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Gender, Coordination Problems, and Coordination Games

Women in the Ashante tribe of West Africa make pottery to be used day to day for cooking and storing food. Men, on the other hand, are responsible for woodworking. In the Hadza tribe, men tend to hunt meat, while women focus on the acquisition of vegetables. In the United States during the 1960s, women were primarily responsible for preparing breakfast, while men did the lawn care.

These patterns are part of what is referred to in humans as the gendered division of labor. Across all observed societies, it is the case that men and women have, at least to some degree, divided labor between them. This creates an explanandum for social scientists—why do we see such patterns? It isn't as if human groups had to arrange themselves in such a way. Labor could have been divided by individual preferences or strengths. Or labor could be undivided, so that each individual does a bit of whatever job needs doing. This has led to questions like: do men and women have different innate preferences that cause them to naturally choose different jobs? Is there a cultural function fulfilled by this division of labor?

Part I of this book will illustrate (among other things) how social categories, like gender, can break symmetry in certain sorts of coordination situations, and so allow groups with categories to coordinate better than groups without them. Because of this functionality, as I will argue, cultural evolution has taken advantage of social categories, shaping many of our conventions around them. In order to tell this story, I'm going to make use of gendered division of labor as a key case. This is, in part, because

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it is so well studied in the social sciences, and in part because it is a paradigm example of how irrelevant differences between individuals can nonetheless become completely central to social coordination. Crucially, previous authors have argued that gendered division of labor is the starting point for gender inequality (Okin, 1989; Ridgeway, 2011), and the cultural evolutionary framework I develop will help inform how natural processes of learning and cultural transmission might lead groups to inequitable norms and conventions of this sort. As we will see in Chapter 4, a cultural evolutionary framework can also shed light on some puzzling features of the gendered division of labor.

All this is not to say that gendered division of labor is the only interesting case where the framework developed here might apply. Both caste and class are social categories that seem to be part of solutions to coordination problems. Since these cases are very different in their details, though, it will be beyond the scope of this book to carefully illustrate how and where this framework applies more broadly. In Part II of the book, we will consider models that apply straightforwardly to a broader set of cases.

In the Introduction, I described two simple coordination scenarios—one where people want to coordinate their dance steps, and another where they need to decide on a division of pizza. Coordination in the broadest sense of the word is central to this book. In particular, coordination problems define the set of strategic, social scenarios where social categories end up mattering deeply to the evolution of conventions and norms. I'll start the chapter with a brief discussion of gender and gendered division of labor, drawing out the features most relevant to the framework developed here. Then I'll discuss generally what coordination problems are and introduce the models used to represent them—coordination games. I'll draw on previous work in economics to explain why division of labor is, itself, a coordination problem in the standard sense. (Along the way, we'll discuss the notions of convention and norm, and the use of game theoretic models to represent them.) As we'll see, not all coordination games are equal. While some can be solved by conventions and norms that are identical for everyone in a society, others, those that require people to take different, complementary actions, pose a special problem. Coordinating behavior in these sorts of games requires extra information to break symmetry between those who are interacting—who is the one who steps forward, and who back? Division of labor, as it turns out, is just such a problem. Actors have to decide who will do which of several complementary actions. This will set the stage for the next two chapters, which will explore how social categories like gender can provide a means of symmetry breaking in these sorts of cases.

1.1 Gender and Gendered Division of Labor

1.1.1 What is gender?

The answer to this question is not straightforward. Gender is not a simple concept, nor is it a unified one. Across academic disciplines different definitions of gender are employed for different reasons.[1] Since this book is not a work of gender theory, but a work of evolutionary game theory that addresses social categories, we will want to understand the aspects of gender that have the most to do with strategic social behavior. In particular, I will focus more here on the role gender plays in such strategic behavior, rather than, say, how gender shapes personal experience.

Sociologists Candace West and Don Zimmerman, in their seminal paper, "Doing Gender," point out that "[i]n Western societies, the accepted cultural perspective on gender views women and men as naturally and unequivocally defined categories of being . . . Competent adult members of these societies see differences between the two as fundamental and enduring" (West and Zimmerman, 1987, 128). The claim is that we tend to think of men and women as inherently different, and as belonging to clear, distinct categories. These categories seem so natural that until relatively recently, there was little push to examine them. Money (Money et al., 1955) was the first academic to use the term "gender role" to refer to something that associates with biological sex, but is not identical to it. Theorists have subsequently endorsed the distinction between biological sex and gender, where, roughly, the former tracks inborn biological differences, and the latter constructed social categories. (Things are not actually so simple because, for example, cultural differences

[1] In philosophy, Haslanger (2000) provides a discussion of different types of definitions of gender, and introduces what she calls a pragmatic definition—one that is useful for positive social change.

shape the development of bodies (Butler, 2011a), but such considerations are beyond the scope of this exploration.[2] See also Haslanger (2015b) for an analysis of the ways culture influences our concept of "sex".)

A useful notion of gender for our purposes goes something like this. Based on innate biological sex differences, we can determine *sex categories*, or categories that neatly divide the human population into types based on sex (West and Zimmerman, 1987; Ridgeway and Smith-Lovin, 1999). These categories piggyback on biological sex differences, but are separate from them because, for example, intersex people tend to be assigned to one category or the other and trans people may switch sex categories (Money and Ehrhardt, 1972).[3] Using these sex categories, societies develop patterns of social behavior that constitute gender. These patterns are governed by normative expectations for a person's behavior across many behavioral arenas.

So what are these normatively governed patterns of behavior? There are several broad classes of patterned behavior related to gender that I will focus on here as especially useful for understanding the evolutionary models that will be developed, though these will not capture all gendered patterns of behavior. First, cross-culturally, gender, as a rule, is used to divide labor, but this division is often conventional. In the next section, this will be elaborated. Second, sex category and gender identity is usually signaled, often elaborately, through both appearance and behavior. In Chapter 2, I will further discuss this sort of signaling in service of a more general discussion of social categories and their instantiation in models. Third, gendered behaviors are reproduced in human populations via learning and punishment. In Chapter 3, we will come back to the relevance of this to evolutionary models of gender.

[2] Butler (2011a) argues that sex should be understood "no longer as a bodily given on which the construction of gender is artificially imposed, but as a cultural norm which governs the materialization of bodies" (xi).

