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Donkey anaphora is in-scope binding*

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Abstract We propose that the antecedent of a donkey pronoun takes scope over and binds the donkey pronoun, just like any other quantificational antecedent would bind a pronoun. We flesh out this idea in a grammar that compositionally derives the truth conditions of donkey sentences containing conditionals and relative clauses, including those involving modals and proportional quantifiers. For example, an indefinite in the antecedent of a conditional can bind a donkey pronoun in the consequent by taking scope over the entire conditional. Our grammar manages continuations using three independently motivated type-shifters, Lift, Lower, and Bind. Empirical support comes from donkey weak crossover (**He beats it if a farmer owns a donkey*): in our system, a quantificational binder need not c-command a pronoun that it binds, but must be evaluated before it, so that donkey weak crossover is just a special case of weak crossover. We compare our approach to situation-based E-type pronoun analyses, as well as to dynamic accounts such as Dynamic Predicate Logic. A new 'tower' notation makes derivations considerably easier to follow and manipulate than some previous grammars based on continuations.

Keywords: donkey anaphora, continuations, E-type pronoun, type-shifting, scope, quantification, binding, dynamic semantics, weak crossover, donkey pronoun, variable-free, direct compositionality, D-type pronoun, conditionals, situation semantics, c-command, dynamic predicate logic, donkey weak crossover

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1 Introduction

A donkey pronoun is a pronoun that lies outside the antecedent of a conditional (or outside the restrictor of a quantifier), yet covaries with some quantificational element inside it, usually an indefinite.

(1) a. If a farmer owns a donkey, he beats it.
    b. Every farmer who owns a donkey beats it.

Evans 1977 made it standard to assume that the indefinite *a donkey* cannot take scope over the pronoun *it* in (1), and therefore cannot bind it, at least not in the ordinary sense of binding. To the contrary, we claim that the relationship between *a donkey* and *it* in (1) *seems* like binding because it *is* just binding. More specifically, we argue that the indefinites in (1) do take scope over their donkey pronouns, and bind them in the ordinary way, just as a quantifier such as *everyone* takes scope over and binds the pronoun in the bound reading of *Everyone$_i$ thinks he$_i$ is intelligent*.

As far as we know, no one has ever advocated an in-scope binding analysis of donkey anaphora. It turns out that the right theory of scope and binding makes an in-scope binding analysis not only feasible but straightforward.

1.1 Why not?

One reason people discounted the possibility of in-scope binding in examples like those in (1) is a tradition going back at least to Evans 1977 and May 1977 that says that the scope of all quantifiers is clause bounded.

(2) a. *[Everyone$_i$ arrived] and [she$_i$ spoke].
    b. A woman$_i$ arrived and she$_i$ spoke.

If *everyone* can only take scope over the first clausal conjunct in (2a), that explains why it cannot bind the pronoun in the second. But it has been known at least since Farkas 1981 (see Szabolcsi 2007 for a fuller picture) that the scope options for indefinites are strikingly different from those of *every* and certain other quantifiers. And in fact when *everyone* in (2a) is replaced with an indefinite, as in (2b), covariation becomes possible. We will assume, along with many others, that indefinites can take scope wider than their minimal clause, though unlike most, we do not provide any special mechanism like choice functions (e.g., Reinhart 1997) or singleton restricted domains (Schwarzschild 2002).

A second common reason to reject a binding relationship in (1) is the widespread belief that quantificational binding requires c-command.

(3) a. [Everyone$_i$'s mother] loves him$_i$.
b. [Someone from every city$_i$] hates it$_i$.

The universal quantifiers in (3) do not c-command the pronouns that they seem to bind. Büring (2004) concludes that these pronouns, too, are cases of donkey anaphora, and analyzes them using situations. Shan & Barker (2006) claim that what examples like (3) show is that c-command simply isn't required for quantificational binding. Without concentrating on discussing and defending this claim, we use it in this paper to treat a wide range of examples to good effect.

