Phuoc, 2010; Pordié and Gaudilliere, 2014; McKay, 2010). However, the increasing interest in traditional medicine studies and the phenomenon of pharmaceutical scientists looking for different approaches in traditional medicines rather than biomedicine, e.g., Ayurveda, Tibetan medicine, shows the significance of discovering the reasons for this change. The empirical findings in this study contribute to the body of knowledge on encounters between Chinese medicine and modern science. This new kind of interaction between Chinese medicine and systems biology reveals a new understanding of how and why systems biologists, pharmaceutical scientists, chemists, molecular biologist scientifically engage with Chinese medicine diagnosis and practices, Chinese medicine pharmacognosists, its practitioners, and industrials.

With multi-sited ethnography, nine different field sites that worked with Chinese medicine and systems biology were observed (see Table 1 for the fieldwork schedule). Seven of them were involved in ERC TCM consortium for the evaluation of Chinese medicine with systems biology methods. In the other two sites were systems biology experts who used AI and computational modelling to address the challenge of a system-level understanding in Chinese medicine studies. I found that systems biology was either viewed as a discipline or a method. My fieldwork data reflected the incongruent description of systems biology in the literature as a discipline that is formed and influenced by the various backgrounds of its researchers (Nersessian, 2017; Alon, 2007). The actors described systems biology and their work as either a discipline to revolutionize the understanding of biological systems (Kitano, 2002; Bothwell, 2006) or a discipline between reductionism and holism (Calvert and Fujimura, 2011). Accordingly, the actors identified themselves either as systems biologists or they applied systems biology methods into their studies.

The other discoveries I made were that the combination of omics technology and biochemistry co-generated with scientific visions the engagement of European scientists in Chinese medicine studies, as well as Chinese medicine researchers in systems biology. This combination set the groundwork for the co-operation between those two fields. Secondly, the interaction between human actors and nonhuman actors (i.e., omics technology, biochemistry and biofluid samples) was performed during an experiment to acquire data. The relationship was also observed between various sites. These were demonstrated as co-operation to either exchange materials or students between various locations, such as China and the Netherlands, or actors were dual-trained in Chinese medicine and systems biology such as in Harbin. Hence, the Harbin co-operation was not defined by the need to complement their skills in either Chinese medicine or systems biology, they merely wanted to co-operate with the pharmaceutical industry in China. Finally, for the ERC TCM consortium members, the interaction was shown by discussions at conferences and literature reviews on systems biology as the best research approach for the evaluation of Chinese medicine.

This is the first study that has investigated the various involvements of European scientists into Chinese medicine research with the lenses of "modes of ordering" (Law, 1994). I applied Law's (1994) theory of "modes of ordering" in the context of the exploration of this emerging scientific interaction between Chinese medicine and systems biology. The theory is based on ethnography (Law, 1994; Mol, 2002; Moser, 2005) and is useful for organisational studies (Czarniawska-Joerges, 1996) and for ordering the life stories of people (Moser, 2005). I organised my material into three modes; a heterogeneous network, vision and vocation. By doing so, I discovered that what Scheid (2014) describes as an "interface" was a heterogeneous network that was co-generated and performed by human and nonhuman actors in various globally distributed research co-operation. This follows Law's (1994) description of heterogenous networks as being composed of human and nonhuman actors with the inclusion of data from various sites, which are working on Chinese medicine and systems biology. Hence, my understanding of a heterogeneous network also relates to the function of the ERC TCM consortium as a networking project that identified 200 scientists worldwide, working on Chinese medicine and systems biology. It established itself as an umbrella project above all other existing projects, which were created during the time of the consortium. The research into Chinese medicine and systems biology peaked with the ERC TCM consortium, which indicates its central position in Chinese medicine and systems biology research. The interest and the application of systems biology were diverse in this research area and range from a technological focus and advancement, to analysing pathways for new drug development, to diagnosis studies, to achieving holistic studies and understanding in medicine, to eventually publishing papers and obtaining funding. The projects focused on various aspects of a *zheng* and the applications of a *fufang* on different *zhengs*, which makes it heterogeneous in the participation of actors, as well as in the various aspects and distribution of research co-operation and projects. Due to the consortium and the various interests that exist in this research field, I interpret this relationship as a heterogeneous network rather than an "interface".

The “modes of ordering vision” is defined by Law (1994) as a person who attracts and presents his position in a laboratory through grace, charisma and their scientific visions. In my application of modes of vision, I identified that the inner circle of this heterogeneous network produced the first studies on Chinese medicine and systems biology. They became involved in Chinese medicine research through their scientific visions. These European systems biologists wanted to study Chinese medicine research to reform European healthcare systems – this is important as understanding the interest of Western bioscientists in traditional medicines is rare and hardly investigated. They wished to improve the situation in science and healthcare by stopping the reductionistic approach in medicine and science, and the exploitative approach to Chinese medicine drugs studies. Subsequently, these actors aimed to fulfil their visions through a systems biology approach to complex issues, and Chinese medicine as a source for personalised diagnosis and a holistic and complex understanding. Therefore, visions were embodied in several systems biologists that joint their interests and generated the first projects on Chinese medicine and systems biology.

In applying the “modes of ordering vocation” (Law, 1994), I demonstrated that the skills and expertise of the actors with omics technology and biochemistry, was crucial for their employment in Chinese medicine and systems biology research projects. Omics technology was not only the basic technology in systems biology, it also evolved together with biochemistry as a communication tool between Chinese medicine and systems biology, as well as a motivation tool for employing actors into this research field. Omics technology was used for the examination of any study of Chinese medicine drug or its practices. It analysed blood and urine samples and based on the biochemical analysis data, it generated a network analysis of genetic, protein and metabolic relationships that constituted *zheng*, a symptom pattern. Therefore, biochemistry and omics technology provided a crucial method, experiment protocols and analysis data that supported the systems biologists claim that they studied Chinese medicine because of their common understanding of systems thinking and holism and consequently facilitated the interaction between both sides.

The “modes of vision and vocation” revealed different involvements and various motives for research co-operation. The mode of vision showed that active engagements with Chinese medicine were well-considered steps in the private and professional lives of the actors that involved them and maintained their interest in Chinese medicine and systems biology research. While omics technology and biochemistry, co-produced a method to evaluate Chinese medicine and attracted systems biologists and Chinese medicine researchers for their skills in this research relationship.

To sum up, as an empirical contribution, I produced a detailed account on the involvement of the actors from different scientific backgrounds in various research projects on Chinese medicine and systems biology, the challenges they face by taking this step, by co-operating in multi-disciplinary research, and the practices they employ. In this account, the different involvements of the human and nonhuman actors showed that the application of omics technology and biochemistry in Chinese medicine was not challenging. However, the enrolment of humans, in particular, European pharmaceutical scientists and systems biologists in Chinese medicine research was different because humans have goals, intentions, and they evaluate and decide if they want to become involved and associated with Chinese medicine. Technology such as omics technology was employed in Chinese medicine to make it appear more scientific and helped to modernise this medicine. This integration was part of the continuous process that started in the twentieth century to modernise Chinese medicine by following Western scientific practice. Thus, the involvement of technology as a nonhuman actor was an organic development influenced by the political agenda and funding requirements which intended to modernise Chinese medicine. However, the involvement of systems biologists and Western scientists in Chinese medicine studies was until the 2000s uncommon. Thus, I argue that the investigation of involvement was essential to understand how this change of interest occurred.

As presented above, this thesis contributes to the contemporary history of Chinese medicine. With the modes approach, I revealed a difference to previous encounters between Chinese medicine and modern science. Whereas previously, there was primarily only interaction between Chinese scientists and Chinese medicine researchers, in the 2000s, European systems biologists and pharmaceutical scientists started to interact with both Chinese medicine researchers and scientists. Consequently, it was clear that in the 2000s, the relationship between Chinese medicine researchers and systems biologists was established, on an equal understanding of systems theory and holism, and the actors found in systems biology, including omics technology and biochemistry, an approach that allowed Chinese medicine to maintain its concepts without translation it into the Western scientific context. By doing so, systems biologists identified a different way to perform their experiments – for example, they no longer extracted active compounds for potential drugs using Western reductionist methods. Systems biologists now investigated Chinese medicine with systems thinking, using a holistic approach. Hence, European systems biologists demonstrated that they were trying to understand Chinese medicine.

In a historical analysis of the shared root of systems thinking and holism, I discovered that the ideas of cybernetics spread into Chinese medicine in the 1950s and lead to a co-operation between American and Chinese cyberneticians (see for example the work of Norbert Wiener and Li Yurong carried out in 1934 on the control and regulation of electronic systems). My study consequently offers insights into the contemporary history of Chinese medicine and systems biology, and the ordering of scientific engagements with Chinese medicine and systems biology by employing multi-sited ethnography.

This study does not provide an exhaustive account of the entire structure of the heterogeneous network between Chinese medicine and systems biology and every actor involved in it. Rather, it demonstrates the specific modes that generated and represented this network in settings of globally, multidisciplinary and multi-sited research co-operation in the specific field of Chinese medicine and systems biology. Even though this project offers a great deal of complexity, and the represented modes and materials are used in many scientific projects, generalisations were limited due to the specific character every mode presented.

In the future, it would be interesting to examine the involvement of Western scientists in studies on Chinese medicine practice such as acupuncture, *Tuina* and *Qigong* and other traditional medicines to establish whether these findings of scientific vision, personal connection to traditional medicines, and vocation are applicable to other settings and whether new findings emerge. Another possible area of future research would be to investigate the transformation of traditional medicines through the influence of technological advancements in AI and what knowledge of these medicines will be included and excluded for establishing a new and faster AI diagnostic system.

There were two main limitations in this study. First, I analysed Chinese medicine pharmaceutical studies in the absence of voices from acupuncture, *Tuina* and other Chinese medicine practices in this heterogeneous network. The reason for this limitation was the sparse involvement of those researchers in this heterogeneous network as it was dominated by drug researchers and these who were involved did not grant access to their research institutions. Thus, a greater focus on various Chinese medicine practices could produce findings that account for the value of Chinese medicine practices.

The second shortcoming may be identified with regards to the selected methodological approaches. It may be argued that fourteen interviews are not enough to present the perceptions of the actors and demonstrate the historical process. A larger sample of interviews would undoubtedly increase the reliability of the findings. In addition to this, to generalise the involvement of European systems biologists in the research of Chinese medicine, the number of presented samples in this study might be questioned. However, the intention was to identify the key actors that initiated the study on Chinese medicine and systems biology actors and collect their stories. Indeed, for a generalisation of the involvement of European systems biologists, a larger sample would be needed.

My study shows that various actors became differently involved in Chinese medicine and systems biology research, and their type of involvement shaped this research co-operation. For the first research question, it is clear that an scientific relationship emerged, which was demonstrated in the interviews, research publications and co-operation that took place between 2005 and 2015. However, this relationship was not an interface between human actors - it appeared as a globally distributed network of co-operation and interactions between human and nonhuman actors. For the second question, my results showed that the European systems biologists initiated the research on Chinese medicine with systems biology, because of a shared ideology of systems thinking and holism. These shared ideologies were crucial to establishing, based on this common ground, an interaction between systems biologists and Chinese medicine researchers. The third question revealed that European systems biologists became first personally involved in Chinese medicine through visions of a personalised medicine, the desire to perform holistic research or the want to practice holistic medicine and science. With these intentions, the actors began working on their first Chinese medicine and systems biology project. The fourth question showed that the after the first project was established the number of projects increased, and the actors clearly became involved because of their expertise and skills in biochemistry and omics technology. It later became apparent that omics technology was the main reason why scientists decided to participate in Chinese medicine research with systems biology.

To recap, the suspected “interface” between Chinese medicine and systems biology is a heterogenous network that consists of various actors and various research co-operation between China and Europe. The heterogeneous network emerged from an interest in the personalised diagnosis of Chinese medicine, and developed into evaluations on the effect of Chinese medicine drugs on living organisms using genomics, proteomics, transcriptomics and metabolomics analysis.

APPENDIX A: DETAILS OF THE FUNDING GIVEN BY THE NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA (NSFC)

Below you can find information about the research funding structure of the NSFC in China, and how it co-operated with the EU and European countries.

The five Chinese research projects in Chinese medicine and/or systems biology selected for this dissertation (i.e., Lipidomics research, Chinese metabolomics, *in vitro* fertilisation and the fast examination kits) were all funded by the most significant funding agency in China, the NSFC. The NSFC is modelled on Western research funding agencies and directly financed by the State Council (highest governmental institution). In 2012, they announced that they would spend EUR 3,05 billion (GBP 2,7 billion) to fund a number of natural science research projects. Of the proposals they received, 22.88% were for projects concerning Life Sciences and 18.79% for Health Sciences (ESC, 2014).