[3] Additionally, in some societies, there are more than two sex categories. For example, some societies have a third category consisting of biological males who are socially like women, such as hijras in India and some Native American two-spirit people. Other African and Native American societies have third categories for biological females who behave like men by taking the social responsibilities of fathers and husbands (Martin and Voorhies, 1975; Blackwood, 1984; Williams, 1992; Thomas et al., 1997).

1.1.2 *Gendered division of labor*

As mentioned, every culture divides labor by gender.[4] This is true even though human societies have taken on radically different modes of organization cross-culturally and over the course of history ranging, for example, from traditional foraging societies, to agricultural societies, to industrial, and to post industrial, societies (Basow, 1992). Within each of these categories are countless structural differences related to political organization, social structures, marriage rules, etc.

There are two sorts of ways in which labor is divided, the first relating to who does which tasks and the second to the overall amount of work done (Blood and Wolfe, 1960). Under the title "division of labor," I will be concerned with division of complementary jobs. The division of overall amount of labor will fall under "division of resources" and "household bargaining" in particular, and will be discussed at length later in the book, especially in Chapter 8.

Although every society divides labor by gender, this division takes on very different forms (Murdock and Provost, 1973; Dahlberg, 1981; Costin, 2001; Marlowe, 2010). Murdock and Provost (1973), in a classic article look at fifty "technological" activities in 185 societies including things like food collection, production, and preparation, material abstraction/processing, and manufacturing of articles. They coded these based on whether the activities were performed exclusively by men, predominantly by men, by both sexes equally, predominantly by women, or exclusively by women. They found that some activities, like hunting large game, metal and woodworking, mining, and (puzzlingly) making musical instruments, were performed almost exclusively by men across cultures.[5] Other activities—such as spinning, laundering, cooking (especially vegetable food), and dairying—tended to be performed by women. A larger range of activities, to varying degrees, were performed by one gender in some societies and the other in others. These included activities like making rope, planting crops, carrying burdens, caring for small animals, house-building, etc. Some activities were performed by both genders in

4 Evidence discussed in Gibbons (2011) also suggests that this division of labor by gender in humans is ancient.

5 Even activities like big game hunting, though, are sometimes performed by women cross-culturally (Bird and Codding, 2015).

some societies, though it has been subsequently pointed out that many of these activities, when more carefully parsed, consist of sub-activities that *are* divided by gender.[6] Subsequent research reports similar findings. Costin (2001), for example, looks at the manufacture of crafts for trade and sale and finds a substantial division of labor by gender though great variety cross-culturally in who makes what. The key observation here is that for a wide swath of activities, while each group divides them by gender, there is variability across groups as to which gender does the job.

In modern societies, like more traditional ones, household labor also tends to be divided by gender (Blood and Wolfe, 1960; Thrall, 1978; Pinch and Storey, 1992; Bott and Spillius, 2014). In a classic study Blood and Wolfe (1960) surveyed families and asked who performed which of eight household tasks. They found a significant division of household labor with some tasks usually performed by the husband (repairs, lawn care, shoveling snow) and some usually performed by the wife (cooking breakfast, cleaning the living room, and doing dishes), and a few that were performed by either gender (paying bills and buying groceries). Thrall (1978), in looking at household division of labor that included children as well as adults, found that only 20% of the tasks they considered did not fall largely to one gender or another.

Some have attempted to explain these divisions via appeal to innate sex differences in humans (as we will discuss in Chapter 4), though the massive cross-cultural variation in patterns of division of labor presses against such an explanation. A more promising line of explanation in game theory appeals to strategic aspects of coordination (Becker, 1981). The framework I will now begin to develop is in line with this second sort of explanation, though it takes a bigger-picture approach to the role of social categories and coordination, and emphasizes the importance of cultural evolution to understanding these phenomena. Let's get started by delving into the sort of strategic situation where social categories like gender can improve outcomes—coordination problems.

[6] Costin (2001) gives a few examples. "Among the Ashante in west Africa, women produced utilitarian domestic pottery for sale in the marketplace, while men produced ritual ceramic vessels on order for elite patrons" (2). Here pottery-making would count as one technological activity, but we can see that classifying this culture as one where men and women both make pottery misses an important division of labor.

1.2 Coordination Problems

What are the basic features of a coordination problem? Informally, we can boil them down to two. First, actors in a coordination problem usually have some level of *common interest* in that they want to coordinate. For example, in the tango problem described in the Introduction, actors want to end up at the same sorts of outcomes (where one steps forward and the other back). Second, coordination problems are *problems* because despite the common interest of the actors, it is nontrivial for them to coordinate their actions to meet these interests. This is usually the case because there are multiple ways for coordination to happen, and successfully coordinating involves settling on one of them. Schelling (1960) oriented game theorists' attention to this sort of problem. When actors must choose between many equally, or nearly equally, good possible joint coordination outcomes, how do they pick?

We can distinguish two classes of coordination problems. The first I will call a *correlative* coordination problem. In this sort of problem, actors in a social sphere need to coordinate action by making the same choice, or correlating what they do. A classic example is choosing what side of the road to drive on. In any society, everyone would like all members to drive on one side of the road, but it doesn't really matter which. To give another example, most societies have standard working hours and this standard allows for all sorts of further coordination (when restaurants are open, when trains run a heavier schedule, when people schedule meetings, when child care is available, etc.) In the US those hours are 8–5 and in Spain they are 9–2 and 4–8. It matters more that these happen at the same time than that they happen at any particular time. Another example relates to language. In each society, members would like to agree on which word means what, but the actual word itself doesn't matter (again, within reason).

There are also correlative coordination problems that do not need to involve broad societal choices, but more interpersonal ones. For example, a family might wish to do something together, and must somehow all decide what that will be. Perhaps the group could go to the movies, or to the beach, or to the fair, and while members may have preferences about which, their main preference is that they all do the same thing. The same sort of problem can arise for a couple on a date, or friends trying to spend time together, or work colleagues who schedule regular meetings but must decide where and when.