So we'll assume that the indefinites in (1) can take scope over their respective donkey pronouns and bind them. However, we do not get the desired truth conditions if we give the indefinites in (1) scope over the entire sentence.[1]

(4) a. If a donkey eats, it sleeps.
b. $\exists d.\, (\mathbf{donkey}\, d) \wedge \big((\mathbf{eats}\, d) \rightarrow (\mathbf{sleeps}\, d)\big)$

If the indefinite takes scope over the entire sentence, we get the truth conditions for (4a) given in (4b). But as Evans (1980: 342) points out, the most natural reading of (4a) is not that there is some donkey that sleeps when it eats, but rather that when *any* donkey eats, that donkey sleeps. Evans concludes that the indefinite must take scope inside the antecedent clause, leaving the pronoun unbound.

Evans' conclusion is hasty. We should conclude only that the indefinite must take scope under the scope of the *if*. Since the *if* takes scope over the entire conditional, it is feasible for the indefinite to also take scope over the entire conditional.

1.2 Sketch of the account

For a rough idea of how the fragment below achieves this result, consider that many treatments of donkey anaphora analyze the conditional as introducing some generic or universal quantification, giving rise to paraphrases such as

1 We adopt the standard convention that a dot following a binding operator indicates that the scope of the operator extends as far to the right as possible. Thus, $\exists d.\, \phi \wedge \psi$ is shorthand for $\exists d(\phi \wedge \psi)$.

"For all donkeys d, (eats d) → (sleeps d)". (We will discuss more sophisticated modal treatments of the conditional in section 3.3.) Instead of the arrow, as in A → B, we use the logically equivalent expression $\neg(A \wedge \neg B)$. As long as the outer negation takes wide scope, we have (5a) as the truth conditions for (4a).

(5) a. $\neg\exists d.\, ((\textbf{donkey}\, d) \wedge (\textbf{eats}\, d) \wedge \neg(\textbf{sleeps}\, d))$
b. $\forall d.\, \neg((\textbf{donkey}\, d) \wedge (\textbf{eats}\, d) \wedge \neg(\textbf{sleeps}\, d))$

The indefinite interacts with the negation to give the impression of universal force, since (5a) is logically equivalent to (5b).

On the standard treatment, then, *if* is quantificational, but does not participate in scope ambiguities in the same way as other quantificational operators. On our proposal, the scope of *if* interacts with other scope-taking elements in the normal way. Section 3 shows how to arrive at the analysis in (5) compositionally.

A similar challenge arises in the case of donkey anaphora from relative clauses.

(6) a. Most men who own a car wash it on Sundays.
b. Every man who owns a donkey beats it.

Evans (1977: 117) provides an influential assessment:

> If the sentence is to express the intended restrictions upon the major quantifier—that of being a car- or donkey-owner—it would appear that the second quantifier must be given a scope which does not extend beyond the relative clause, and this rules out a bound variable interpretation of the later pronouns.

Once again, appearances are deceiving: the scope of the indefinite need not be limited to the relative clause, even on the intended reading. Section 4 shows how an independently motivated lexical entry for *every* gives rise to the following truth conditions.

(7) a. Every farmer who owns a donkey beats it.
b. $\neg\exists x \exists y.\, \textbf{donkey}\, y \wedge ((\textbf{farmer}\, x \wedge \textbf{owns}\, y\, x) \wedge \neg(\textbf{beats}\, y\, x))$

In section 4, we also generalize this analysis to strong and weak readings of the indefinite with arbitrary quantifiers.

In sum, as long as an indefinite can take scope outside its minimal clause (possibly a relative clause), donkey anaphora falls out from independently motivated compositional semantics.

1.3 Supporting evidence: donkey weak crossover

We cannot respond to all of the vast literature on donkey anaphora in the compass of a single paper. Nevertheless, we should and will evaluate our proposal against some prominent alternatives. Elbourne (2005) presents a recent survey of approaches to donkey anaphora. His own proposal is carefully motivated and empirically robust, and provides stiff competition for any new theory of donkey anaphora. Elbourne analyzes donkey pronouns as covert definite descriptions ("D-type" pronouns) that seek their referents within severely restricted situations.

One challenge for the D-type approach is the celebrated bishop problem, based on examples such as (8).

(8) If a bishop$_i$ meets a bishop$_j$, he$_i$ blesses him$_j$.