According to the NSFC funding guideline (NSFC, 2016), funds were divided into three sectors: the research promotion, talent fostering and infrastructure construction for basic research. Of the five research programs under consideration for this thesis, promotion and talent fostering were the most relevant. They are divided into several themes and are described below:

- Research promotion was divided into:
    - **General Programs** with a total funding of 50% of NSFC total funding. The funds were applied to unsolicited small basic research on bottom-up based topics initiated by a principal investigator (PI) (i.e., senior researcher or PhD degree holder) in natural science projects. This covered projects on Chinese medicine research, Chinese materia medica and Integrated Chinese and Western medicine.

- **Key Programs** supported medium-sized in-depth, systematic and innovative research that aimed for high good research practice and new disciplines, which were conducted in one research institution and within the priority area of the NSFC.
- **Major Program and Major Research Plan** which included funding for large projects grounded in the economic and social development of national priority areas and included three programs: Fostering Program, Key Program and Integrated Program.

Chinese medicine projects are regulated under the General Program under the Department of Health Sciences in Division X (NSFC, 2016). In 2016, The NSCF funded the following three research areas in Chinese medicine: (i) Traditional Chinese medicine and advancing of theories, clinical medicine, acupuncture and other ethnomedicine, (ii) Chinese Materia Medica, pharmacology and ethnopharmacology, and (iii) Integrated Chinese and Western Medicine (IM) with fundamental theories, clinical research and methodological and technical innovations in Chinese medicine (NSFC, 2016). In 2016, the NSFC required the integration of Chinese medicine theory in holistic studies with the use of cutting-edge technology (ibid). The Key Program includes two thematic areas concerning Chinese medicine: (i) biological study on correlations in classical formulas and TCM syndromes, (ii) toxicological analysis and clinical effectiveness in Chinese drugs.

Furthermore, the NSFC funds international co-operation with researcher mobility and joint international research projects under the Major Program, as explained above. The five research projects under consideration of this study obtained funding from the following two talent fostering programs.

- Talent fostering programs:
  - The Key International (Regional) Joint Research Programs are fostering programs that include major international joint research programs and joint research projects. These were established on Agreements/Memoranda of Understanding (MOUs) between the NSFC and the foreign partner. Applicants were expected to research in areas that were urgently needed to develop in China. The projects were conducted as mega projects and supported the mobility of students and

researchers to conduct their research in overseas institutions. This Key International Cooperation Exchange Program supported student exchange of the Dalian-Leiden co-operation (see Chapter 6 for more details).

- The International (Regional) Cooperation and Exchange Program under Agreements/MOUs supported international co-operation and exchange projects including going abroad to attend international academic workshops and a special fund for a short-term return of overseas Chinese scholars to work in China. This sponsored the exchange for the Dalian group with Leiden and the Harbin team with Japan (as described in Chapter 6).

The Joint Research Programs run by the NSFC and ERC, offered financial support of between RMB 1 - 3 Million for five to twenty projects per year. The costs were shared between the NSFC and the ERC. The NSFC supported the travel aspect which included relocation costs, and the ERC covered the scientists' local costs. In the example of the Dalian and Leiden co-operation (see Chapter 6), the agreement between the NSFC and the Netherlands Organization for Scientific Research (NWO) regulated the (i) exchange of short-term academic studies on a common interest, (ii) personal exchange of up to three months and (iii) bilateral workshops between scientists of the two countries.

APPENDIX B: TOPIC GUIDE FOR SEMI-STRUCTURED INTERVIEWS

Below the topics, I used to guide my semi-structured interviews with the four gatekeepers.

- Introduction and personal position in the field:
  - Can you tell me about yourself, your (academic) background and your expertise?
  - Can you tell me about your research?
  - Do you have any experience in Chinese medicine/systems biology?
- Involvement in systems biology/Chinese medicine research:
  - Can you tell me about the Chinese medicine and systems biology research project you were involved?
  - How and when did you find out about the Chinese medicine/systems biology research project on which you are worked?
  - How and when did you become involved in systems biology/Chinese medicine project?
  - How did others become involved in the project?
- Project or consortium structure and organisation:
  - How was the project team/consortium assembled?
  - Did you collaborate with other departments/laboratories/industry for this project?
  - How many students/researchers worked in your project? What was their background?
  - How did you select your partners to work on your project idea?
  - Were you approached by someone else to participate?
  - How did you locate the other researchers with whom you co-operate/co-operated on the project?
  - Can you tell me about the management structure?
  - Who controlled and monitored the consortium/projects?
  - How was the work allocated between the partners?
  - How did you communicate with your partners? Did you meet regularly?

  - Was there any problem with the co-operation partners?
  - What is your current project on?
  - Can you tell me more about the reason for this topic and the research design?
- Funding:
  - How was the project funded?
  - Were there any alternative funders?
  - Who was involved in writing the proposal for your project/consortium?
  - Did you interact with funding bodies? Did you report to them?
- Definitions and perceptions:
  - How do you define systems biology/Chinese medicine?
  - How do you think do Chinese medicine and systems biology relate to each other?
  - Why do you think is in particular systems biology the right approach for Chinese medicine research?
- Experience and reflection on the Chinese medicine/systems biology project:
  - What was your experience with the project X?
  - What was your experience with the co-operation partners?
  - How would you describe the Chinese medicine and systems biology relationship?
  - How did the project develop?
  - When did this the first projects on Chinese medicine/systems biology start?
  - Who initiated the first project?
- Future outlooks for Chinese medicine/systems biology research?
  - What do you expect from systems biology/Chinese medicine research?
  - What do you think about the acceptance of systems biology/Chinese medicine research by other natural science fields?

APPENDIX C: PARTICIPATION INFORMATION SHEET

Elucidating the Relationship between Chinese Medicine and Systems Biology

Researcher: ______________________________

Supervisors: ______________________________, ______________________________

You are invited to take part in a research study on systems biology (following just SB) and Chinese medicine (CM), which involves conducting participant observation in research laboratories, workplaces, conferences, workshops, meetings, or any other place and event and interviews. There is evidence form many studies on CM herbal remedies, acupuncture, and diagnosis with omics technology that CM and SB interact with each other. The aim of this research is to elucidate this "interface" between CM and SB, and also to demonstrate whether or not it differs from previous encounters between CM and biomedicine.

This research is being undertaken as part of the researcher's studies for a doctoral research programme at the university.

The study will involve you:

1) Participating in observations. The researcher will take part in the participant's daily working live as a participant observer in order to understand how and where SB and CM are interfacing. The researcher may ask questions to the participant and other persons in the field. This will take around one or two months to complete.

2) Participating in an interview with the researcher, about your professional position in this "interface" and your relationships with SB or CM. This will take about 1 hour and will be tape-recorded. The recording will be transcribed, and the audio recording retained by the researcher as part of this research without access of any third person.

Please note:

- Your participation in this research is entirely voluntary.
- You have the right to withdraw at any time without giving a reason.
- You have the right to ask for your data to be withdrawn as long as this is practical, and for personal information to be destroyed.
- You do not have to answer particular questions in observations or in interviews if you do not wish to do so.

- Your responses and your present research data will normally be made anonymous, unless indicated above to the contrary, and will be kept confidential unless you provide explicit consent to do otherwise, for example, the use of your image from photographs and/or video recordings. [NOTE: In case it may not be possible to maintain confidentiality in certain circumstances, you should seek clarification from the researcher and/or their supervisor if you are concerned about this].
- No individuals should be identifiable from any collated data, written report of the research, or any publications arising from it.
- All computer data files will be encrypted, and password protected. The researcher will keep files in a secure place and will comply with the requirements of the Data Protection Act.
- All hard copy documents, e.g. consent forms, completed questionnaires, etc. will be kept securely and in a locked cupboard, wherever possible on University premises. Documents may be scanned and stored electronically. This may be done to enable secure transmission of data to the university's secure computer systems.
- If you wish you, can receive information on the results of the research. Please indicate on the consent form if you would like to receive this information.
- The researcher can be contacted during and after participation by email (s.glatz@westminster.ac.uk) or by telephone (0044 7479 208121).
- If you have a complaint about this research project, you can contact the project supervisor, {Volker Scheid} by e-mail (v.g.scheid@westminster.ac.uk) or by telephone (+44 (0) 207 911 5000 x 64662).

APPENDIX D: CONSENT FORM

Title of Study: Elucidating the Relationship between Chinese Medicine and Systems Biology

Lead researcher: ____

I have been given the Participation Information Sheet and/or had its contents explained to me.	Yes ❐	No ❐
I have had an opportunity to ask any questions and I am satisfied with the answers given.	Yes ❐	No ❐
I understand I have a right to withdraw from the research at any time and I do not have to provide a reason.	Yes ❐	No ❐
I understand that if I withdraw from the research any data included in the results will be removed if that is practicable (I understand that once anonymised data has been collated into other datasets it may not be possible to remove that data).	Yes ❐	No ❐
I would like to receive information relating to the results from this study.	Yes ❐	No ❐
I wish to receive a copy of this Consent form.	Yes ❐	No ❐
I confirm I am willing to be a participant in the above research study.	Yes ❐	No ❐
I note the data collected may be retained in an archive and I am happy for my data to be reused as part of future research activities. I note my data will be fully anonymised (if applicable).	Yes ❐	No ❐

Participant's Name: ____________________________

Signature: ____________________________ **Date:** _______________

This consent form will be stored separately from any data you provide so that your responses and data remain anonymous.

I confirm I have provided a copy of the Participant Information Sheet approved by the Research Ethics Committee to the participant and fully explained its contents. I have given the participant an opportunity to ask questions, which have been answered.

Researcher's Name: ____________________________

Signature: ____________________________ **Date:** _______________

Appendix E: Statistics on Asian students at the University of Salzburg in 2000/2001

bmwfw, Abt. IV/9 unidata/04.01.2018

Internationale Mobilität
Studierende Universitäten

Studierendenmobilität nach Kontinenten - Incoming

Ordentliche Studierende, die einen Aufenthalt an einer österreichsichen Universität im Rahmen eines geförderten Mobilitätsprogramms absolvieren.
Anmerkung: Ab dem WS 2016 erfolgt die zähltechnische Abbildung der Studierenden auf Basis des Verteilungsschlüssels gemäß § 9 Abs. 2 UniStEV 2004.

Quelle: Datenmeldungen der Universitäten auf Basis UniStEV zum jeweiligen Stichtag
Datenprüfung und -aufbereitung: bmwfw, Abt. IV/9

ALLG Semester.Studienjahr (Kurzbezeichnung)	2000/01
Universität	Universität Salzburg
Mobilitätsprogramm	Gesamt
Staatsangehörigkeit (Kurzbezeichnung)	Gesamt
Staatengruppe (Ö, andere)	Gesamt
EU-Mitgliedsstaaten	Gesamt

		Incoming		
Kontinent	Geschlecht	Gesamt	Sommersemester 2001 (Stichtag: 30.09.2001)	Wintersemester 2000 (Stichtag: 28.02.2001)
Afrika	Gesamt	0	0	0
	Frauen	0	0	0
	Männer	0	0	0
Amerika	Gesamt	0	0	0
	Frauen	0	0	0
	Männer	0	0	0
Asien	Gesamt	0	0	0
	Frauen	0	0	0
	Männer	0	0	0
Europa	Gesamt	0	0	0
	Frauen	0	0	0
	Männer	0	0	0
Keine Angabe	Gesamt	0	0	0
	Frauen	0	0	0
	Männer	0	0	0
Gesamt	Gesamt	0	0	0

Source: Bundesministerium für Bildung, Wissenschaft und Forschung. (2018). Internationale Mobilität Studierende Universitäten Studierendenmobilität nach Kontinenten. Universität Salzburg. Kontinent Asian.Incoming 2000/2001. Vienna. Available from https://suasprod.noc-science.at/XLCubedWeb/WebForm/ShowReport.aspx?rep=011+internationale+mobilität/001+universitäten/006+studierendenmobilität+nach+kontinenten+-+incoming.xml&toolbar=true [Accessed 6 January 2019].