The second class of coordination problems I will call *complementary* coordination problems. In these cases, actors need to coordinate action, but they have to do so by using different strategies, or complementing each other, rather than by all doing the same thing. The tango problem introduced at the beginning of the book is a good example of a complementary coordination problem. People coordinate by taking complementary roles, stepping forward and back, rather than by both stepping forward or both stepping back. There are many coordination problems that have this complementary character. Consider things like getting on and off an elevator or stopped subway car. The people on the inside and the outside need to coordinate by doing different things, one group moving while the other waits. Or suppose two people want to order at McDonald's. Who goes first? What if two people arrive at a doorway at the same time—who enters and who waits (or holds it open)?

Division of labor falls squarely into this type of coordination problem (which will be further elaborated later in the chapter). Consider division of labor within a modern household. A single household needs a person to clean the bathroom, take out the trash, do the grocery shopping, etc.[7] However, there are many jobs to keep a household running, and it makes sense to divide them among various members. In this case, everyone wants to coordinate who does what, but often by *not* doing the same thing. (As I will elaborate later, this sort of division of labor is most important for jobs that require some skill. For entirely skill-less jobs everyone can more easily do a bit of everything.) In the same way, a village needs a police officer, a bank clerk, a grocer, etc., and ideally just one person (or a small number) doing each of these.

Another sort of complementary coordination problem relates to leadership. Human groups often need to coordinate flexibly, by responding to changes around them. Coordinated group action is facilitated by having one individual, or a small number, making decisions. For instance, a military without a strict hierarchy of leaders would be utterly useless. Even in romantic relationships, friend pairings, or small tribes, it is often easier to have a decision-maker than having to always make decisions by committee. In all these cases, actors can coordinate more effectively by taking different roles—leader and follower—rather than by taking the

[7] A similar point can be made about traditional households and groups if we substitute these jobs for gathering, hunting, toolmaking, etc.

same role. Now, though, these roles specify not a particular behavior, but a pattern of behavior (i.e. making the decisions, rather than driving on the left side of the road).[8,9]

One last category of complementary coordination problem we'll address, which will become particularly important in Part II of the book, involves the division of resources. Whenever humans jointly produce resources, or whenever they otherwise obtain sharable resources, they must decide who will get what. These problems have a complementary coordination character because in order to successfully divide resources, actors must have compatible expectations or demands for what they receive. We cannot both take home 60% of a carrot harvest. If our company earns fifty thousand dollars in surplus this year, we cannot each take home 30k. When two actors form a household, if they jointly take too much free time (arguably a precious resource) the outcome will be credit card debt and a pile of dirty dishes. Traditionally, these sorts of resource division cases have fallen under the heading of "bargaining" rather than that of "coordination," and they are usually represented by a bargaining game. I will wait until Chapter 5 to introduce models that specifically represent this sort of complementary coordination.

Lewis (1969), in his famous work on convention, calls the differences between correlative and complementary coordination problems "spurious" (10). As he points out, by redefining behaviors in a coordination game, one can go from one type of problem to the other. For instance, Lewis describes a real-world coordination problem he encountered while living in Oberlin, Ohio. All phone calls in the town were automatically cut off after three minutes. The coordination problem here was to determine which party would call back. This, on first glance, looks

[8] Notice that in the tango, the two partners must both know who will perform which of the two basic versions of the steps (the one that starts by going forward or the one that starts by going back). They also must select one partner to *lead*. Since there is no preset choreography for the entire dance, if both dancers try to lead, they will fail to coordinate, and ditto if they both try to follow. Both sorts of divisions are crucial for coordination in human groups.

[9] Millikan (2005) distinguishes what she calls "leader–follower" conventions from other sorts of conventions. These are conventions where one actor observably takes the leadership part of an established convention, and the other actor is then able to take up the follower role and coordinate. These are distinct from the types of problems just described, because they involve rigid, or semi-rigid behaviors that actors simply figure out how to divide via a leader–follower distinction. I refer here to flexible behaviors where the problem is to determine who will be the leader in general.

like a complementary problem—one actor must call and the other must not in order to be successful. As Lewis argues, though, one can instead think of the possible actions here not as "call back" and "wait," but as "call back if one is the original caller" and "call back if one is not the original caller." On this rebranding, a solution to the problem entails everyone taking the same action. As will become clear, this redescription of the problem is only available if there is some way to break symmetry between the two actors—some extra information available to determine who does what. (In his case, that asymmetry is provided by the fact that one person must always be the caller and the other receive the call.) For this reason, Lewis is overlooking a key difference between these sorts of problems. The restatement is only possible in some cases, and how to make a complementary problem a correlative one is a thorny topic in its own right.

1.3 Coordination, Convention, and Norm

In human groups coordination problems tend to be solved by conventions. When it comes to driving, the convention in the US is to go right, and the convention in India is to go left. As discussed, conventional working hours differ in Spain and America. In my childhood family, the convention is to go for a long walk after dinner, instead of playing Scrabble. My husband does the cooking, and I do the laundry, whereas we might have gone the other way.

Lewis (1969) was one of the first philosophers to bring game theory to bear on social conventions.[10] Indeed, he *starts* with coordination games in order to define what conventions themselves are. On Lewis's account conventions are behavioral regularities in groups of actors faced with repeated coordination problems. His definition is quite detailed, but, approximately, for such regularities to constitute conventions it is necessary that members of the group mostly conform to them, they expect others to conform to the same patterns, and they have generally similar preferences over outcomes in the problem (78). In addition, Lewis

[10] Though discussion of social convention by philosophers goes much farther back. Hume, in *The Treatise on Human Nature,* describes a convention with a coordination character. "Two men who pull at the oars of a boat, do it by an agreement or convention, tho' they have never given promises to each other"(Hume, 1888, Bk III, Pt II, Sec II).

stipulates a requirement of common knowledge, which is approximately that each actor involved knows that the things just listed hold true, and that the others know this, etc. If these conditions obtain, actors should be expected to continue to conform to their conventional solution to whatever coordination problem it is they face. Each expects that changing behavior will detriment them, and so continues to make the same choices. And, jointly, the actors continue to successfully solve their problem.[11]