As shown below in section 3.1, bishop sentences are perfectly straightforward on a binding account: the first indefinite binds one pronoun, and the second indefinite binds the other pronoun.

Elbourne argues specifically against dynamic treatments and variable-free treatments. Since our system can be seen as both dynamic and variable-free, we will consider several of Elbourne's arguments. One telling argument that Elbourne advances against Groenendijk & Stokhof's (1989; 1991) dynamic treatment (to be discussed in section 7) involves disjunctive antecedents.

(9) If a farmer owns a donkey or a goat, he beats it.

Given the independently motivated theory of generalized disjunction in Barker 2002, we show in section 5 that such examples fall out without further stipulation in our system. Thus Elbourne's arguments against dynamic treatments of donkey anaphora apply not in general but only to specific dynamic theories.

One appeal of dynamic semantics is that at least quantificational anaphora is clearly sensitive to order.

(10) a. A woman$_i$ arrived and she$_i$ spoke.
b. *She$_i$ arrived and a woman$_i$ spoke.

Only the example (10a), in which the indefinite precedes the pronoun, allows binding.

An in-scope binding analysis of donkey anaphora, then, predicts similar order sensitivity. It is well known (e.g., Büring 2004) that donkey anaphora out of a DP exhibits crossover effects.

(11) a. Most women who have a son$_i$ love his$_i$ father.
b. *His$_i$ father loves most women who have a son$_i$.

Crossover occurs when a quantificational expression (*most women who have a son*) takes scope over a pronoun that linearly precedes it. It is called crossover because, on a movement approach such as Quantifier Raising, the quantificational DP crosses over the position of the pronoun. As the contrast in (11) shows, donkey anaphora requires the indefinite to precede the covarying pronoun, even though the quantifier *most* takes scope over the entire sentence in both (11a) and (11b).

Büring derives the contrast in (11) from his assumption that a DP that contains a donkey antecedent must c-command the donkey pronoun. Without invoking c-command, we explain donkey weak crossover just as we explain weak crossover.

What is less well-known is that donkey anaphora in a conditional is sensitive to order just as donkey anaphora out of a DP is.

(12) a. If a farmer owns a donkey, he beats it. (= (1a))
b. *?If he owns it, a farmer beats a donkey.

The D-type account correctly predicts that anaphora from the antecedent into the consequent is good, as in the standard sentence repeated in (12a), and that similar anaphora from the consequent into the antecedent is significantly more difficult, as in (12b).

Although the contrast in (12) appears to be reliable across speakers, some judge (12b) as not so bad in absolute terms. Indeed, some cases of donkey cataphora are unexpectedly good,[2] as in this example from Chierchia (1995: 129):

(13) If it is overcooked, a hamburger usually doesn't taste good.

However, if the donkey antecedent is not in subject position, or if the sentence is episodic (Reinhart 1983: 115–116), acceptability degrades significantly:[3]

(14) a. *If it is overcooked, John doesn't like a hamburger.
b. *If John overcooked it, a hamburger tasted bad.

2 That is, unexpected given our analysis. We claim that c-command is not necessary for quantificational anaphora, but c-command or something like it could still facilitate some types of cataphora, as in Reinhart's (1983) *Near him, John saw a snake.*

3 In order to guarantee that we have cataphora, it is important to consider the examples in (14) in a context in which hamburgers have not been given as a pre-established topic. In (14a), one way to achieve this is by putting the default nuclear stress pitch accent on *HAMburger*.

As predicted by our analysis, if the order of the *if* clause and the main clause are reversed, the donkey anaphora becomes effortless.

In any case, if we return the *if* clause to its canonical position as a subordinating conjunction, as in (15), judgments are considerably more robust.

(15) a. A farmer beats a donkey if he owns it.
b. *He beats it if a farmer owns a donkey.

The anaphora from the consequent into the antecedent in (15a) is good, but the anaphora from the antecedent into the consequent in (15b) is bad. An account based on situations at best fails to predict this contrast.