1/1

GLOSSARY

bagang bianzheng 八纲辨证	classification of syndromes according to the eight principles: *yin* and *yang*, exterior and interior, cold and hot, depletion and repletion (see Farquhar, 1994).
biantong 变通	the process of change and transformation (Scheid, 2016)
bianzheng lunzhi 辨证论治	pattern differentiation and treatment determination (Farquhar, 1994)
changshan 常山	*Dichroa febrifuga*
chijiao yisheng 赤脚医生	Barefoot doctors
daojiao 道教	Daoism, Chinese philosophy, Taoist religion
duili tongyi 对立统一	unity of opposites (Scheid, 2016)
fangji 方剂	large repertoire of "formulae" or drug prescriptions or recipes (Farquhar, 1994)
fen fang ji 粉防己	*Aristolochia* plant (Debelle, Vanherweghem and Nortier, 2008)
fufang 复方	Chinese medicine multiple herb prescriptions or formula (Wang and Chan, 2010)
guifanhua 规范化	standardisation
guocui 国粹	national essence
guoyi guan 国医官	Institute of National Medicine
guoyi yundong 国医运动	National Medicine Movement
han fang ji 汉防己	*Stephania tetrandra* plant (Debelle, Vanherweghem and Nortier, 2008)
huanyuan lun 还原论	the theory of return to the original condition or reconstruction theory (Zhang and Li, 2006)

jingluo 经络	meridian, main and collateral channels
kejiao xingguo 科教兴国	Rejuvenation of the country through science and technology
kexue 科学	science
laozhongyi 老中医	senior doctors
lixinji 离心机	centrifugal machine, centrifuge
neike 内科	department of internal medicine
qi 气	the concept of energy being active and a material (see Farquhar, 1994)
qigong 气功	Chinese medicine practice, bodily cultivation (Xu, 1999)
quanpan xihua 全盘西化	wholesale westernisation
sai xiansheng 赛先生	Mr Science
san tiao daolu 三条道路	three-pillar system
shenjing bingli xue 神经病理学	neuro-pathology theory
sizhen 四诊	four methods of examination: observation (*wang* 望), auscultation and olfaction (*wen* 闻), interrogation (*wen* 问), touching pulse feeling and palpation (*qie* 切) (Farquhar, 1994)
Taiji 太极	the supreme ultimate, the great pole as the two extremes or contradictions of the absolute in ancient Chinese cosmology (see Schroën et al., 2014)
Taijiquan 太极拳	Chinese medicine physical movement, martial art (shadowboxing) (Xu, 1999)
tang 汤	hot liquid or decoction, liquid preparation of medicinal herbs (Unschuld, 2005)

tongbian 通变	interpenetration of opposites to grasp the dynamic of the relationships that constitute the world (Scheid, 2016).
tuina 推拿	Chinese medical massage (Zhan, 2001)
wuxing 五行	five Elements, originally with emphasis on the five phases in the relationships between body and nature. Since the start of the publication of the *Outline* (1958), it has focused on five visceral functions and physiological transformations of substances (see Scheid, 2002a; Hsu, 1999)
xitonghua 系统化	systematisation
xuewei 穴位	acupuncture point
yin/yang 阴阳	the concept of polarities to describe extreme points such as hot and cold as a medical analysis technique (see Farquhar, 1994).
Yinchenhao tang 茵陈蒿汤	*Virgate Wormwood* decoction to treat *yang* jaundice (Wang, Zhang and Sun, 2012)
zheng 证	pattern or symptom (Farquhar, 1994)
zhengti guannian 整体观念	translation of holism in 1950s, *zhengti* stands for the "whole", *guannian* is translated as the "direction of one's attention" (Scheid, 2016)
zhongxiyi hezuo 中西医合作	Co-operation between Chinese and Western Medicine
zhongxiyi jiehe 中西医结合	integrating Chinese and Western Medicine
zhongxiyi tuanjie 中西医团结	unifying Chinese and Western Medicine
zhongyixue gailun 中医学概论	*Outline of Traditional Chinese Medicine*
ziqiang yundong 自强运动	Self-Strengthening Movement

ANT	Actor-network theory
CAM	Complementary and alternative medicine
CCP	Chinese Communist Party
CM	Chinese medicine
CMP	Chinese medicine pharmacotherapies
EBM	evidence-based medicine
EPC	European Pharmacopoeia Commission
ERC	European Research Council
ERC TCM	European Research Council Traditional Chinese medicine consortium
EU	European Union
HGP	Human Genome Project
HLPC	High-Liquid Performance Chromatography
ISO	International Organisation for Standardisation
MAAH	Medical anthropology at home
MOH	Chinese Ministry of Health
MOST	Chinese Ministry of Science and Technology
MOU	Memorandum of Understanding
NSFC	National Science Foundation of China
PRC	People’s Republic of China
SAC	Standardisation Administration of China

SATCM	State Administration of Traditional Chinese Medicine
SB	systems biology
SFDA	State Food and Drug Administration
STS	Science and Technology Studies
TCM	Traditional Chinese medicine
UPLC	Ultra-High Performance Liquid Chromatography
WHO	World Health Organisation

References

Adams, V. (2001). The Sacred in the Scientific: Ambiguous Practices of Science in Tibetan Medicine. *Cultural Anthropology*, 16 (4), 542–575.

Adams, V., Dhondup, R. and Phuoc, V. L. (2010). A Tibetan Way of Science: Revisioning Biomedicine as Tibetan Practice. In: Adams, V., Schrempf, M. and Craig, S.R. (eds.) *Medicine between science and religion: explorations on Tibetan grounds*. New York: Berghahn Books.

Allen, D. (2014). Lost in translation? 'Evidence' and the articulation of institutional logics in integrated care pathways: from positive to negative boundary object? *Sociology of Health & Illness*, 36 (6), 807–822. doi: 10.1111/1467-9566.12111.

Alon, U. (2007). *An Introduction to Systems Biology: Design Principles of Biological Circuits*. Boca Raton: Chapman & Hall.

Amsterdamska, O. (1990). Surely You Are Joking, Monsieur Latour! *Science, Technology & Human Values*, 15 (4), 495–504. doi: 10.1177/016224399001500407

Amsterdamska, O. (2008). Practices, People, and Places. In: Hackett, E. J., Amsterdamska, O., Lynch, M. and Wajcman, J. (eds.) *The handbook of science and technology studies.* 3rd ed., Cambridge, Mass.: MIT Press

Anderson, W. and Adams, V. (2008). Pramoedya's Chickens: Postcolonial Studies of Technoscience. In: Hackett, E. J., Amsterdamska, O., Lynch, M. and Wajcman, J. (eds.) *The handbook of science and technology studies*. 3rd ed., Cambridge, Mass.: MIT Press.

Andrews, B. (2014). *The making of modern Chinese medicine, 1850 - 1960*. Vancouver: UBC Press.

Angelova, N., Kong, H.W., van der Heijden, R., Yang, S-Y., Choi, Y.H., Kim, H.K., Wang, M., Hankemeier, T., van der Greef, J., Xu, G. and Verpoorte, R. (2008). Recent Methodology in the Phytochemical Analysis of Ginseng. *Phytochemical analysis: PCA*, 19 (1), 2–16.

Ansari, M.S. (2016). Evaluation of role of traditional knowledge digital library and traditional Chinese medicine database in preservation of traditional medicinal knowledge. *DESIDOC Journal of Library and Information Technology*, 36 (2), 73–78.

Ariën, I. and van Genugten, L. (2012). Based on Science, Built on Trust. Netherlands Organisation for Scientific Research (NWO) and the Royal Netherlands Academy of Arts and Sciences (KNAW).

Ashby, W.R. (1958). *An introduction to cybernetics*. London: Chapman & Hall.

Asprem, E. (2015). Dis/unity of Knowledge: Models for the Study of Modern Esotericism and Science. *Numen*, 62 (5–6), 538–567. doi: 10.1163/15685276-12341391

Auffray, C., Imbeaud, S., Roux-Rouquié, M. and Hood, L. (2003). From functional genomics to systems biology: Concepts and practices. *Comptes Rendus Biologies*, 326 (10–11), 879–892.

Baer, H. A., Singer, M. and Susse, I. (2003). *Medical Anthropology and the World System*. Westport: Praeger Publishers.

Barad, K. (2007). *Meeting the Universe Halfway*. Durham and London: Duke University Press.

Barlow, D.J., Buriani, A., Ehrman, T., Bosisio, E., Eberini, I. and Hylands, P. J. (2012). In-silico studies in Chinese herbal medicines' research: Evaluation of in-silico methodologies and phytochemical data sources, and a review of research to date. *Journal of Ethnopharmacology*, 140 (3). 526–534. doi: 10.1016/j.jep.2012.01.041

Barnes, B. (1981). On the 'Hows' and 'Whys' of Cultural Change (Response to Woolgar). *Social Studies of Science*, 11 (4), 481–498.

Barnes, L.L. (2005). *Needles, Herbs, Gods, and Ghosts: China, Healing, and the West To 1848.* Cambridge, Mass.; London: Harvard University Press.

Barnes, L.L. (2009). Practitioner decisions to engage in Chinese medicine: cultural messages under the skin. *Medical Anthropology*, 28 (2), 141–165.

Bauer, M.W. and Gaskell, G. (2007). *Qualtitative Researching with text, image and sound.* In: Bauer, M.W., and Gaskell, G. (eds.) 6th ed. London, California, New Dehli, Singapore: SAGE Publications Ltd.

Beer, S. (1994). *Designing freedom*. Toronto: House of Anansi Press.

Berthin, M. (2014). Touch future x ROBOT: examining production, consumption, and disability at a social robot research laboratory and a centre for independent living in Japan. doctoral thesis. London School of Economics. London

Bijker, W.E. (1993). Do Not Despair: There Is Life after Constructivism. *Science, Technology & Human Values*, 18 (1), 113–138.

Bijker, W.E., Hughes, T.P. and Pinch, T.J. (1987). *The Social construction of technological systems: new directions in the sociology and history of technology.* Cambridge, Mass: MIT Press.

Bijker, W.E., Hughes, T.P. and Pinch, T.J. (2012). *The social construction of technological systems new directions in the sociology and history of technology.* Bijker, W.E., Hughes, T.P., and Pinch, T. (eds.) Cambridge, Mass: MIT Press.

Biesalski, H. et al. (2009). Bioactive compounds: Safety and efficacy. *European Journal of Pediatrics*, 25, 1206–1211.

Bishop, R. (2017). *Chaos*. In: Zalta, E. N. (ed.) *The Stanford Encyclopedia of Philosophy (Spring 2017 Edition)*. Available from https://plato.stanford.edu/archives/spr2017/entries/chaos/ [Accessed 3 January 2019].

Blaikie, C. (2013). Currents of Tradition in Sowa Rigpa Pharmacy. *East Asian Science, Technology and Society*, 7 (3), 425–451. doi: 10.1215/18752160-2332223

Bodeker, G. (2006). Traditional Medical Knowledge and Twenty-first Century Healthcare: the Interface between Indigenous and Modern Science. In: Sillitoe, P. (ed.) *Local Science Vs Global Science: Approaches to Indigenous Knowledge in International Development*. New York: Berghahn Books.

Boellstorff, T., Nardi, B., Pearce, C. and Taylor, T. L. (2012). *Ethnography and virtual worlds: A handbook of method*. Princeton and Oxford: Princeton University Press.

Booker, A., Johnston, D. and Heinrich, M. (2012). Value chains of herbal medicines—Research needs and key challenges in the context of ethnopharmacology. *Journal of Ethnopharmacology*, 140 (3), 624–633. doi: 10.1016/j.jep.2012.01.039

Bothwell, J.H.F. (2006). The long past of systems biology. *New Phytologist*, 170 (1), 6–10.

Britten, N. (1995). Qualitative interviews in medical research. *BMJ (Clinical research ed.)*, 311 (6999), 251–253.

Bundesministerium für Bildung, Wissenschaft und Forschung (BMBWF). (2018). *Internationale Mobilität Studierende Universitäten Studierendenmobilität nach Kontinenten. Universität Salzburg. Kontinent Asien. Incoming 2000/01*. Vienna: Bundesministerium für Bildung, Wissenschaft und Forschung. Available from https://suasprod.noc-science.at/XLCubedWeb/WebForm/ShowReport.aspx?rep=011+internationale+mobilität/001+universitäten/006+studierendenmobilität+nach+kontinenten+-+incoming.xml&toolbar=true [Accessed 6 January 2019].

Burgess, R. (2013). Supporting 'community' in an era of global mental health: a case study of an HIV-affected South African community. doctoral thesis. London School of Economics. London.

Buriani, A., Garcia-Bermejo, M.L., Bosisio, E., Xu, Q., Li, H., Dong, X., Simmonds, M.SJ., Carrara, M., Tejedor, N., Lucio-Cazana, J. and Hylands, P.J. (2012). Omic techniques in systems biology approaches to traditional Chinese medicine research: Present and future. *Journal of Ethnopharmacology*, 140 (3), 535–544. doi: 10.1016/j.jep.2012.01.055

Callon, M. (1986). Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. *Power, Action and Belief: A New Sociology of Knowledge?*, 196–223. doi: 10.1111/j.1467-954X.1984.tb00113.x

Callon, M. and Law, J. (1982). On Interests and Their Transformation: Enrolment and Counter-Enrolment. *Social Studies of Science*, 12 (4), 615–625.

Calvert, J. (2008). The Commodification of Emergence: Systems Biology, Synthetic Biology and Intellectual Property. *BioSocieties*, 3 (4), 383–398.

Calvert, J. (2013). Systems biology, big science and grand challenges. *Biosocieties*, 8 (4). Nature Publishing Group.

Calvert, J. and Fujimura, J. H. (2011). Calculating life? Duelling discourses in interdisciplinary systems biology. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences*, 42 (2), 155–163. doi: 10.1016/j.shpsc.2010.11.022

Cambridge Dictionary (no date). Quack | definition in the Cambridge English Dictionary. Available from https://dictionary.cambridge.org/us/dictionary/english/quack [Accessed 16 January 2019].