On this definition, only groups of actors with high levels of rationality—really only groups of humans—can have conventions. Since Lewis's *Convention*, though, a body of work has emerged in philosophy showing that solutions to coordination problems can emerge endogenously through processes of learning or biological evolution, both for simple and for more complex actors. Skyrms (2010), for example, investigates how signaling conventions can emerge in evolutionary models as solutions to signaling games, which are a branch of coordination problem (and which Lewis uses to explain linguistic convention). The striking thing about these sorts of models is that they have served as successful representations of incredibly diverse sorts of populations—bacteria, vervet monkeys, humans, businesses looking to hire, etc. This diversity of explanatory success raises a question: are the solutions to these problems in human groups importantly different from the solutions elsewhere? In other words, is there an important difference between Lewisean conventions in human societies, and, say, alarm calls in animals? What about sex roles in plants?[12]

In this book, I employ evolutionary models with low to medium rationality requirements. I think it is useful to conceive of the solutions that arise in these as conventional, even when they do not involve expectations or common knowledge, or any of the human-level rationality requirements of Lewis. Conventions in this sense should be thought of as behavioral regularities across groups that solve coordination problems

[11] Schelling (1960), in his seminal work on coordination, has something similar in mind as the typical solution to a coordination problem—that actors have mutual expectations, and expectations about each others' expectations, driving them to a solution.

[12] Cao (2012), in a discussion of whether signaling games can represent neuronal signaling, makes a point relevant to distinguishing between these sorts of conventions. As she observes, if we look at different cases where signals "might have been otherwise" (the usual bare requirement for conventionality), some of these are easy to change now (like language), and others very hard (like bacterial signals). The sense of "could have been otherwise" in the latter cases appeals to deep evolutionary counterfactuals.

broadly defined. This is not a careful definition, but the goal of this book is not to provide an analysis of convention. The claim here, note, is not that *every* convention is a solution to a coordination problem. We will simply focus on a particular set of conventions that are.[13]

I would like to draw a few distinctions that will be useful later. The first distinction is between solutions to coordination problems that consist in behavioral regularities, on the one hand, and such solutions that have obtained normative force. Conventions, on the definition here, need not carry normative force. If bacteria have evolved a chemical signal that solves a coordination problem, this constitutes a convention. It should be obvious that if some bacterium fails to send this signal, the other bacteria will not shun or punish the dissenter, and there will be no expectations that something different *should* have happened. In human groups, on the other hand, conventional solutions to coordination problems often also constitute norms in the sense that members of the population feel that they themselves and others *ought* to act in a particular way.[14]

Arguably, most human conventions acquire some sort of normative force, and previous authors have argued that this is *always* the case. Gilbert (1992), for example, argues that conventions are norms because they consist in joint acceptance that a group ought to behave in a certain way. On the definition from Lewis (1969, 97) conventions are norms because one will be going against one's best interest by switching behavior, and so others will believe one ought to conform to the conventional behavior. Furthermore, others will respond badly to a failure to conform since it matters to their payoffs.[15] Weber (2009) defines convention as a

[13] The notion that every convention solves a coordination problem has been successfully challenged. Gilbert (1992) offers a thorough critique of Lewis's account of convention where she gives examples of social conventions that cannot be represented by Lewis's proper coordination equilibria. Millikan (2005), likewise, points out that conventions like saying "Damn" when you stub your toe are not well represented as solutions to coordination problems. Binmore (2008) argues against Lewis's common knowledge requirement for conventions, using an evolutionary game theoretic perspective.

[14] Although it is slightly orthogonal to this discussion, readers might be interested in Anderson (2000), who discusses several approaches to understanding social norms, including rational-choice and evolutionary-based approaches.

[15] Sugden (2000) outlines in detail why Lewisian conventions obtain normative force via an analysis of mutual expectations. And Guala (2013) uses an experiment to show that it is very easy for conventions in the Lewis sense to gain normative force, though he argues that they gain an intrinsic normativity rather than a "should" based on a consideration of others' payoffs as described by Lewis.

"binding" custom, where failure to meet it will lead to "sanctions of disapproval" (127), implying that normative force is attached to conventions by definition.

This running together of conventions and norms in the human case obscures the fact that there is a continuum along which conventions hold normative force. For example, it is a convention that people wear formal attire to a wedding. Failing to do so will annoy and clearly is in violation of a social norm, but not to an extreme degree. Failing to drive on the correct side of the road, however, is an egregious norm violation and will tend to create quite a lot of consternation. Furthermore, there exist human conventions which meet the definition here, and even which meet Lewis's requirements, but almost entirely lack normative force.[16] Millikan (2005), who defines conventions as patterns of behavior that are reproduced, where part of this reproduction depends on the force of precedent, agrees that a distinction should be made between conventions and norms because many conventions are not typically followed (and thus are missing the "should").[17] An analysis from Bicchieri (2005) is perhaps most useful here. She distinguishes between conventions—behavioral regularities which actors wish to follow if they expect others to follow them because of the strategic structure of the interaction—and social norms, which actors wish to follow if others expect them to or will punish them for deviance. As she points out, stable conventions can become this sort of social norm over time, though this does not necessarily happen. She points out that this is especially likely when breaking a convention will lead to "negative externalities."[18]

Throughout the book, I will distinguish between conventions and norms, though, as mentioned, I think these are best understood as existing on a continuum. Because the work of the book consists in

[16] My husband and I have a convention of watching "The Office" together at the end of the day, but there is no sense in which either of us feels that we ought to do this. (Probably we ought to get to work on the laundry and dishes.) Failure to abide by this convention would lead to absolutely zero disapproval or censure by the other party.

[17] She gives an example of handing out cigars after having a child. This is not a convention of the sort I am concerned with here because it does not solve a coordination problem.

[18] Arguably, by definition, breaking a convention that solves a coordination problem will lead to a negative externality since it will lower a partner's payoff from what is expected. There are degrees to which this can happen, though. I might disappoint my husband by deciding not to watch The Office, but if I decide not to follow driving rules I might kill someone.

using evolutionary models to understand the emergence of behavioral regularities, I will focus on conventions to a much greater degree.

