INTRODUCTION

In most philosophy and history of science, science is usually identified with its most resource-rich contexts and its most successful practitioners. The bulk of the work in philosophy and history of science thus remains focused on analyzing and exploring those famous events, and by association, the stories of those event makers. Names such as Galileo and Einstein abound in that kind of literature. In contrast, this book is about a few names who are relatively unknown actors in the history of science; who remained marginalized, even neglected, within its practices; who began life perhaps with very few resources; and who, consequently, have received little attention from either the historians or the philosophers of science. Such people have, on occasion, also been denied the title of "scientist" or have been accused of dropping out of its practice altogether. Yet protagonists like this also often have made significant contributions to scientific knowledge, and have provided science with new breakthroughs and novel ideas, that afterward went on to have a robust track record of new developments.

Generally, however, such people and their work remain little discussed, and equally little understood, within the standard literature on

philosophy of science. This arises of course as a direct hangover from a well-known model proposed in the 1960s by George Basalla (1967), according to which science always moves from Western to various non-Western locations, mostly consisting of the former colonies of European powers, via a process called diffusion. In this diffusionist image, the West naturally emerges as the contributor of all central theories in science—the peripheries show up mostly as sources of data or new specimens but with little cognitive contributions otherwise. Thus, while officially still part of the scientific network, the contribution of those peripheries remains quite minimal in the story of science itself, and they are generally seen in the role of passive recipients or perhaps lacking in a proper scientific temper. With minor modifications, versions of this model have been repeated by almost everybody who has ever sought to describe any colonial or peripheral situations in science, especially their cognitive contributions to the stock of human knowledge. Viewed from the peripheral side, this same idea reappears in the guise of a transplant model—diffusion and transplantation being two sides of the same coin. It must be admitted that this model has been extensively criticized, and it has also been suggested that perhaps science is more a case of a moving metropolis—that the established centers of knowledge in science shift over time (McLeod 1987). However, precisely how the metropolis shifts from one place to another, and what roles the newcomers, who join the game of science in the hope of building future metropolises, play within it, have remained unclear. Thus, Basalla's model might have been rejected, but nothing adequate so far has been put into its place. The overall effect of this diffusionist discourse has been to create a general attitude of neglect for all scientific creativity and innovations outside a few Euro-American metropolises.

The purpose of this book is to set aside this attitude of general neglect and to try to highlight the importance of such emerging—but often unknown—peripheries, and to try to explore the processes of creativity of those peripheral actors by using a cognitive-philosophical-historical (CPH) method. This method reclaims the core-periphery language from the various diffusionist discourses and places it within the framework of a new cognitive analysis, making it potentially available for multiple contexts and multiple situations. By "CPH method," then, I understand a general way of unpacking the developments and the transformations that such scientists carry out on various mental and embodied representations, and an exploration of the social medi-

um by means of which they receive those representations. Since this work usually gets lost within a diffusionist framework, people who accomplish this hard task often receive scant recognition for their efforts, and as I have said above, often they have been denied the very title of scientist altogether. Even when briefly mentioned, such people tend to disappear after a few cursory mentions in the literature. The bulk of our philosophical attention thereafter remains squarely focused upon a few famous figures and their equally famous discoveries and contributions. What I claim in this book is that, contrary to this usual practice, the peripheral actors reveal to us a surprisingly important phenomenon about science—they show us that sometimes the best ideas in science can be born from hard and resource-poor conditions.

The bias toward resource-rich communities and the central contexts of science arises, I suggest, from our conceptual shortcomings of what we take science to be. Since the primary goal of philosophy of science is to provide various rational justifications for our current all-encompassing theories, science is frequently identified with its long-standing communities and its sophisticated centers of expertise. This creates the impression that almost all of our creative and innovative science arises from within those resource-rich contexts, the story of which then naturally absorbs all our attention. Furthermore, the literature in philosophy of science does not afford us any alternative accounts of representing the kind of creativity that one can see in peripheral thinkers, who are frequently self-trained, and also continue their trade from those different self-trained contexts.

There exists, of course, another well-known literature about science—a literature of a highly critical sort. This is the analysis that focuses on the colonial and the postcolonial contexts of science, making a list of the various negative consequences of those practices that we collectively name as "scientific." This literature generally delves into the various harmful impacts of modern scientific practices on many different kinds of things—traditional worldviews, environment, different cultures, and so on. These two lines of thinking on science hardly ever recognize each other's existence. Instead, they remain simply side by side, embodying two radically dissimilar ways of thinking about science and its implications.