Cao, C., Suttmeier, R.P. and Simon, D.F. (2006). China's 15-year science and technology plan. *Physics Today*, 59 (12), 38–43.

Capra, F. (1975). *The Tao of Physics: An Exploration of the Parallels Between Modern Physics and Eastern Mysticism*. New York: Bantam Books.

Capra, F. (1982). *The turning point: science, society and the rising culture*. New York: Simon and Schuster.

Capra, F. (1996). *The web of life: a new synthesis of mind and matter.* London: Harper Collins.

Cassidy, C.M. (2013). Review of Integrating East Asian Medicine into Contemporary Healthcare. *The Journal of Alternative and Complementary Medicine*, 19 (2), 182–183. doi: 10.1089/acm.2012.0651

Caudill, M. (2000). Foreword. In: Kaptchuk, T., (ed.) *The web that has no weaver: Understanding Chinese Medicine*. London: Rider, xiii–xv.

Chan, K., Shaw, D., Simmonds, M.S.J., Leon, C.J., Xu, Q., Lu, A., Sutherland, I., Ignatova, S., Zhu, Y.-P., Verpoorte, R., Williamson, E.M. and Duez, P. (2012). Good practice in reviewing and publishing studies on herbal medicine, with special emphasis on traditional Chinese medicine and Chinese materia medica. *Journal of Ethnopharmacology*, 140 (3), 469–475. doi: 10.1016/j.jep.2012.01.038

Chee, L.P.Y. and Clancey, G. (2013). The Human Proteome and the Chinese Liver. *Science Technology & Society*, 18 (3), 307–319. doi: 10.1177/0971721813498496

Chen, H. and Cheng, D. (2007). Early Developments of Control Theory in China. *European Journal of Control*, 13, 25–29.

Chen, Z., Wang, H.-G., Wen, Z.-J., & Wang, Y. (2007). Life sciences and biotechnology in China. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *362*(1482), 947–957. doi: 10.1098/rstb.2007.2025

Clancey, G. and Chen, H. (2013). Introduction: Asian Biopoleis--Biomedical Research in “The Asian Century”. *Science Technology & Society*, 18 (3), 267–273. doi: 10.1177/0971721813498490

Collins, H.M. (1995). Science Studies and Machine Intelligence. In: Jasanoff, S., Markle, G.E., Petersen, J.C., et al. (eds.) *Handbook of Science and Technology Studies*. Revised Ed. Thousand Oaks: SAGE Publications, Inc., 286–301. doi: 10.4135/9781412990127.n13

Colquhoun, D. (2012). Complementary medicine courses in universities: how I beat the varsity quacks. *The Telegraph*, 31 December, 1–5.

Coyne, I.T. (1997). Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries? *Journal of Advanced Nursing*, 26 (3), 623–30.

Croizier, R. C. (1968). *Traditional medicine in modern China; science, nationalism, and the tensions of cultural change*. Cambridge, Mass.: Harvard University Press.

Czarniawska-Joerges, B. (1996). Organizing modernity. *Scandinavian Journal of Management*, 12 (2), 216–219. doi: 10.1016/0956-5221(96)90003-2

Debelle, F.D., Vanherweghem, J.L. and Nortier, J.L. (2008). Aristolochic acid nephropathy: A worldwide problem. *Kidney International,* 74 (2), 158–169.

Dobos, G.J., Tan, L., Cohen, M.H., McIntyre, M., Bauer, R., Li, X. and Bensoussan, A. (2005). Are national quality standards for traditional Chinese herbal medicine sufficient? Current governmental regulations for traditional Chinese herbal medicine in certain Western countries and China as the Eastern origin country. *Complementary Therapies in Medicine*, 13 (3), 183–190.

Doing, P. (2008). Give Me a Laboratory and I Will Raise a Discipline: The Past, Present, and Future Politics of Laboratory Studies in STS. In: Hackett, E. J., Amsterdamska, O., Lynch, M. and Wajcman, J. (eds.) *The handbook of science and technology studies.* (3rd ed.). Cambridge, Mass.: MIT Press.

Efferth, T., Banerjee, M., Abu-Darwish, M.S., Abdelfatah, S., Böckers, M., Bhakta-Guha, D., Bolzani, V., Daak, S., Demirezer, Ö.L., Dawood, M., Efferth, M., El-Seedi, H.R., Fischer, N., Greten, H.J., Hamdoun, S., Hong, C., Horneber, M., Kadioglu, O., Khalid, H.E., Khalid, S.A., Kuete, V., Mahmoud, N., Marin, J., Mbaveng, A., Midiwo, J., Nakagawa, H., Naß, J., Ngassapa, O., Ochwang'i, D., Omosa, L.K., Ooko, E.A., Özenver, N., Poornima, P., Romero, M.R., Saeed, M.E.M., Salgueiro, L., Seo, E.-J., Yan, G., Yasin, Z., Saeed, E.M. and Paul, N.W. (2018). Biopiracy versus One-World Medicine–From colonial relicts to global collaborative concepts. *Phytomedicine*. doi: 10.1016/j.phymed.2018.06.007

Embassy of Switzerland in China (ESC). (2014). *Fact Sheet; National Natural Science Foundation of China*. 1-4. Beijing. Available from http://www.nsfc.gov.cn/publish/portal1 [Accessed 17 January 2019].

Erling, J. (2015). Wie Mao einst Franz Josef Strauß entführte (How Mao once kidnapped Franz Josef Strauss). *Welt N24*, 18 1–7. Available from https://www.welt.de/politik/article136090954/Wie-Mao-einst-Franz-Josef-Strauss-entfuehrte.html [Accessed 16 January 2018].

European Commission (EC). (2006). FP7 Cooperation Work Programme: Theme 10-Security Call Fiche. Topics called. 1–6. Available from http://ec.europa.eu/research/participants/portal/doc/call/fp7/fp7-sec-2007-1/29230-k_ct_200701_en.pdf [Accessed 5 January 2019].

European Commission (EC). (2007a). Work Programme 2007-2008 Cooperation Theme 2 Food, Agriculture and Fisheries, and biotechnology. http://ec.europa.eu/research/participants/data/ref/fp7/88207/b_wp_200702_en.pdf [Accessed 12 December 2017].

European Commission (EC). (2007b). *FP7 in Brief*. 32. Available from http://ec.europa.eu/research/fp7/pdf/fp7-inbrief_en.pdf [Accessed 17 January 2019].

European Commission (EC). (2012). GP-TCM Project details. *Reports*. Available from http://cordis.europa.eu/project/rcn/90960_en.html [Accessed 12 December 2017].

European Commission (EC). (n.d.). What is Horizon 2020? Available from https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020 [Accessed 19 January 2019].

European Directorate for the Quality of Medicines & HealthCare (EDQM). (2010). *Annual Report 2010*. Strasbourg. Available from https://www.edqm.eu/sites/default/files/medias/fichiers/EDQM_Annual_Report_2010.pdf [Accessed 5 January 2019].

European Directorate for the Quality of Medicines & HealthCare (EDQM). (2011). *Annual Report 2011*. Strasbourg. Available from https://www.edqm.eu/medias/fichiers/annual_report_2011.pdf [Accessed 5 January 2019].

European Parliament and Council of the European Union (EPCEU). (2006). Decision No 1982/2006/EC Concerning the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007-2013). Decision. *Official Journal of the European Union*. Available from https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32006D1982 [Accessed 6 January 2019].

Evans, R. (1997). *Deng Xiaoping and the making of modern China*. London: Dover Publications.

Fainzang, S. (2010). Anthropology and Biomedicine: A Dangerous liaison? Conditions for a partnership. In: Fainzang, S., Hem, H.E., and Risør, M.B. (eds.) *Taste for Knowledge: Medical Anthropology Facing Medical Realities*. Aarhus: Aarhus University Press, 41–56.

Fairbank, J.K. and Goldman, M. (1998). *China: a new history*. Cambridge, USA.: Harvard University Pres.

Falzon, M.-A. (2009). *Multi-sited ethnography: theory, praxis and locality in Contemporary research*. Surrey, England: Ashgate Publishing Limited.

Farquhar, J. (1994). *Knowing Practice: The Clinical Encounter of Chinese Medicine.* Oxford; Colorado: Westview Press.

Finetti, C. (2011). Traditional knowledge and the patent system: Two worlds apart? *World Patent Information*, 33 (1), 58–66. doi: 10.1016/j.wpi.2010.03.005

Flick, U. (2000). Episodic Interviewing. In: Bauer, M. (ed.) *Qualitative Researching with Text, Image and Sound*. London, England: SAGE Publications Ltd, 76–92.

Flick, U. (2014). *An introduction to qualitative research.* Los Angeles, Sage Publications Ltd.

Flower, A., Witt, C., Liu, J.-P.P., Ulrich-Merzenich, G., Yu, H. and Lewith, G. (2012). Guidelines for randomised controlled trials investigating Chinese herbal medicine. *Journal of Ethnopharmacology*, 140 (3), 550–554. doi: 10.1016/j.jep.2011.12.017

Franklin, S. (1995). Science as Culture, Cultures of Science. *Annual Review of Anthropology*, 24 (1995), 163–184.

Fruehauf, H. (1999). Chinese Medicine in Crisis: Science, Politics and the Making of 'TCM'. *Journal of Chinese Medicine*, 61 (61), 6–14.

Fusch, P.I., Fusch, G.E. and Ness, L.R. (2017). How to Conduct a Mini-Ethnographic Case Study: A Guide for Novice Researchers. *The Qualitative Report*, 22 (3), 923–941.

Gatherer, D. (2010). So what do we really mean when we say that systems biology is holistic? *BMC systems biology*, 4 (22).

Gatt, C. (2009). Multi-Sited Ethnography Theory, Praxis and Locality in Contemporary Research. In: Falzon, M.-A. (ed.) *Multi-Sited Ethnography Theory, Praxis and Locality in Contemporary Research*. London: Taylor and Francis, 103–118.

Geertz, C. (1988). Thick description: toward an interpretive theory of culture. *High Points in Anthropology*, 531–552.

Geertz, C. and Darnton, R. (2017). *The Interpretation of Cultures*. New York: Basic Books.

Gerson, E.M. (1995). John Law, Organizing Modernity. *Social Studies of Science*, 25 (2), 382–388. doi: 10.1177/030631295025002019

Gottweis, H. and Lauss, G. (2012). Biobank governance: heterogeneous modes of ordering and democratization. *Journal of Community Genetics*, 3 (2), 61–72. doi: 10.1007/s12687-011-0070-0

Green, S. (2014). Revisiting Generality in Biology: Systems Biology and the Quest for Design Principles. *Biological Philosophy*, 30 (5), 1–25.

Green, S. and Wolkenhauer, O. (2013). Tracing Organizing Principles: Learning from the History of Systems Biology. *History and Philosophy of the Life Sciences,* 35, 553–576.

Greenhalgh, S. (2008). *Just one child: science and policy in Deng's China.* Berkeley, Calif.: University of California Press.

Gu, S. and Pei, J. (2017). Chinese Herbal Medicine Meets Biological Networks of Complex Diseases: A Computational Perspective. *Evidence-Based Complementary and Alternative Medicine*. 1–7. doi: 10.1155/2017/7198645

Guo, N., Yang, D., Wang, X., Dai, J., Wang, M. and Lei, Y. (2014). Metabonomic study of chronic heart failure and effects of Chinese herbal decoction in rats. *Journal of Chromatography A*, 1362, 89–101. doi: 10.1016/j.chroma.2014.08.028

Guo, R.-J., Ma, B.R., Xie, M. and Chen, W.-L. (1981). 中医计算机诊断治疗系统与模糊数学模型 (Computerized diagnosis system in traditional Chinese medicine and Fuzzy set modelling). *计算机学报 (Journal of Computer studies)*, 4.

Hackett, E., Amsterdamska, O., Lynch, M. and Wajcman, J. (2008). *The handbook of science and technology studies*. Cambridge, Mass; London, England: MIT Press.

Hacking, I. (1992). 'Style' for historians and philosophers. *Studies in History and Philosophy of Science Part A*, 23 (1), 1–20.

Hadolt, B. (1998). Locating difference: A medical anthropology "at home"? *Anthropology & Medicine*, 5 (3), 311–323.

Hadolt, B. and Lengauer, M. (2009). *Genetische Beratung in der Praxis Herausforderungen bei präsymptomatischer Gendiagnostik am Beispiel Österreichs (Genetic counseling in practice Challenges in presymptomatic gene diagnostics using the example of Austria.)*. Frankfurt am Main: Campus-Verl.

Hadolt, B., Hörbst, V. and Müller-Rockstroh, B. (2012). Biomedical Techniques in Context: On the Appropriation of Biomedical Procedures and Artifacts. *Medical Anthropology*, 31 (3), 179–195. doi: 10.1080/01459740.2011.63641

Hammersley, M. (2006). Ethnography: problems and prospects. *Ethnography and Education*, 1 (1), 3–14.