A second distinction has to do with the type of underlying coordination problem. Lewis (1969) claims that conventions are arbitrary, in the sense that they could have been otherwise. This arbitrariness is a key aspect of all accounts of convention. In her extensive critique of Lewis's account, though, Gilbert (1992) points out that there are coordination problems, in his sense, where "one of the two proper coordination equilibria gives each player a payoff vastly superior to the other, while the other gives each player a payoff little better than zero" (342). In other words, one way of coordinating will be strongly preferred by both players. For such problems, she claims, solutions will not be arbitrary in the right sense for them to be conventions. The tension in this critique can be resolved by pointing out that there is a continuum along which conventions are more or less arbitrary (as well as a continuum along which they are more or less normative). For some problems, there are multiple possible outcomes that might be equally good solutions. The left and the right sides of the road fall under this heading. In other sorts of problems, there are multiple solutions, but they vary with respect to goodness. For example, I cited working hours as a solution to a social coordination problem, but it is not the case that *any* hours will work. If working hours were from midnight until 8 am, people would be unhappy and unwell.[19] For still other problems, there might be one solution that is very clearly better than the others—in a pair of friends learning to rock climb, having the one with experience do the lead climb is clearly better than having the inexperienced climber do it, though the complementary roles could potentially be filled by either member. Coordination problems can be thought of as existing on a spectrum from those where there are many equally good solutions, and those where some solutions are more attractive (Simons and Zollman, 2018). I will call solutions on the former end of the spectrum more conventional and those on the latter end less conventional (and sometimes more functional). In Chapter 4, I will return to this theme to give a simple formal measure intended to capture where on this spectrum a coordination problem lies. As we will see, this understanding of conventions as having varying degrees of arbitrariness will help elucidate the conventionality of patterns of gendered division

[19] See, for example, Davis et al. (2001).

of labor. Let's now turn to game theory to start building models of coordination problems.

1.4 Coordination Games

Game theory was developed as a framework for modeling strategic interactions among humans. By "strategic," I mean any interaction that involves multiple actors who choose how to behave, where these actors care about what their partners do.[20] Coordination problems obviously fall under this heading—each person involved wants to make a choice based on what their partner does. If you step forward, I want to step back, and vice versa. Game theory attempts to explain and understand behavior by simplifying such interactions, modeling them, and then using a relatively bare set of assumptions about human choice to predict or explain strategic outcomes.

In game theoretic models of coordination problems—*coordination games*—actors have to coordinate strategies to be successful, and there are multiple ways to do so. In the last section, I sometimes described coordination problems with multiple actors. (In the military, for example, the coordination problem is solved when many actors align in a proper hierarchy that facilitates flexible action.) In this section, and throughout the book, I will focus on problems with only two actors. This is not because some of the interactions I will address cannot be fruitfully represented by more complex models, but because the goal here is to provide explanatory clarity, sometimes at the expense of more fine-grained representation. Furthermore, small games have been found, in many cases, to provide deep insight into behavioral interactions despite their simplicity (Sigmund et al., 2001).

1.4.1 Correlative coordination games

A game involves three things: *actors*, *strategies*, and *payoffs*.[21] Actors in a game are those involved in the strategic interaction. Strategies define what each actor can do (step forward or back in the tango, for example).

[20] Note that this definition does not require that these interactions involve conflict (as is sometimes assumed about game theory).

[21] Usually games also define *information* for the actors, or what each actor knows about the interaction. In this book, this element will be downplayed, since it is less relevant to emerging or evolving behaviors than it is to rationality-based analyses.

		Player 2	
		A	B
Player 1	A	1, 1	0, 0
	B	0, 0	1, 1

Figure 1.1 Payoff table for a simple, correlative coordination game

Payoffs determine outcomes for each actor given the set of strategies they have chosen.

Figure 1.1 shows what is called a *payoff table* for the simplest type of correlative coordination game—one with two players, where both coordination outcomes are equally preferred. The actors are player 1 and player 2, who each have two strategies—A or B. A could be "drive on the right side of the road" and B could be "drive on the left," and for this reason I will sometimes call this the driving game. Rows in the table correspond to possible strategies for player 1 and columns to possible strategies for player 2. Entries to the table represent payoffs to the two players for any combination of strategies, with player 1's payoff listed first. So if both players choose A, they each get 1. Ditto if they both choose B. If they choose A and B, they get nothing. They succeed only by correlating action.

What, in this figure, do the payoff numbers correspond to? The answer given by game theorists is *utility*, an abstract representation of whatever it is a player prefers or likes. Most game theoretic analysis proceeds by assuming that actors try to maximize their utility by choosing the strategy that is expected to provide the best payoff as determined by a calculation involving beliefs about the strategic situation. Sometimes it is easy to say what the best strategy will be. Other times, there may be multiple reasonable strategies to choose from. In many cases, expected behavior in games accords to what is called a *Nash equilibrium* (Nash, 1951). This is a set of strategies where no actor can deviate and improve her payoff. For this reason, these sets of strategies are thought of as stable and likely to arise in the real world.[22]

[22] Evidence from experimental economics indicates that, indeed, humans often learn to play Nash equilibria in the lab, though not always. (See Smith (1994) for examples of cases where experimental play does and does not conform to Nash equilibrium predictions.) Besides the Nash equilibrium concept, there are a host of other solution concepts developed by game theorists to predict and explain strategic behavior. A discussion of these concepts is beyond the scope of this book.

In any particular game, the absolute numbers are in some ways less important than the comparisons between the numbers for each player (though they still matter for plenty of things). Here it matters that player 1 prefers 1 to 0 and player 2 likewise, but this strategic scenario could also be represented by a game where the entries had 100 and 0, or 2 and -50 for the coordination and non-coordination outcomes. If these changes were made, the ordering would still capture the idea that each player prefers the coordination outcomes, and does not prefer one of these over the other. Once we use these games in evolutionary models, the significance of these numbers will shift, though, as will the method of analyzing the model. Instead of representing utility the numbers will instead determine how evolutionary change happens, and the details of payoffs will often be very significant. More on this in Chapter 3.

The game in Figure 1.1 has two Nash equilibria.[23] In fact, this is a general property of coordination games—that there be at least two plausible outcomes actors might end up at. The Nash equilibria here are the strategy pairings where both actors choose A or both choose B. In either of these pairings, neither actor can switch strategies and improve her payoff. (If either switches, she goes from getting a 1 to getting a 0.) Also note that, in this case, neither player prefers one Nash equilibrium over the other because both players get the same payoff (1) for either equilibrium. This means that they are both happy to coordinate in whatever way.