Setting aside this customary practice of separation, in this book I shall look for a middle course between the two—to envision a third way of conceptualizing what science is or might be when it is practiced under various hard and resource-poor conditions. To do this work in any

depth, however, I will need to explore some specific historical context. I thus choose a few seminal figures from the history of the early twentieth-century science in India to serve as my case studies. Each of these people occupied a rather marginal position within the scientific community, especially in the beginning of their lives, and yet somehow they met with innovative successes in spite of all their constraints. Such constraints might have arisen from various factors; for example, distance from mentors or from resource-rich communities, entry in science as a self-trained newcomer, the lack of a community at home, and so on. Often such people disappeared from science after making a few brief contributions, even though those contributions themselves went on to have important track records in science. There is usually no overarching model for this kind of creativity in the sciences, and the little attention that such people occasionally receive dissolves very quickly after they are labeled as one-time wonders, incapable of repeating their successes. Into this group fall people like S. N. Bose, Srinivas Ramanujan, and many others, such as the pioneering women mathematicians of the Harvard Observatory during the 1920s. Is there more to this kind of science than what meets the eye?

The literature on philosophy of science does not usually have much to say about such newcomers and outsiders, even though now and then such people are admitted within the boundaries of scientific practice. The field thus remains populated by two large modes of thinking about science—first, that which ascribes to science the glamorous properties of progress, and the other, which critiques it sharply, rejecting most of its practices as structures of power. When all is said and done, science still remains firmly identified with its resource-rich contexts, its long-standing communities, its sophisticated sets of instrumentation, and its aura of expertise. This creates the impression that almost of our innovative and sophisticated science will arise from those contexts—and that such contexts will naturally continue to be the home of the best science.

By and large, this clash has kept the mainstream philosophy of science almost completely unaffected by the track record of science in its various peripheral contexts. All the known frameworks of science, whether they come from the logical positivists or from their later, more holistic, successors, remain almost completely preoccupied with the first type of science, even though, post-Kuhn, we now have a few studies of scientific reasoning that address various peripheral and international settings. Yet there is still no overarching framework within which

we could pull together such studies into one coherent pattern, fitting them with a general model of what science is or might be under those hard conditions. This rather serious theoretical shortcoming creates a dangerous gap—science becomes simply part of the story of a few resource-rich communities and attracts much rejection from various other contexts. But important scientific discoveries could equally well come from rather resource-poor conditions, and the human activity that we call "scientific thinking" can span an enormous range of situations, including in it the rather surprising phenomenon that sometimes strong constraints can turn out to be one of the most important springs for new discoveries.

The absence of a framework for science under those hard conditions limits our imagination about science and forces philosophers and historians—as well as everybody else—to concentrate on only the resource-rich contexts of scientific practice and to identify it with all of science. But if we want to tell ourselves a more nuanced story about scientific practice, one that incorporates into it multiple kinds of contexts and practices, we will have to revise and update our current models and move away from the older diffusionist image. Can we build an alternative framework that can tell us how scientific creativity operates under some of its most difficult and resource-poor conditions?

This book is an attempt to deal seriously with this question and to explore the phenomenon of peripheral creativity; that is, creativity in science when it operates under various hard and marginal conditions involving challenges of resources, training, and the overall lack of a home community. Since such highly marginal conditions occur frequently within various colonial contexts, created by different projects of European expansion, in this book, I try to unpack such contexts of science by looking into a small set of case studies from early twentieth-century colonial India, analyzing both its difficult epistemic as well as political conditions. The lessons that I extract from those historic contexts allow us to see—I hope—its relevance for the current twenty-first-century transnational practices of science. This is the context when many different kinds of communities might function as part of one complex (but rather nonegalitarian) network of practice. My case study of Bose-Einstein statistics tells us the story of a young Indian mathematician, S. N. Bose, who in 1924 developed the first quantum statistics for indistinguishable particles. Bose thereafter ended his short international career in science by falling into a sharp controversy with Einstein. By looking into the processes of how Bose formulated his first quantum

statistics from his remote and peripheral location, and how his thinking underwent a gradual transformation during his processes of self-study, we see the glimpses of what might be called "peripheral creativity," and how such creativity can bring about important conceptual shifts in science.