Hammersley, M. and Atkinson, P. (2007). *Ethnography: principles and practice.* New York; Routledge.

Hampshire, K. R. and Owusu, S. A. (2013). Grandfathers, Google, and Dreams: Medical Pluralism, Globalization, and New Healing Encounters in Ghana. *Medical Anthropology: Cross Cultural Studies in Health and Illness*, 32 (3), 247–265. doi: 10.1080/01459740.2012.692740

Hannerz, U. (1998). *Transnational connections: culture, people, places*. London; New York: Routledge.

Hanson, M.E. (2011). *Speaking of Epidemics in Chinese Medicine: Disease and the Geographic Imagination in Late Imperial China*. Abingdon: Routledge.

Hao, D.C. and Xiao, P.G. (2014). Network Pharmacology: A Rosetta Stone for Traditional Chinese Medicine. *Drug Development Research*, 75 (5), 299–312. doi: 10.1002/ddr.21214

Haraway, D.J. (1991). *Simians, cyborgs, and women: the reinvention of nature*. New York: Routledge.

Haraway, D.J. (2016). *Staying with the Trouble*. Durham and London: Duke University Press.

Harbers, H. (2005). Book Review: Putting Science in Its Place: Geographies of Scientific Knowledge; The Body Multiple: Ontology in Medical Practice. *Science, Technology & Human Values*, *30* (4), 575–582. doi: 10.1177/0162243905279462

Hare, M.L. (1993). The Emergence of an Urban U.S. Chinese Medicine. *Medical Anthropology Quarterly*, *7* (1), 30–49. doi: 10.1525/maq.1993.7.1.02a00030

Hayles, N.K. (1999). *How we became posthuman: virtual bodies in cybernetics, literature, and informatics*. Chicago, Ill.: University of Chicago Press.

He, F.C. (2006). Proteomics in China. *Proteomics*, 6, 397–403.

He, F.C. (2011). At a glance: Proteomics in China. *Science China Life Sciences*, 54 (1), 1–2.

Hedgecoe, A.M. and Martin, P.A. (2008). Genomics, STS, and the Making of Sociotechnical Futures. In: Hackett, E. J., Amsterdamska, O., Lynch, M. and Wajcman, J. (eds.) *The handbook of science and technology studies*. (3rd ed.). Cambridge, Mass; London, England: MIT Press.

Hein, W., O'Donohoe, S. and Ryan, A. (2011). Mobile phones as an extension of the participant observer's self. Prince, M. (ed.) *Qualitative Market Research: An International Journal*, 14 (3), 258–273. doi: 10.1108/13522751111137497

Heinrich, M., Ankli, A., Frei, B., Weimann, C. and Sticher, O. (1998). Medicinal plants in Mexico: Healers' consensus and cultural importance. *Social Science and Medicine*, 47 (11), 1859–1871.

Helfferich, C. (2005). *Die Qualität qualitativer Daten: Manual für die Durchführung qualitativer Interviews (The quality of qualitative data: Manual for conducting qualitative interviews)*. Wiesbaden: VS Verlag für Sozialwissenschaften.

Helman, C. G. (2007). *Culture, Health and Illness.* London: London Hodder Arnold.

Hess, D. J. (1998). If You're Thinking of Living in STS... A Guide for the Perplexed. In: Downey, G. and Dumit, J. (eds.) *Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies*. Santa Fe: SAR Press.

Hess, D., Breyman, S., Campbell, N. and Martin, B. (2008). Science, technology, and social movements. In: Hackett, E., Amsterdamska, O., Lynch, M., et al. (eds.) *The handbook of science and technology studies*., 3rd ed. Cambridge, Mass; London, England: MIT Press, 473–498.

Heylighen, F. and Joslyn, C. (2001). Cybernetics and Second-Order Cybernetics. In: Meyers, R.A. (ed.) *Encyclopedia of Physical Science & Technology*. New York: Academic Press.

Hinrichs, T. J. (1998). New geographies of Chinese medicine. *Osiris*, *13*, 287–325.

Hood, L. (2003). Systems biology: integrating technology, biology, and computation. *Mechanisms of Ageing and Development*, 124 (1), 9–16.

Hsu, E. (1996). Innovations in acumoxa: Acupuncture analgesia, scalp and ear acupuncture in the People's Republic of China. *Social Science and Medicine*, 42 (3), 421–430. doi: 10.1016/0277-9536(95)00106-9

Hsu, E. (1999). *The transmission of Chinese medicine*. Cambridge; New York: Cambridge University Press.

Hsu, E. (2006). The history of *qing hao* in the Chinese materia medica. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 100 (6), 505–508.

Hsu, E. (2008). The History of Chinese Medicine in the People's Republic of China and its Globalization. *East Asian Science, Technology and Society: an International Journal*, 2 (4), 465–484.

Hsu, E. (2009). Chinese Propriety Medicines: An “Alternative Modernity?” The Case of the Anti-Malarial Substance Artemisinin in East Africa. *Medical Anthropology*, 28 (2), 111–140. doi: 10.1080/01459740902848303

Hu, C. (2012). Systems Biology for Evaluating System-based Medicine. doctoral thesis. University Leiden. Leiden.

Huang, Q., Yin, P., Wang, J., Chen, J., Kong, H., Lu, X. and Xu, G. (2011). Method for liver tissue metabolic profiling study and its application in type 2 diabetic rats based on ultra performance liquid chromatography–mass spectrometry. *Journal of Chromatography,* 879 (13–14), 961–967. doi: 10.1016/j.jchromb.2011.03.009

Huang, T.黄廷翼．(1962). 从經絡針灸上看中医辨証論治的整体观念 (Viewing the overall concept of TCM syndrome differentiation and treatment from meridian acupuncture). *福建中医药 (Fujian Traditional Chinese Medicine)*, 1, 13–15.

Ideker, T., Galitski, T. and Hood, L. (2001). A new approach to decoding life: Systems Biology. *Annual Review of Genomics and Human Genetics,* 2, 343–372.

Ilgauds, H.J. (1984). *Norbert Wiener.* In: Müller, H. (ed.) Wiesbaden: Vieweg+Teubner Verlag.

Jaros, G. (2002). Holism revisited: Its principles 75 years on. *World Futures: The Journal of General Evolution*, 58, 13–32.

Jenkins, H., Hardy, N., Beckmann, M., Draper, J., Smith, A.R., Taylor, J., Fiehn, O., Goodacre, R., Bino, R.J., Hall, R., Kopka, J., Lane, G.A., Lange, B.M., Liu, J.R., Mendes, P., Nikolau, B.J., Oliver, S.G., Paton, N.W., Rhee, S., Roessner-Tunali, U., Saito, K., Smedsgaard, J., Sumner, L.W., Wang, T., Walsh, S., Wurtele, E.S. and Kell, D.B. (2004). A proposed framework for the description of plant metabolomics experiments and their results. *Nature Biotechnology*, 22 (12), 1601–1606.

Jia, J., Yu, Y., Deng, J.H., Robinson, N., Bovey, M., Cui, Y.-H., Liu, H.-R., Ding, W., Wu, H.-G. and Wang, X.-M. (2012). A review of Omics research in acupuncture: The relevance and future prospects for understanding the nature of meridians and acupoints. *Journal of Ethnopharmacology*, 140 (3), 594–603. doi: 10.1016/j.jep.2012.01.034

Jia, Q. (2005). Traditional Chinese Medicine Could Make "Health for One" True. *Commissioned study of the Commission on Intellectual Property Rights, Innovation and Public Health (CIPIH)*. Available at: http://www.who.int/intellectualproperty/studies/Jia.pdf. [Accessed 13 January 2019].

Jiang, M., Lu, C., Zhang, C., Yang, J., Tan, Y., Lu, A. and Chan, K. (2012). Syndrome differentiation in modern research of traditional Chinese medicine. *Journal of Ethnopharmacology*, 140 (3). doi: 10.1016/j.jep.2012.01.033.

Jiang, W.-Y. (2005). Therapeutic wisdom in traditional Chinese medicine: A perspective from modern science. *Trends in Pharmacological Sciences*, 26 (11), 558–563.

John Hopkins School of Medicine. (2018). What is Phenotyping? *The Department of Molecular and Comparative Pathobiology*. Available from http://mcp.bs.jhmi.edu/what-phenotyping-0 [Accessed 10 September 2018].

Jolibert, C. (2012). Governance of Biodiversity: Bringing together society, policy and science Four studies. doctoral thesis. University of Barcelona. Barcelona.

Kaimal, V., Sardana, D., Bardes, E.E., Gudivada, R.C., Chen, J. and Jegga, A.G. (2011). Integrative Systems Biology Approaches to Identify and Prioritize Disease and Drug Candidate Genes. *Methods in molecular biology (Clifton, N.J.)*, 241–259. doi: 10.1007/978-1-61737-954-3_16

Kaptchuk, T. J. (2000). *The web that has no weaver: understanding Chinese medicine*. London: Rider.

Karchmer, E. I. (2010). Chinese medicine in action: on the postcoloniality of medical practice in China. *Medical Anthropology*, 29 (3), 226–252. doi: 10.1080/01459740.2010.488665

Keith, W. and Rehg, W. (2008). Argumentation in Science: The Cross-Fertilization of Argumentation Theory and Science Studies. In: Hackett, E.J., Amsterdamska, O., Lynch, M., et al. (eds.) *The Handbook of Science and Technology Studies.* 3rd ed. Cambridge, Mass; London, England: MIT Press.

Keshet, Y. and Popper-Giveon, A. (2013). Integrative Health Care in Israel and Traditional Arab Herbal Medicine: When Health Care Interfaces with Culture and Politics. *Medical Anthropology Quarterly*, 27 (3), 368–384.

Kiely, J., Goossaert, V. and Lagerwey, J. (2015). *Modern Chinese Religion II: 1850 - 2015 (2 vols)*. Leiden: Brill.

Kilshaw, S. (2018). Qatari intersections with global genetics research and discourse. *Anthropology and Medicine*, 25 (1), 50–67.

Kim, J. (2009). Transcultural medicine: a multi-sited ethnography on the scientific-industrial networking of Korean medicine. *Medical Anthropology*, 28 (1), 31–64. doi: 10.1080/01459740802640909

Kitano, H. (2002). Systems Biology: A Brief Overview. *Science*, 295, 1662–1664.

Kleinman, A. (1980). *Patients and Healers in the Context of Culture: An Exploration of the Borderland Between Anthropology, Medicine, and Psychiatry*. Berkeley: University of California Press.

Kloos, S. (2008). The History and Development of Tibetan Medicine in Exile. *The Tibet Journal*, 33, 15–49.

Kloos, S. (2013). How Tibetan Medicine in Exile Became a ‘Medical System’. *East Asian Science, Technology and Society*, 7 (3), 381–395. doi: 10.1215/18752160-2333653

Kloos, S. (2017). The Politics of Preservation and Loss: Tibetan Medical Knowledge in Exile. *East Asian Science, Technology and Society*, 11 (2), 135–159.

Knorr-Cetina, K. (1981). The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science. Oxford [etc]: Pergamon Press.

Knorr Cetina, K. (1983). New developments in science studies: The ethnographic challenge. *Canadian Journal of Sociology*, 8 (2), 153–177. doi: 10.2307/3340124

Knorr Cetina, K. (1995). Laboratory Studies: The Cultural Approach to the Study of Science. In: Jasanoff, S., Markle, G.E., Petersen, J.C., et al. (eds.) *Handbook of Science and Technology Studies*. Thousand Oaks: SAGE Publications. 140–166.

Kuriyama, S. (1999). *The expressiveness of the body and the divergence of Greek and Chinese medicine*. New York: Zone Books.

Kvale, S. (2006). Dominance Through Interviews and Dialogues. *Qualitative Inquiry*, 12 (3), 480–500.

Langwick, S. (2011). *Bodies, Politics, and African Healing. The Matter of Maladies in Tanzania*. Bloomington: Indiana University Press.

Latour, B. (1987). *Science in action: how to follow scientists and engineers through society*. Cambridge Mass.: Harvard University Press.

Latour, B. (1993). *We Have Never Been Modern*. No{û}s (Vol. 12). Cambridge Mass.: Harvard University Press. doi: 10.1016/0956-5221(96)88504-6

Latour, B. (1999). *Pandora's hope: essays on the reality of science studies*. Cambridge, Mass.; London: Harvard University Press.

Latour, B. (2011). Drawing Things Together. In: Dodge, M. (ed.) *The Map Reader*. Chichester, UK: John Wiley & Sons, 65–72. doi: 10.1002/9780470979587.ch9

Latour, B. (2013). Is there an ANT at the beginning of ANThropology? A few responses to the subject matter of the collection. *Social Anthropology*, 21 (4), 560–563.

Latour, B. and Woolgar, S. (1986). *Laboratory Life*. *The effects of brief mindfulness intervention on acute pain experience: An examination of individual difference*. New Jersey: Princeton University Press.