Correlative coordination games do not always have this character. Consider the games presented in Figure 1.2. In both of these games, there are two coordination equilibria, and they are the same as for the game in Figure 1.1 (A vs. A, and B vs. B). In both of these cases, though, there is a difference between the two equilibria. In (a), one coordination outcome is better than the other for both actors. While both players prefer to coordinate over not coordinating, they also both prefer B vs. B to A vs. A. This game represents scenarios where, for example, the less preferred outcome could represent working hours from midnight to 8 instead of 8 to 5. Note that this game moves slightly away from a pure

[23] To be more precise, the game has two *pure strategy Nash equilibria*. These are Nash equilibria where both actors play *pure strategies*, or choose the same action all the time. One can also consider *mixed strategies*, where actors make two choices probabilistically, but for now I will ignore these. For the most part, mixed strategies will only be discussed in this book when they are significant from an evolutionary point of view, and this will not be often.

(a)

	Player 2: A	Player 2: B
Player 1 A	1, 1	0, 0
Player 1 B	0, 0	2, 2

(b)

	Player 2: A	Player 2: B
Player 1 A	2, 1	0, 0
Player 1 B	0, 0	1, 2

Figure 1.2 Payoff tables for two simple, correlative coordination games. (a) shows one where outcome B vs. B is preferred to A vs. A by both actors. (b) shows one where actors have different preferences over the two outcomes

convention character and toward a functional character, as discussed in the last section, for this reason.

In the game presented in (b), the actors now no longer have interests that perfectly line up. In each previous example, they preferred the same outcomes. Now, each actor prefers to coordinate, but player 1 prefers that both play A and player 2 prefers B. This game has traditionally been referred to (suggestively) as the battle of the sexes. The story is that a man and a woman would like to go out together, but she prefers the opera and he prefers the baseball game. Osborne and Rubinstein (1994) uses a non-gender normative story where two friends want to go to the opera, but one prefers Bach and the other Stravinsky. I'll refer to it as the Bach–Stravinsky game. Note that this game has a strongly conventional character, despite the modification to create conflict of interest. Here, as in the driving game, there is not an outcome that is obviously better. (At least from a general point of view. Players 1 and 2, of course, have views about which outcome is better.)

The Bach–Stravinsky game may be called a *conflictual* coordination game, indicating that while the coordination character holds, there is now some conflict of interest between the actors. Games are sometimes referred to as either conflict of interest or common interest games, but, in fact, many of the most interesting games in game theory are both. For zero-sum games, one player's gain is another's loss, for complete common interest games one player's gain is the other's gain. Bach–Stravinsky is a perfect example of something in the middle. Schelling (1960) refers to this sort of game as a "mixed-motive" game because it represents a "mixture of mutual dependence and conflict, of partnership and competition" (89).[24]

1.4.2 Complementary coordination games

In this section, I'll introduce the games that we'll spend the most attention on throughout the book, and, as we will see, that best represent gendered division of labor—complementary coordination games.[25]

Figure 1.3 shows the simplest example of a complementary coordination game. This two-person game is identical to that in Figure 1.1, but now the actors only receive payoffs when they choose complementary actions. The two Nash equilibria of this game are A vs. B and B vs. A. In these strategy pairings, if either party switches actions she goes from getting 1 to getting 0. For simplicity's sake, throughout the book, I'll call this game the dancing game, because in this game A could represent "step forward" and B "step back." A and B could likewise be "cook" and "clean," in a household. Or "lead" and "follow" in a management situation. Or "make pottery" and "make wood crafts."

As with the simplest correlative coordination game, actors playing the dancing game do not care which equilibrium they arrive at. They simply care about coordination. In other words, there is no conflict of interest in this game. Again, though, as with correlative coordination games, there are variations on this complementary coordination game that change the

		Player 2	
		A	B
Player 1	A	0, 0	1, 1
	B	1, 1	0, 0

Figure 1.3 Payoff table for the dancing game

[24] He describes the following way of determining whether actors in a game have common interests, conflicts of interest, or something in between. Make a chart where the x-axis represents player 1's payoffs and the y-axis represents player 2's payoffs. Mark down a point representing each possible outcome. If the slope of lines between these points is always negative, the game is a conflict-of-interest game, and vice versa for common interest. A game in the middle will have both positive and negative slopes between outcomes.

[25] It is typical to call these "anti-coordination" games. There are a few reasons I do not use this label here. First, it seems to imply that actors do not wish to coordinate, which is the opposite of the truth. Second, they are sometimes referred to as "discoordination" games, and I have seen *both* of these labels applied to games where one actors attempts coordination and the other prefers to avoid it, like matching pennies. So I start with fresh terminology.

(a)

Player 2

		A	B
Player 1	A	0, 0	2, 2
	B	1, 1	0, 0

(b)

Player 2

		A	B
Player 1	A	0, 0	1, 2
	B	2, 1	0, 0

Figure 1.4 Payoff tables for two simple, complementary coordination games. In (a) actors both prefer one coordination outcome to the other. In (b) actors have conflicting preferences over the two coordination outcomes

strategic character of the situation. Consider the games in Figure 1.4. They are complementary versions of those introduced in Figure 1.2.

In the game in (a), the two actors coordinate by taking complementary actions, but the overall payoff is better for both if they choose one particular pairing. This game could represent a scenario where, for example, one of the partners is better suited to one of the two complementary social roles. Perhaps one spouse really likes doing laundry and the other likes doing dishes. Obviously both will prefer the division of household labor that accords with these preferences. Or suppose that one person likes sitting down and thinking all day while another likes being outside walking around and talking to people. It is obvious which of these two should be a bank clerk and which a police officer. Throughout the book, I will call this the MFEO (made for each other) game since it represents scenarios where individuals fit well into complementary social roles. This game, like its corollary in the previous section, has a more functional character and less of a conventional one, since there is a preferable outcome for both players.

The game in (b) represents scenarios where actors need to take complementary actions, but one is preferable to both. For example, perhaps all members of a company would like to be the CEO, rather than the lowly clerk. When getting drinks at Peet's, everyone would like to order first, rather than second. In dividing labor, perhaps everyone prefers a job that gives them direct control over food resources. I will call this game the leader–follower game for scenarios like the first one mentioned here—where both actors would like to play a social role that has higher status or benefits. This is the first complementary coordination game we are considering that has a conflictual character. As will become clear later, these games are of special interest when it comes to inequity.