Similarly, in the story of C. V. Raman we see how a peripheral actor develops an ambitious research program on the phenomenon of the scattering of light beginning with his modest experiments designed to understand musical acoustics. We will also examine the case of M. N. Saha, who developed a new theory of the stellar spectra by combining his critical readings of the German scientific journals, Einstein's quantum theory of light, and a number of anomalous results about the spectra of the sun. In my final chapter, I take up this story one generation further by putting together a sketch of G. N. Ramachandran and his development of the triple-helix model of collagen. As I mention above, my framework remains broadly cognitive; that is, I seek to look at the representations, mental models, and various other embodied practices of these scientists to understand how they developed new representations or created new conceptual shifts, often succeeding in their task despite all odds. Those solutions, once in hand, allow them to start a trade with their metropolitan counterparts, which gradually places them within a lengthy context of acceptance and circulation, but sometimes also to summary rejection.

The overall framework that I offer here for capturing this complex process is a simple one of trade in the cognitive contents between two unequal communities where one community holds more resources and more epistemic authority than the other. An emerging trade in cognitive contents then begins from the opposite direction—from the smaller and the more peripheral side. It is thus a study of science under its less-than-ideal conditions. I propose to consider such cases of creativity as emerging trading zones, which gradually form between two unequal groups as a result of the efforts of the newcomer. Such trading zones then lead to research programs that are in constant states of flux, cycling between various up and down stages. This is no doubt a rather simple model, but I hope that other, more sophisticated, models will soon follow that will revise my first tentative attempts. The concept of a trading zone has already been applied to many analyses of science, beginning with Peter Galison's *Image and Logic* in the 1980s, followed shortly thereafter by various refinements by Harry Collins, Robert Ev-

ans, and Michael Gorman. In this book I mostly follow Gorman's account, whose stage analysis of trading zones between unequal communities can be used as a first tentative sketch of how science emerges under those asymmetric and peripheral conditions. I suggest also that this account can give us a model of how contributory expertise can be born in science in the midst of hard and marginal situations via some inspired cycles of self-training.

In recent years, however, the domain of peripheral science has attracted some serious attention from different scholars. Within this existing field of scholarship, I quickly point to two strands of work. The first sees purely Eurocentric models of science as insufficient and inadequate and thus calls for new analyses. The second seeks to provide detailed case studies, showing how rich scientific practices have often emerged elsewhere—for example, in different cultural and national contexts. Sharon Traweek's work on high energy physicists in Japan is a well-known example of this second kind, and to this set we can also add the more recent contributions by Adriana Novoa and Alex Levine on Darwinism in Argentina (Traweek 1988; Novoa and Levine 2010, 2012; see also Dasgupta 1999). Another contribution in this genre is Robert Anderson's book *Nucleus and Nation* (2010), on the rise of the nuclear program in India after the Second World War. These and other similar works provide a rich background when the time is especially ripe for a generalized philosophical framework about all peripheral scientific practices. Once formulated, such a model could then become an exploratory tool for understanding how new scientific centers begin working with their metropolitan partners collaboratively, but also differentially, in the process of making new scientific knowledge. In spite of these contributions, we still do not have enough literature on this kind of science. Finding a good set of course readings still remains a struggle, if the goal of that course is to explore scientific practices outside its routine Western contexts. This is the gap that my contribution seeks to fill, offering a generalized theory for all such scientific situations.

Outside the standard university contexts, where academics live in their happy isolation, there is now a quickening of interest on the emerging countries and their emerging economies. Since many emerging nations are going to invest heavily in developing scientific communities of their own, a story of science in such contexts becomes closely wrapped up with the overall story of an emerging world. As the home of a substantial-sized scientific community that began its journey well

over a hundred years ago, India can serve as a window to understand how those processes take a (new) community from its hesitant first steps to a more mature, and relatively sophisticated, practice.

Finally, even though my primary intended audience here is the philosophers and the historians of science, I hope that this book will be of some use to the general reader, who might be interested in the broad question of how scientific practices unfold in various complicated contexts, including in several non-Western contexts. Above all, I hope that this book will be of some use to the generations of creative young researchers who are now at work in various emerging contexts of science that I have tried to explore and analyze, and which might make them see the creative possibilities in their own future practice. A story of peripheral science, I hope, can thus serve as a source for self-awareness and self-image for such researchers and help them in their task of designing newer and more pertinent research programs for their own specific contexts.