Law, J. (1992). Notes on the theory of the actor-network: Ordering, strategy, and heterogeneity. *Systems Practice*, 5 (4), 379–393. doi: 10.1007/BF01059830

Law, J. (1994). *Organizing Modernity: Social Ordering and Social Theory.* Oxford, UK; Cambridge, USA: Wiley-Blackwell.

Law, J. (1997). *Heterogeneities.* Lancaster, UK: Centre for Science Studies, Lancaster University. Available from http://www.comp.lancs.ac.uk/sociology/papers/Law-Heterogeneities.pdf [Accessed 18 May 2017].

Law, J. (1999). After ANT: Complexity, Naming and Topology. *The Sociological Review*, 46, 1–14.

Law, J. (2004). *After Method: Mess in Social Science Research*. London; New York: Routledge.

Law, J. (2007). *Actor Network Theory and Material Semiotics*. version of 25th April 2007. Available from http://www.heterogeneities.net/publications/Law2007ANTandMaterialSemiotics.pdf [Accessed 18 May 2017].

Law, J. (2012). Notes on fish, ponds and theory. *Norsk Antropologisk Tidsskrift*, 23 (3–4), 225–236.

Law, J. and Mol, A. (2002). *Complexities: social studies of knowledge practices*. Durham: Duke University Press.

Lawrence, C. and Weisz, G. (1998). *Greater than the parts: holism in biomedicine, 1920-1950*. New York: Oxford University Press.

LeCompte, M.D. and Goetz, J.P. (1982). Problems of Reliability and Validity in Ethnographic Research. *Review of Educational Research*, 52 (1), 31–60.

Lei, S.H. (1999). From Changshan to a New Anti-Malarial Drug: Re-Networking Chinese Drugs and Excluding Chinese Doctors. *Social Studies of Science,* 29 (3), 323–358.

Lei, S.H. (2014). *Neither Donkey Nor Horse: Medicine in the Struggle Over China's Modernity*. Chicago, London: University of Chicago Press.

Leslie, C. M. (1976). *Asian Medical Systems: A Comparative Study*. In: C. M. Leslie, (ed.) Berkeley: University of California Press.

Leslie, C. M. (1992). *Paths to Asian Medical Knowledge*. Berkeley: University of California Press.

Leung, P.-C. and Xue, C. C. (2005). *Chinese medicine modern practice*. Hackensack, NJ: World Scientific Pub.

Leung, P.-C., Fong, H. and Xue, C.C. (2006). Current Review of Chinese Medicine: Quality Control of Herbs and Herbal Material. In: Leung, P.-C., Fong, H. and Xue, C. C. (eds.) *Medicine*. Singapore: World Scientific Pub.

Levine, T.B.-Y. (2012). *Gestalt therapy: advances in theory and practice*. New York: Routledge.

Li, P., Yang, L. and Gong, Y. (2009). Application of Systems Biology Technology in Research of Traditional Chinese Medicine. *Journal Traditional Chinese Medicine*, 29 (2), 153–157.

Li, Q. and Su, S. (2008). Application of Systems Biology in Traditional Chinese Medicine Research. *Modernisation of Traditional Chinese Medicine and Materia Medica,* 10 (4), 1–6.

Litscher, G. (2012). *High-Tech-Akupunktur computergestützte Objektivierungs-techniken der Akupunktur (High-tech acupuncture computerized objectification techniques of acupuncture)*. Lengerich [etc.]: Pabst Science Publ.

Liu, S.-H. and Cheng, Y.-C. (2012). Old formula, new Rx: The journey of PHY906 as cancer adjuvant therapy. *Journal of Ethnopharmacology*, 140 (3), 614–623. doi: 10.1016/j.jep.2012.01.047

Lock, M. (2015). Comprehending the Body in the Era of the Epigenome. *Current Anthropology*, 56 (2), 151–177. doi: 10.1086/680350

Lou, L.I.T. (2016). Beyond Miracles: How Traditional Chinese Medicine Establishes Professional Legitimacy in Post-colonial Macau. Available from http://somatosphere.net/?p=13214 [Accessed 9 December 2016].

Lu, A., Bian, Z. and Chen, K. (2012). Bridging the traditional Chinese medicine pattern classification and biomedical disease diagnosis with systems biology. *Chinese Journal of Integrative Medicine*, 18 (12), 883–890. doi: 10.1007/s11655-012-1290-6

Lü, B. 吕炳奎. (1981). 同志在中医理论整理研究讨论会上的讲话 (Comrade Lu Bingkui's speech at the seminar on the research and discussion of TCM theory). *河北中医 (Hebei Journal of Traditional Chinese Medicine).*

Lu, G., Wang, J., Zhao, X., Kong, H. and Xu, G. (2006). Study on Gender Difference Based on Metabolites in Urine by Ultra High Performance Liquid Chromatography/Time of Flight Mass Spectrometry. *Chinese Journal of Chromatography*, 24 (2), 109–113. doi: 10.1016/S1872-2059(06)60005-9

Luo, G., Wang, Y., Liang, Q. and Liu, Q. (2012a). *Systems Biology for Traditional Chinese Medicine*. Hoboken, NJ: John Wiley & Sons.

Luo, H., Li, Q., Flower, A., Lewith, G. and Liu, J. (2012b). Comparison of effectiveness and safety between granules and decoction of Chinese herbal medicine: A systematic review of randomized clinical trials. *Journal of Ethnopharmacology*, 140 (3), 555–567. doi: 10.1016/j.jep.2012.01.031

Lynch, Michael. (1993). *Scientific Practice and Ordinary Action: Ethnomethodology and Social Studies of Science*. Cambridge: Cambridge University Press.

Ma, B. 马伯英. (2010). *中国医学文化史 (A history of medicine in Chinese culture).* 上海: 上海人民出版社 (Shanghai: Shanghai Peoples Publishing House).

MacPhail, T. (2009). The 'problem' of Science in China. *East Asian Science, Technology and Society*, 3 (1), 27–50.

Manderson, L., Hardon, A. and Cartwright, E. (2016). *The Routledge handbook of medical anthropology*. In: Manderson, L., Cartwright, E. and Hardon, A. (eds.) New York, NY: Routledge, Taylor & Francis Group.

Marcus, G.E. (1995). Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. *Annual Review of Anthropology*, *24*, 95–117.

Marcus, G.E. and Fischer, M.M.J. (2004). *Anthropology as cultural critique: an experimental moment in the human sciences*. Chicago: The University of Chicago Press.

Martini, A., Massa, S. and Testa, S. (2013). The firm, the platform and the customer: A 'double mangle' interpretation of social media for innovation. *Information and Organization*, 23 (3), 198–213.

Masani, P.R. (1990). *Norbert Wiener, 1894-1964*. Basel: Birkhäuser.

McKay, A. (2010). Biomedicine in Tibet at the Edge of Modernity. In: Adams, V., Schrempf, M. and Craig, S.R. (eds.) *Medicine between science and religion: explorations on Tibetan grounds*. New York: Berghahn.

McMillen, H. (2004). The adapting healer: pioneering through shifting epidemiological and sociocultural landscapes. *Social Science & Medicine*, 59 (5), 889–902. doi: 10.1016/j.socscimed.2003.12.008

Medicine Evaluation Board. (2012). *Diao Xin Xue Kang, capsules for oral use SU BioMedicine B.V., The Netherlands BioMedicine B.V., The Netherlands*. 13. Netherlands. Available from https://db.cbg-meb.nl/Pars/h102142.pdf [Accessed 17 January 2019].

Michaels, P.A. (2006). Review: Chinese Medicine in Early Communist China, 1945–1963: A Medicine of Revolution. *Social History of Medicine*, 19 (2), 338–340. doi: 10.1093/shm/hkl010

Mol, A. (2002). *The body multiple: Ontology in medical practice*. Durham: Duke University Press.

Mol, A. (2010). Actor-network theory: sensitive terms and enduring tensions. *Kölner Zeitschrift für Soziologie Und Sozialpsychologie.* Sonderheft, 50, 253–269.

Moser, I. (2005). On Becoming disabled and articulating alternatives. *Cultural Studies*, 19 (6), 667–700. doi: 10.1080/09502380500365648.

Müller-Wille, S., Powell, A., O'Malley, M., Calvert, J. and Dupré, J. (2007). Disciplinary baptisms: A comparison of the naming stories of genetics, molecular biology, genomics and systems biology. *History and Philosophy of the Life Sciences*, 29 (1), 5–32.

Nappi, C. (2009). *The monkey and the inkpot: natural history and its transformations in early modern China*. Cambridge Mass.: Harvard University Press.

National Center for Complementary and Integrative Health (NCCIH). (2018). Complementary, Alternative, or Integrative Health. *What's in a name*. Available from https://nccih.nih.gov/health/integrative-health [Accessed 20 January 2019].

National Natural Science Foundation China. (2016). *National Natural Science Fund: Guide to Programs*. Available from http://www.nsfc.gov.cn/english/site_1/pdf/NationalNaturalScienceFundGuidetoPrograms2016.pdf [Accessed 19 January 2019].

Nersessian, N.J. (2017). Philosophy of Systems Biology. In: Green, S. (ed.) *Philosophy of Systems Biology: Perspectives from Scientists and Philosophers*. Cham: Springer International Publishing. doi: 10.1007/978-3-319-47000-9

Nichter, M. and Lock, M. (2002). *New Horizons in Medical Anthropology*. Abingdon, UK: Taylor & Francis. doi: 10.4324/9780203398517

Noble, D. (2006). *The Music of Life: Biology Beyond the Genome*. Oxford: Oxford University Press.

Noble, D. (2010). Biophysics and systems biology. Philosophical Transactions of the Royal Society A: *Mathematical, Physical and Engineering Sciences*, 368, 1125–1139.

Noordenbos, B. (2008). Copy-writing Post-Soviet Russia. *Dutch contributions to the fourteenth International Congress of Slavists*, Ohrid, September 10-16, 2008. Amsterdam, Rodopi. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=257403 [Accessed 17 January 2019].

Orhan, I.E. (2014). Pharmacognosy: Science of natural products in drug discovery. *BioImpacts*, 4 (3), 109–110. doi: 10.15171/bi.2014.001

Ouedraogo, M., Baudoux, T., Stévigny, C., Nortier, J., Colet, J.M., Efferth, T., Qu, F., Zhou, J., Chan, K., Shaw, D., Pelkonen, O. and Duez, P. (2012). Review of current and "omics" methods for assessing the toxicity (genotoxicity, teratogenicity and nephrotoxicity) of herbal medicines and mushrooms. *Journal of Ethnopharmacology*, 140 (3), 492–512. doi: 10.1016/j.jep.2012.01.059

Ownby, D. (2013). Invented Qigong. In: Hinrichs, T. and Barnes, L.L. (eds.) *Chinese medicine and healing: an illustrated history*. Cambridge (Mass.); London (Engl.): Harvard University Press.

Pálsson, G. and Rabinow, P. (2015). Iceland: The Case of a National Human Genome Project. *Royal Anthropological Institute of Great Britain and Ireland*, 15 (5), 14–18.

Passoth, J. H. and Rowland, N. J. (2013). Beware of Allies! Notes on Analytical Hygiene in Actor-Network Account-making. *Qualitative Sociology*, 36 (4), 465–483.

Pelkonen, O., Pasanen, M., Lindon, J.C., Chan, K., Zhao, L., Deal, G., Xu, Q. and Fan, T.P. (2012). Omics and its potential impact on R&D and regulation of complex herbal products. *Journal of Ethnopharmacology*, 140 (3), 587–593. doi: 10.1016/j.jep.2012.01.035

Peng, Y. 彭永东. (2004). 控制论思想在中国的 早期传播 (1929-1966 年) (The Early Diffusion of Cybernetics in China (1929-1966)). *自然科学史研究 (Studies in the History of Natural Sciences)*, 23 (4), 299–318.

Phytomedicine. (2015). *ScienceDirect.com*. Available from https://www.sciencedirect.com/journal/phytomedicine?aims-and-scope=true [Accessed 27 December 2018].

Pickering, A. (1995). *The mangle of practice: time, agency, and science*. Chicago: University of Chicago Press.

Pickering, A. (2009). Cybernetics. In: Olsen, J.K.B. (ed.) *A Companion to the Philosophy of Technology*. Oxford, UK: Wiley-Blackwell, 118–122.

Pickering, A. (2010). *The Cybernetic Brain: Sketches of Another Future*. Chicago: University of Chicago Press.

Pordié, L. (2012). Branding Indian Aromatherapy. Differentiation through transnational networks. In: Scheid, V. and MacPherson H. (eds.) *Integrating East Asian Medicine into Contemporary Healthcare,* 93–103.

Pordié, L. (2014). Pervious Drugs. *Asian Medicine*, 9 (1–2), 49–76. doi: 10.1163/15734218-12341292

Pordié, L. and Gaudilliere, J.-P. (2014). The Reformulation Regime in Drug Discovery: Revisiting Polyherbals and Property Rights in the Ayurvedic Industry. *East Asian Science, Technology and Society*, 8 (1), 57–79. doi: 10.1215/18752160-2406053

Porkert, M. (1982). *The theoretical foundations of Chinese medicine: systems of correspondence*. Cambridge (Mass.): The MIT Press.