At this point, I have introduced quite a few coordination games, each corresponding to slightly different types of coordination problems. At the risk of overwhelming readers, I will discuss one further game that has a coordination character, but is less purely a coordination game. This is because actors have preferences about what happens when they do not coordinate, and these preferences can influence outcomes in this strategic scenario.[26]

Hawk–dove is shown in Figure 1.5. This is a game where two players have the choice to be aggressive or passive. If two aggressive types (Hawks) meet, they fight, to their detriment. If an aggressive type meets a passive type (Dove), the aggressive type takes advantage of the situation and extracts extra resources or benefits. If two Doves meet they both act passively and neither benefits at the other's expense.[27]

This game can also be interpreted as having to do with division of resources. Under this interpretation, the two parties will divide a resource of predetermined size (in Figure 1.5, this size is 4), unless they are both aggressive types. If both bargain passively, they divide the resource equally. If one is aggressive, they take home a greater portion of the resource. This could represent a situation, for example, where members

		Player 2	
		Hawk	Dove
Player 1	Hawk	0, 0	3, 1
	Dove	1, 3	2, 2

Figure 1.5 Payoff table for hawk–dove

[26] I am being a bit imprecise here. A payoff of 0 in a game—which has been the payoff for non-coordination outcomes in the games so far—actually does correspond to a preference. Zero is better than −3 and worse than 3, for example. It is more precise to say that actors have preferences over which of the two non-coordination outcomes they arrive at.

[27] This game is sometimes called "chicken," and is interpreted in the following way. Two drag racers decide to play chicken. Both hurtle toward each other and have the choice to either swerve aside, or drive straight onward. If both drive straight (choose Hawk), they crash, which is obviously bad for both. If both turn, they do not crash, which is better, but neither improves their reputation as tough. If one drives straight and the other turns, the one who chose straight looks cool, while the other looks like a loser.

of a household are each incentivized to monopolize resources under the risk that their partner will instead.

Hawk–dove has two Nash equilibria—Hawk vs. Dove and Dove vs. Hawk. Again, these equilibria have a complementary coordination character. Both parties take complementary roles in equilibrium. However, those playing Dove would actually prefer that their opponents play Dove as well. In other words, they would like to be in a more egalitarian arrangement, even though this arrangement is not an equilibrium.[28]

Now that these games are on the table I will say something more general about when a game is a complementary coordination game. Figure 1.6 shows a payoff table, but with variables instead of numbers as entries. The usual requirements for a (two-player, two-strategy) game to be a complementary coordination game are that $e > a$, $c > g$, $d > b$, and $f > h$. These conditions hold for all of the complementary coordination games introduced so far. They mean that the Nash equilibria of the game will always be the complementary strategies B vs. A and A vs. B.

I have now introduced the games that will be employed in the first half of the book—a representation of resource division called the Nash demand game will be the primary focus of the second half, and I'll introduce it there. As mentioned, complementary coordination games will be of particular interest, and will be the main games employed to represent the sorts of situations in which social categories can facilitate coordination.

1.4.3 Why division of labor is a coordination game

In introducing coordination problems, I claimed that division of labor is a classic case of a complementary coordination game, but this claim

		Player 2	
		A	B
Player 1	A	a, b	c, d
	B	e, f	g, h

Figure 1.6 A general payoff table for a two–person, two-strategy game

[28] The equilibria in hawk–dove do not meet the Lewis (1969) definition of a coordination equilibrium which is, "a combination in which no one would have been better off had *any one* agent acted otherwise, either himself or someone else" (14, emphasis his). Sugden (2000) calls these *mutual benefit equilibria*.

needs a bit more filling in. In particular, we need to explore why there is some coordination benefit to actors taking complementary roles in jointly beneficial labor.

Blood and Wolfe (1960) point out that "To a considerable extent, the idea of shared work is incompatible with the most efficient division of labor. Much of the progress of our modern economy rests upon the increasing specialization of its division of labor. A specialist is able to develop his particular skills in a way a jack-of-all-trades never can" (48). In fact, the complementary coordination games we have been looking at, when applied to the case of division of labor, implicitly make the assumption that Blood and Wolfe pull out here. There is no "jack-of-all-trades" strategy in these games. Actors can succeed only by choosing complementary strategies.[29]

We could consider instead, though, a coordination game with three options——two division-of-labor choices and one "jack-of-all-trades" choice where actors both perform some of each available task. Figure 1.7 shows such a game. Here we can see that actors get good payoffs (3) when they perform complementary tasks. When actors do not specialize, they get a less preferable payoff, 2, and when jack-of-all-trades types meet specialists, they each get a payoff of 1 since the various jobs are all being performed, but not at the right levels.

If tasks are particularly difficult to learn, as many traditional skills are, the payoff for the jack-of-all-trades equilibrium of this game will be very low compared to that for the coordination equilibria. In these cases, the model in Figure 1.7 will look increasingly like the dancing game. For

		Player 2		
		A	B	A-B
Player 1	A	0, 0	3, 3	1, 1
	B	3, 3	0, 0	1, 1
	A-B	1, 1	1, 1	2, 2

Figure 1.7 A division-of-labor game with an egalitarian, but less efficient, option

[29] Notably, there is some empirical data suggesting that in traditional societies, failure to appropriately divide labor often leads to marital dissolution (Betzig, 1989). Furthermore, Gurven et al. (2009) find that among the Tsimane forager-horticulturalists of Bolivia, spouses choose partners in part based on their working abilities, spouses divide labor, and this division provides benefits to both members of the pairing, though the benefits may not be equal. They also find that higher-productivity pairs have more offspring. This data underscores the importance of complementary coordination to the success of a household.

this reason—that most human labor requires learned specialization—complementary coordination games effectively represent many sorts of gendered interactions. In game theoretic models from economics of the gendered division of labor, as we will see, complementary coordination games are a central paradigm for this reason.[30]

So, division of labor is a complementary coordination game, but this does not tell us what this has to do with gender. In the next section, I will make clear why correlative and complementary coordination problems pose different sorts of challenges to coordinating groups, and why this creates a role for social categories to play.

1.5 Pairs and Populations

How do coordination problems like those represented by the games above get solved? There are many answers to this question. When it comes to one-on-one human interactions, though, one obvious way to solve such problems is through communication, or else the development of a convention via individual learning.