Potrata, B. (2005). ‘She did, he said’: The use of ethnography in CAM research. *Complementary Therapies in Medicine*, 13 (2), 131–138.

PubMed. (2019). PubMed result on ‘Science’ and ‘Chinese medicine’. *PubMed - NCBI*. Available from https://www.ncbi.nlm.nih.gov/pubmed/details?querykey=3 [Accessed 4 January 2019].

Qian, X. 钱学森. and Dai, R. 戴汝为. (2007). 论信息空间的大成智慧 (Emergence of metasynthetic wisdom in cyberspace). *上海: 交通大学组编 (Shanghai: Jiaotong University Group).*

Qin, B. 秦伯未. (1955). 中医理论中的阴阳观点 (Yin and Yang views in TCM Theory). *上海市立十一人民医院 (Shanghai Eleventh People's Hospital).*

Qin, B. 秦伯未. (1964). 总桔中医疗效的我见 (Summary of my experience with Chinese medical effects). *广东医学(祖国医学版) [Guangdong Medicine (Mother's Medical Edition)]*, 6, 1–4.

Qiu, R. 邱仁宗. (1982). Philosophy of medicine in China (1930-1980). *Metamedicine*, 3, 35–73. doi: 10.1017/CBO9781107415324.004

Qiu, R. 邱仁宗. (1987). 精神病行为控制和传理学 (Mental disorder behavioral control and communication). *医学与哲学 (Medicine and Philosophy)*, (3), 20–21.

Ratain, MJ. and Plunkett, WK. Jr. (2003). Principles of Pharmacokinetics. In: Kufe, DW., Pollock, RE., Weichselbaum, RR., et al. (eds.) *Holland-Frei Cancer Medicine.* Hamilton (ON): BC Decker.

Ren, Y. 任應秋. (1956). 祖国医学的阴阳认识论 (The Yin and Yang Epistemology of the Motherland Medicine). *江西中医药 (Jiangsu Traditional Chinese medicine)*, 3, 1–10.

Robinson, N., Lorenc, A., Ding, W., Jia, J., Bovey, M. and Wang, X.M. (2012). Exploring practice characteristics and research priorities of practitioners of traditional acupuncture in China and the EU—A survey. *Journal of Ethnopharmacology,* 140 (3), 604–613. doi: 10.1016/j.jep.2012.01.052

Rogaski, R. (2004). *Hygienic modernity: meanings of health and disease in treaty-port China (Asia-Local)*. Berkeley: University of California Press.

Sayes, E. (2014). Actor-Network Theory and methodology: Just what does it mean to say that nonhumans have agency? *Social Studies of Science*, 44 (1), 134–149. doi: 10.1177/0306312713511867

Scheid, V. (1999). The Globalisation of Chinese medicine. *The Lancet*, 354, 10–11. doi: 10.1002/tie

Scheid, V. (2002a). *Chinese medicine in contemporary China: plurality and synthesis*. Durham NC: Duke University Press.

Scheid, V. (2002b). Remodeling the Arsenal of Chinese Medicine: Shared Pasts, Alternative Futures. *The ANNALS of the American Academy of Political and Social Science*, 583 (136), 0–17.

Scheid, V. (2007). *Currents of tradition in Chinese medicine, 1626-2006*. Seattle: Eastland Press.

Scheid, V. (2013). The people's republic of China. In: Hinrichs, T. and Barnes L. L. (eds.) *Chinese medicine and healing: An illustrated history*. Cambridge: Harvard University Press.

Scheid, V. (2014). Convergent Lines of Descent: Symptoms, Patterns, Constellations, and the Emergent Interface of Systems Biology and Chinese Medicine. *East Asian Science, Technology and Society*, 8 (1), 107–139.

Scheid, V. (2016). Holism, Chinese Medicine and Systems Ideologies: Rewriting the Past to Imagine the Future. In: Whitehead, A., and Woods, A. (eds.) *The Edinburgh Companion to the Critical Medical Humanities*. Edinburgh (UK): Edinburgh University Press.

Scheid, V. and Karchmer, E. I. (2016). History of Chinese Medicine, 1890-2010. In: Goossaert, V., Kiely, J., Lagerwey, J., and Faure, D. (eds.) *Modern Chinese Religion II: 1850-2015,* (Vol. 1, pp. 141–194). Leiden, Boston: Brill.

Scheid, V. and Lei, S. X. (2014). The Institutionalisation of Chinese Medicine. In: Bullock, M. B. and Andrews, B. J. (eds.) *Medical transitions in twentieth-century China*. Bloomington, IN: Indiana University Press.

Scheid, V. and MacPherson, H. (2012). *Integrating East Asian medicine into contemporary healthcare.* In: Volker, S. and MacPherson, H. (eds.) Edinburgh; New York: Churchill Livingstone Elsevier.

Scheper-Hughes, N. and Lock, M.M. (1987). The mindful body: a prolegomenon to future work in medical anthropology. *Medical anthropology quarterly: international journal for the cultural and social analysis of health*, 1, 6–41.

Schmerz: Therapieaussicht kann bereits helfen. (2005). *Der Standard Online*. 14 November 2005. Available from https://derstandard.at/2239151/Schmerz-Therapieaussicht-kann-bereits-helfen [Accessed 2 August 2018].

Schrempf, M. (2015). Contested Issues of Efficacy and Safety between Transnational Formulation Regimes of Tibetan Medicines in China and Europe. *Asian Medicine*, 10 (1–2), 273–315. doi: 10.1163/15734218-12341360

Schroën, Y., van Wietmarschen, H.A., Wang, M., van Wijk, E., Hankemeier, T., Xu, G. and van der Greef, J. (2014). The Art and Science of Traditional Medicine Part 1: TCM Today — A Case for Integration. *Science*, 346 (6216), 1569. doi: 10.1126/science.346.6216.1569-d

Seising, R. (2010). Cybernetics, system(s) theory, information theory and Fuzzy Sets and Systems in the 1950s and 1960s. *Information Sciences*, 180 (23), 4459–4476. doi: 10.1016/j.ins.2010.08.001.

Shannon, C.E. and Weaver, W. (1949). *The mathematical theory of communication*. Urbana: University of Illinois Press.

Shao, J. (2011). Minkan in China: 1949-89. doctoral thesis. University of Westminster. London.

Shaw, D., Graeme, L., Pierre, D., Elizabeth, W. and Kelvin, C. (2012). Pharmacovigilance of herbal medicine. *Journal of Ethnopharmacology*, 140 (3), 513–518. doi: 10.1016/j.jep.2012.01.051

Shen, Z. 沈自尹. (2005). 系统生物和中医的研究 (Research on Systems Biology and Chinese Medicine Patterns). *中国中医结合杂志 (Chinese Journal of Integrated Chinese and Western Medicine),* 5 (5), 55–58.

Sheridan, H., Krenn, L., Jiang, R., Sutherland, I., Ignatova, S., Marmann, A., Liang, X. and Sendker, J. (2012). The potential of metabolic fingerprinting as a tool for the modernisation of TCM preparations. *Journal of Ethnopharmacology*, 140 (3), 482–491. doi: 10.1016/j.jep.2012.01.050

Sieder, R. (2008). Erzählungen analysieren - Analysen erzählen: Narrativ-biographisches Interview, Textanalyse und Falldarstellung (Narrate analysis: narrative-biographical interview, text analysis and case presentation). In: Wernhart, K.R. and Zips, W. (eds.) *Ethnohistorie: Rekonstruktion und Kulturkritik; eine Einführung (Ethno-history: reconstruction and cultural criticism; An introduction).* Wien: Promedia.

Sino-European Conference. (2007). International Co-operation and Perspective in Science and Technology. Sino-European Conference *on Traditional Chinese medicine (TCM).* Rome: China Academy of Chinese Medical Sciences, Italian National Institute of Health (ISS). Available from http://www.iss.it/binary/pres/cont/Sino-europeanconference2007.1181815166.pdf [Accessed 12 December 2017].

Sismondo, S. (2004). *An introduction to Science and Technology Studies.* Malden, MA: Blackwell Publishing Ltd.

Sivin, N. (1987). Traditional medicine in contemporary China. Ann Arbor, Mich.: Center for Chinese Studies, University of Michigan.

Sleeboom-Faulkner, M. (2013). Latent science collaboration: Strategies of bioethical capacity building in Mainland China's stem cell world. *Biosocieties*, 8 (1), 7–24. doi: 10.1057/biosoc.2012.32

Smith, S. and Ward, V. (2015). The role of boundary maintenance and blurring in a UK collaborative research project: How researchers and health service managers made sense of new ways of working. *Social Science & Medicine*, 130, 225–233.

Smuts, J.C. (1926). *Holism and Evolution*. London: Macmillan & Co.

Springer, L. (2015). Collectors, Producers, and Circulators of Tibetan and Chinese Medicines in Sichuan Province. *Asian Medicine*, 10 (1–2), 177–220.

Star, S.L. and Griesemer, J.R. (1989). Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, 19 (3), 387–420.

Stollberg, G., Pritzker, S., Ahmad, L., Zhan, M., Kaptchuk, T.J. and Barnes, L.L. (2009). A World of Chinese Medicine and Healing: Part One. In: Hinrichs, T., and Barnes, L.L. (eds.) *Chinese medicine and healing: An illustrated history*. Cambridge: Harvard University Press.

Strange, K. (2005). The end of "naive reductionism": rise of systems biology or renaissance of physiology? *American journal of physiology. Cell physiology*, 288 (5), C968–C974. doi: 10.1152/ajpcell.00598.2004

Strathern, M. (1995). *The Relation: Issues in Complexity and Scale*. Cambridge, U.K.: Prickly Pear Press.

Sunder Rajan, K. (2002). Biocapital: The constitution of postgenomic life. doctoral thesis. Massachusetts Institute of Technology. Massachusetts.

Taylor, K. (2004). Divergent interests and cultivated misunderstandings: The influence of the West on modern Chinese medicine. *Social History of Medicine*, 17 (1), 93–111.

Taylor, K. (2005). *Chinese medicine in early communist China, 1945-63: a medicine of revolution.* London; New York: Routledge Curzon.

Tejedor Garcia, N., Garcia Bermejo, L., Fernandez Martinez, A.B., Olmos Centenera, G., Kumari, R., Xu, Q., Cheng, X., Watson, S. and Lucio Cazaña, F.J. (2012). MEDLINE-based assessment of animal studies on Chinese herbal medicine. *Journal of Ethnopharmacology*, 140 (3), 545–549. doi: 10.1016/j.jep.2012.02.008

Tewari, D., Mocan, A., Parvanov, E.D., Sah, A.N., Nabavi, S.M., Huminiecki, L., Ma, Z.F., Lee, Y.Y., Horbańczuk, J.O. and Atanasov, A.G. (2017). Ethnopharmacological Approaches for Therapy of Jaundice: Part I. *Frontiers in Pharmacology*, 8, 1–18. doi: 10.3389/fphar.2017.00518

Timmermans, S. and Berg, M. (1997). Standardization in Action: Achieving Local Universality through Medical Protocols. *Social Studies of Science*, 27 (2), 273–305. doi: 10.1177/030631297027002003

Tong, L. (2009). Shifted Research Approach for New Drug Discovery. *Archives of Medical Research*, 40 (1), 62–63.

Tonietti, T.M. (2003). Determinism, Holism, and Complexity. In: Benci, V., Cerrai, P., Freguglia, P., et al. (eds.) *Determinism, holism, and complexity*. Boston, MA: Springer US.

Twycross, A. (2007). Children's nurses' post-operative pain management practices: An observational study. *International Journal of Nursing Studies*, 44 (6), 869–881.

Uehleke, B. (2007). Naturheilverfahren und „Traditionelle Europäische Medizin" TEM: Ergebnisse einer Experten-Umfrage (Delphi-Methode) [Naturopathic and Traditional European Medicine TEM: Results of an Expert Survey (Delphi Method)]. *Schweizer Zeitschrift für GanzheitsMedizin (Swiss Journal of Holistic Medicine)*, 19 (4), 199–203.

Umpleby, S.A. (2008). A brief history of cybernetics in the United States. *Österreichische Zeitschrift für Geschichtswissenschaften (Austrian Journal of Contemporary History)*, 19 (4), 28–40.

Unschuld, P. U. (1973). *Die Praxis des traditionellen chinesischen Heilsystems unter Einschluss der Pharmazie dargestellt an der heutigen Situation auf Taiwan (The practice of traditional Chinese healing system including pharmacy presented at the present situation in Taiwan).* Wiesbaden: Franz Steiner.

Unschuld, P. U. (1985). *Medicine in China: a history of ideas.* Berkeley: University of California Press.

Unschuld, P. U. (1986). *Medicine in China: a history of pharmaceutics.* Berkeley, Los Angeles: University of California Press.

Unschuld, P.U. (2005). *Chinese life sciences: introductory readings in classical Chinese medicine: sixty texts with vocabulary and translation, a guide to research aids, and a general glossary*. Taos, N.M.: Paradigm Publications.

Uzuner, H., Bauer, R., Fan, T.-P., Guo, D.-A., Dias, A., El-Nezami, H., Efferth, T., Williamson, E. M., Heinrich, M., Robinson, N., Hylands, P. J., Hendry, B. M., Cheng, Y.-C. and Xu, Q. (2012). Traditional Chinese medicine research in the post-genomic era: Good practice, priorities, challenges and opportunities. *Journal of Ethnopharmacology*, 140 (3), 458–468. doi: 10.1016/j.jep.2012.02.028

Van der Greef, J. (2005). Systems biology, connectivity and the future of medicine. *IEE Proceedings - Systems Biology*, 152 (4), 174. doi: 10.1049/ip-syb:20050034

Van der Greef, J., Hankemeier, T. and Mcburney, R. (2006). Metabolomics-based systems biology and personalized medicine: moving towards n=1 clinical trials? *Pharmacogenomics*, 7 (7), 1087–1094.

Van der Greef, J., Martin, S., Juhasz, P., Adourian, A., Plasterer, T., Verheij, E.R. and Mcburney, R.N. (2007). The art and practice of systems biology in medicine: mapping patterns of relationships. *Journal of Proteome Research*, 6 (4), 1540–1559.

Van der Greef, J., Stroobant, P. and Van Der Heijden, R. (2004). The role of analytical sciences in medical systems biology. *Current Opinion in Chemical Biology*, 8 (5), 559–565.

Van der Greef, J., van Wietmarschen, H., Schroën, J., Wang, M., Hankemeier, T. and Xu, G. (2010). Systems biology-based diagnostic principles as pillars of the bridge between Chinese and Western medicine. *Planta Medica*, 76 (17), 2036–2047.

Van der Greef, J., van Wietmarschen, H., Schroën, Y., Babouraj, N. and Trousselard, M. (2015). Systematic Approaches to Evaluation and Integration of Eastern and Western Medical Practices. *Medical Acupuncture*, 27 (5), 384–395.

Van der Greef, J., van Wietmarschen, H., van Ommen, B. and Verheij, E. (2013). Looking back into the future: 30 years of metabolomics at TNO. *Mass Spectrometry Reviews*, 32 (5), 399–415.

Van der Valk, J.M.A. (2017). The technoscientific becomings of Tibetan medicines in-between. doctoral thesis. University of Kent. Kent.

Van Dongen, E. and Fainzang, S. (1998). Editorial: Medical anthropology at home: Creating distance. *Anthropology & Medicine*, 5 (3), 245–250.

Van Hollen, C. (2005). Nationalism, transnationalism, and the politics of "traditional" Indian medicine for HIV/AIDS. In: Alter, J.S. (ed.) *Asian Medicine and Globalization.* Philadelphia: University of Pennsylvania Press.

Van Wietmarschen H.A., Reijmers T.H., van der Kooij A.J., Schroën J., Wei H., Hankemeier, T., Meulman, J.J. and van der Greef, J. (2011) Sub-Typing of Rheumatic Diseases Based on a Systems Diagnosis Questionnaire. *PLoS ONE,* 6 (9): e24846. doi:10.1371/journal.pone.0024846

Van Wietmarschen, H.A., Dai, W., van der Kooij, A.J., Reijmers, T.H., Schroën, Y., Wang, M., Xu, Z., Wang, X., Kong, H., Xu, G., Hankemeier, T., Meulman, J.J. and van der Greef, J. (2012). Characterization of Rheumatoid Arthritis Subtypes Using Symptom Profiles, Clinical Chemistry and Metabolomics Measurements. *PLoS ONE*, 7 (9), e44331. doi: 10.1371/journal.pone.0044331

Van Wietmarschen, H.A., Yuan, K., Lu, C., Gao, P., Wang, J., Xiao, C., Yan, X., Wang, M., Schroën, J., Lu, A., Xu, G. and van der Greef, J. (2009). Systems Biology Guided by Chinese Medicine Reveals New Markers for Sub-Typing Rheumatoid Arthritis Patients. *JCR: Journal of Clinical Rheumatology*, 15 (7), 330–337.

Varela, F.G., Maturana, H.R. and Uribe, R. (1974). Autopoiesis: The organization of living systems, its characterization and a model. Biosystems, 5 (4), 187–196.

Verpoorte, R., Crommelin, D., Danhof, M., Gilissen, L.J.W.J., Schuitmaker, H., van der Greef, J. and Witkamp, R.F. (2009). Commentary: "A systems view on the future of medicine: Inspiration from Chinese medicine?" *Journal of Ethnopharmacology*, 121 (3), 479–481. doi: 10.1016/j.jep.2008.11.005

Vinck, D. (2010). *The sociology of scientific work*. Cheltenham, UK; Northampton, MA, USA: Edward Elgar Publishing Limited.

Von Bertalanffy, L. (1968). *General System Theory*. New York: George Braziller, Inc.

Von Neumann, J. and Morgenstern, O. (1944). *Theory of games and economic behaviour*. Princeton: Princeton Univ. Press.

Waddell, G. (2016). The Enchantment of Western Herbal Medicine. doctoral thesis. University of Westminster. London.

Walter, W.G. (1968). *The living brain*. Harmondsworth: Penguin Books.

Wang, M., Lamers, R., Korthout, H., Van Nesselrooij, J.H.J., Witkamp, R.F., Van Der Heijden, R., Voshol, P.J., Havekes, L.M., Verpoorte, R. and Van Der Greef, J. (2005). Metabolomics in the context of systems biology: Bridging Traditional Chinese Medicine and molecular pharmacology. *Phytotherapy Research*, 19 (3), pp. 173–182. doi: 10.1002/ptr.1624.

Wang, T. (2012). Writing Live Fieldnotes: Towards a More Open Ethnography. *Ethnography Matters*. Available from http://ethnographymatters.net/2012/08/02/writing-live-fieldnotes-towards-a-more-open-ethnography/ [Accessed 15 November 2018].

Wang, X. and Chan, A. (2010). Challenges and patenting strategies for Chinese herbal medicine. *Chinese Medicine*, 5 (1), 24. doi: 10.1186/1749-8546-5-24

Wang, X., Zhang, A. and Sun, H. (2012). Future perspectives of Chinese medical formulae: chinmedomics as an effector. *Omics: a journal of integrative biology*, 16 (7–8), 414–21.

Wang, Z. 王致譜. and Chen, Y. 陈贻庭. (1996). 民俗文化与中医学 (Folk culture and Chinese medicine). *福建科学技术出版社 (Fuzhou: Fujian Science and Technology Publishing House).*

Ward, T. (2011). Mapping the Epistemological Diversity of Chinese Medicine; a Q Methodology Study. doctoral thesis. University of Westminster. London.

Web of Science (2018). Chinese medicine and systems biology statistic. Available from http://apps.webofknowledge.com.ezproxy.westminster.ac.uk/CitationReport.do?action=home&product=WOS&search_mode=CitationReport&cr_pqid=3&qid=3&isCRHidden=&SID=D3VYF5qAaCOw4EqstSn [Accessed 23 January 2019].

Weber, M. and Esfeld, M. (2003). Holism in the Sciences. *Encyclopedia of Life Support Systems Publishers*, 1–16. Available from http://www.unil.ch/files/live//sites/philo/files/shared/EOLSS-HolismSciences03.pdf [Accessed 12 December 2018].

Wei, H. (1996). Norbert Wiener at Qinghua University. In: Dainian, F., and Cohen, R. (eds.) *Chinese Studies in the History and Philosophy of Science and Technology*. Dordrecht: Springer, 447–451.

Wiechers, I. R., Perin, N. C., and Cook-Deegan, R. (2013). The emergence of commercial genomics: analysis of the rise of a biotechnology subsector during the Human Genome Project, 1990 to 2004. *Genome Medicine*, 5 (9), 83. doi: org/10.1186/gm487

Wiener, N. (1994). *Cybernetics Or Control and Communication in the Animal and the Machine*. 2nd edition. Cambridge Mass.: MIT Press.

Wiesener, S., Falkenberg, T., Hegyi, G., Hök, J., Roberti, P., Sarsina, D., Fønnebø, V. and Weidenhammer, W. (2010). A pan-European research network for Complementary and Alternative Medicine (CAM). *Final Report Cambrella Work Package 2 ERC Fp7.* Available from https://cordis.europa.eu/project/rcn/92501/reporting/en [Accessed 5 January 2019].

Wolkenhauer, O., Auffray, C., Jaster, R., Steinhoff, G. and Dammann, O. (2013). The road from systems biology to systems medicine. *Pediatric Research,* 73 (4–2), 502–507. doi: 10.1038/pr.2013.4

Wood, L.S. (2010). *A More Perfect Union: Holistic Worldviews and the Transformation of American Culture after World War II*. Oxford Scholarship Online. doi: 10.1093/acprof:oso/9780195377743.001.0001

Woolgar, S. (1981). Interests and Explanation in the Social Study of Science. *Social Studies of Science*, 11 (3), 365–394. doi: 10.1177/030631278101100304

World Health Organisation (WHO). (2002). Traditional Medicine-Growing Needs and Potential. *World Health Organization Policy Perspectives on Medicines*, 2, 6.

World Health Organisation (WHO). (2016). WHO/Constitution of WHO: principles. *WHO World Health Organization*. Available from https://www.who.int/about/mission/en/ [Accessed 20 December 2018].

Wu, W.-Y., Yang, W.-Z., Hou, J.-J. and Guo, D.-A. (2015). Current Status and Future Perspective in the Globalization of Traditional Chinese Medicines. *World Journal of Traditional Chinese Medicine*, 1 (1), 1–4. doi: 10.15806/j.issn.2311-8571.2014.0027

Xu, J. (1999). Body, Discourse, and the Cultural Politics of Contemporary Chinese Qigong. *The Journal of Asian Studies*, 58 (4), 961–991.

Xu, Q., Bauer, R., Hendry, B., Fan, T., Zhao, Z., Duez, P., Simmonds, M., Witt, C., Lu, A., Robinson, N., Guo, D. and Hylands, P. (2013). The quest for modernisation of traditional Chinese medicine. *BMC Complementary and Alternative Medicine*, 13 (1), 132.

Yao, X., Li, D. and Pei, G. (2013). In focus: molecular and cell biology research in China. *Nature Reviews Molecular Cell Biology*, 14 (9), 600–606. doi: 10.1038/nrm3638

Zelko, F. (2013). A Flower Is Your Brother! Holism, Nature, and the (Non-ironic) Enchantment of Modernity. *Intellectual History Review*, 23 (4), 517–536.

Zhan, M. (2001). Does It Take a Miracle? Negotiating Knowledges, Identities, and Communities of Traditional Chinese Medicine. *Cultural Anthropology*, 16 (4), 453–480. doi: 10.1525/can.2001.16.4.453.

Zhan, M. (2009). *Other-worldly: making Chinese medicine through transnational frames*. Durham: Duke University Press.

Zhang, A., Sun, H., Wang, P., Han, Y. and Wang, X. (2012). Future perspectives of personalized medicine in traditional Chinese medicine: A systems biology approach. *Complementary Therapies in Medicine*, 20 (1–2), 93–99. doi: 10.1016/j.ctim.2011.10.007.

Zhang, A., Sun, H., Wang, Z., Sun, W., Wang, P. and Wang, X. (2010). Metabolomics: Towards understanding traditional Chinese medicine. *Planta Medica*, 76 (17), 2026–2035. doi: 10.1055/s-0030-1250542.

Zhang, B. and Wang, X. (2017). Empirical study on influence of university-industry collaboration on research performance and moderating effect of social capital: evidence from engineering academics in China. *Scientometrics*, 113 (1), 257–277. doi: 10.1007/s11192-017-2464-1.

Zhang, W.R. and Li, J. (2006). 浅谈系统生物学与中医体质学的关系 (Relationship between system biology and traditional Chinese constitutional medicine). *Journal of Chinese Integrative Medicine (Zhong Xi Yi Jie He Xue Ba),* 4 (6), 575–578.

Zhao, Z., Guo, P. and Brand, E. (2012). The formation of daodi medicinal materials. *Journal of Ethnopharmacology*, 140 (3), 476–481. Available from http://www.sciencedirect.com/science/article/pii/S037887411200061X [Accessed 20 December 2018].

Zhou, P. and Leydesdorff, L. (2006). The emergence of China as a leading nation in science. *Research Policy*, 35 (1), 83–104.

Zschocke, S., Klaiber, I., Bauer, R. and Vogler, B. (2005). HPLC-coupled spectroscopic techniques (UV, MS, NMR) for the structure elucidation of phthalides in Ligusticum chuanxiong. *Molecular Diversity*, 9 (1–3), 33–39. doi: 10.1007/s11030-005-1305-y.