Imagine that you and I are in a situation well-modeled by an MFEO game. Perhaps we are researchers synthesizing a new drug. You like pipetting, while I prefer working the centrifuge. I communicate to you which role I prefer to play, you communicate that you prefer the other, and the problem is solved. This sort of verbal negotiation is obviously more complicated in situations where our preferences do not line up so neatly. Suppose we are spouses and while one of us likes the movies, the other prefers a long walk. This scenario can be well modeled by the Bach–Stravinsky game. Despite the conflict of interest, it does not make sense to argue every evening about what we will do. Instead, we might develop a convention. Maybe we always go to the movies, or the reverse. An equitable solution is also available—switch movies and walks every other day, or week, or month—though this solution is less simple in that it requires us to remember what we did last, and suffer mild inconveniences from changing behaviors.

[30] Relatedly, Nakahashi and Feldman (2014) find that division of labor evolves in human groups when the benefits of acquiring skills are steeper, meaning that the situation more closely accords to a complementary coordination game.

One thing to note is that when solving coordination problems one on one, there is no real difference in solving a complementary problem from solving a correlative problem. Indeed, as mentioned earlier in the chapter, Lewis calls the difference between them "spurious." In either case, explicit discussion or the emergence of a private convention can solve the problem. One way to think about this is that in such cases there is always a piece of information that actors can use to break symmetry and choose roles—I am me and you are you. What I will point out now is that this is not the case when one considers many interacting individuals, all solving the same coordination problem.

Imagine a group where members periodically engage in two-person coordination games, but with different partners. For example, individuals might live with multiple partners over the course of their lives and have to divide labor with all of them. People regularly conduct business interactions with strangers and must decide whether to behave aggressively or passively during these interactions. And, in more mundane cases, group members engage in paired coordination problems such as choosing who will go first through a subway door, who will order their coffee first, which side of the sidewalk to walk down, etc.

What happens when a group of people play correlative coordination problems (ones, remember, where they must take the same actions)? This sort of problem can be solved when all group members adopt the same strategy in response to the problem—all choosing A, or all choosing B. (All driving on the left, or on the right.) If they do so, whenever any group members meet they will play a Nash equilibrium. Indeed, in real societies, these are the sorts of conventional solutions we tend to see emerging to solve these problems. We would be very surprised to see a country where some people drive on the left side of the road and some on the right, or a tight-knit community where people all speak mutually unintelligible languages.

The nice thing about correlative coordination problems is that they *can* be solved this way—with a single, broad convention that every member of a society should follow. In cases that are well represented by the Bach–Stravinsky game, where actors prefer to coordinate, but have different preferences about how to do so, some members of the society will be less happy with the social convention than others, but nonetheless in every case people will manage to coordinate, and benefit from doing so, as long as they follow the rule.

In complementary coordination problems, things are not so simple. Suppose every member of a group decided to take the same action by stepping forward in the dancing game. No one would ever be happy, because in each pairing actors would mis-coordinate. Likewise, if everyone in a society took the cooking role in a household, and no one the cleaning role, every household would have too much food and be completely filthy. Or imagine if everyone decided to play the role of the CEO of the company, or if everyone was socially aggressive, and never took a more passive or deferential role, or everyone tried to follow in all social interactions and never to lead. It is clear that there is no way for everyone to take the same role and do well, but there is something more to be said. For complementary coordination problems, there is no profile of strategies that a group can adopt that ensures the group always succeeds in coordinating. To see this, imagine a group that has at least two people playing strategy A—whenever they meet they fail to coordinate. Now imagine a group with at least two people playing strategy B. Again, they fail to coordinate whenever they meet. So, any group with more than two people (i.e., more than one person playing A and one playing B) is guaranteed to have pairings that fail to coordinate.

The distinction between these two sorts of situations can be illustrated by an example. Consider greetings in various societies. These are conventional, and take the form of handshakes, cheek kisses, multiple cheek kisses, waves, hugs, bows, and the like. All these behaviors are ones that both parties can perform identically upon meeting and successfully coordinate. In contrast, consider a greeting that is asymmetric, so that the two parties have to perform different roles to successfully carry it out. Perhaps one party must wave while the other bows, or the two parties shake right hand and left hand. It is perhaps noteworthy that standard greetings do not tend to take these forms. We see societies adopting conventions that simultaneously *create* the right sort of coordination problem (correlative) and solve it. Exceptions are greetings performed between actors of two observably different types. One example is the greeting where a lady puts out her hand and a gentleman kisses it. Or consider the convention of bowing in Japan. The lower-status actor must bow lower than the high-status actor.

A central observation of this book is that because populations cannot solve complementary coordination problems by adopting one conventional role, there is a function that social categories can play in these cases. In particular, actors can use social categories to identify what sort of role each actor should play in social interaction. This is not to say that categories provide the only sorts of solution to population-wide coordination problems; but they do provide a solution, and one that seems to crop up regularly in many real-world populations. In particular, we can conceptualize categories as providing an asymmetry necessary to redescribe a complementary game as a correlative game, a la Lewis. In the dancing problem one could relabel the possible choices as "step forward if you are a woman and back if you are a man" and "step forward if you are a man and back if you are a woman." Then the problem is solved when the group settles on one of these compound choices.

• • •

In this chapter, we introduced the central case that this half of the book will work around—that of gendered division of labor. As we saw, gendered division of labor raises an explanandum: why is there such regularity across cultures in the sense that humans always divide labor by gender? (And why is there such irregularity in the sense that these divisions vary widely from society to society?)

In order to start addressing this explanandum, we began to build a set of game theoretic models. I argued that division of labor is a coordination problem, and, in particular, a complementary coordination problem, or one where actors must take complementary roles to solve it. As we saw, this particular sort of coordination problem poses a special challenge to populations of actors. How do those engaged in it break symmetry and decide who will take what role? As we will see in the next chapter, social categories, such as gender, can provide solutions to this sort of problem by creating asymmetries between actors who are men and women, or black and white, or young and old, or brahmin and dalit. These asymmetries can improve group coordination, even when there is nothing relevantly different about members of the particular categories at hand. In the case of gendered division of labor, as we will see, gender provides just such a symmetry breaker.