1.4 Dynamic semantics?

Before getting to the analysis, a brief note on our conception of dynamic semantics. We consider our analysis dynamic, but not quite in the traditional sense of, say, Heim 1982 or Groenendijk & Stokhof 1991. There, sentence meanings are conceived as context update functions: functions that map an initial information state to an updated information state. On our view, the essence of a dynamic analysis is a principled distinction between the side effects of an expression and its main semantic contribution (Shan 2005). Here, the main contribution is to local argument structure, and the side effects are potentially long-distance semantic relationships, including scope-taking and binding. Our denotations are the ordinary ones found in any extensional semantics: individuals, truth values, and functions built from them. There is no need to assume that expressions directly manipulate the pragmatic context, whether it is a set of worlds, a set of assignment functions, or another kind of information state. Thus on our analysis, expressions can be viewed as denoting updates, but what gets updated is the semantic context, not the utterance context.

See section 7 for a more detailed comparison with other dynamic treatments of donkey anaphora, including Groenendijk & Stokhof's (1989) Dynamic Montague Grammar and Shan's (2001) and de Groote's (2006) variable-free analyses based on continuations.

2 Fragment

Compositional truth conditions are the crux of our claim, so we will present our analysis in detail as a concrete fragment. The fragment is directly compositional and variable-free in the sense of Jacobson 1999, although that plays no special role in the explanations below. More crucial is our use of continuations, heralded by the fact that we give a categorial grammar with two flavors of slashes: not just \ and /, which encode syntactic adjacency on the left and on the right respectively, but also $\backslash\!\!\backslash$ and $/\!\!/$, which, as we will see, govern scope-taking where an in-situ quantifier is pronounced and where it takes scope.

The fragment here is identical to a part of the system presented in Shan & Barker 2006 (see the appendix below for details of the correspondence). However, the presentation here is different and, we hope, simpler. There are three sources of simplicity. First, we need only present the mechanisms for scope-taking and binding, not *wh*-movement. Second, although the system relies heavily on continuations, we do not pause here to motivate them or discuss their theory; such discussions can be found in Barker 2002, Shan 2005, and Shan & Barker 2006. Third, in this paper we adopt a notation that makes the derivations far easier to understand compared with the derivations in Shan & Barker 2006.

Our new notation consists of a syntactic part and a semantic part. In syntactic categories, we write $B/\!\!/(A\backslash\!\!\backslash C)$ vertically as $\dfrac{B \mid C}{A}$ and omit the double slashes. Here A, B, C can be any categories. For example, we write the category $\mathrm{S}/\!\!/(\mathrm{DP}\backslash\!\!\backslash\mathrm{S})$ as $\dfrac{\mathrm{S} \mid \mathrm{S}}{\mathrm{DP}}$. In semantic values, we write $\lambda\kappa.\, f[\kappa(x)]$ vertically as $\dfrac{f[\ ]}{x}$ and omit κ. Here x can be any expression, and $f[\ ]$ can be any expression with a hole $[\ ]$. Free variables in x can be bound by binders in $f[\ ]$. For example, we write the value $\lambda\kappa.\, \neg\exists x.\, \kappa(\mathbf{mother}\, x)$ as $\dfrac{\neg\exists x.\, [\ ]}{\mathbf{mother}\, x}$, in which the variable x in $\mathbf{mother}\, x$ is bound by $\exists x$. We call the original style 'linear' notation, and the new style 'tower' notation.

This tower notation will become clearer as we use it below. We first derive quantificational sentences with linear (surface) scope, then turn to inverse scope and binding.

2.1 The tower notation: taking scope

We'll stack information about each expression like this:

(16)
$$\begin{array}{cc} \mathrm{DP} & \text{syntactic category} \\ \textit{John} & \text{expression} \\ \mathbf{j} & \text{semantic value} \end{array}$$

In the simplest case, syntactic combination proceeds as in standard combinatory categorial grammar. For example, we derive *John left* as follows.

(17)
$$\left(\begin{array}{cc} \mathrm{DP} & \mathrm{DP}\backslash\mathrm{S} \\ \textit{John} & \textit{left} \\ \mathbf{j} & \mathbf{left} \end{array}\right) = \begin{array}{c} \mathrm{S} \\ \textit{John left} \\ \mathbf{left}\,\mathbf{j} \end{array}$$

As usual, the category under the slash (here DP) cancels with the category of the argument expression, and the semantics is function application.

Quantificational expressions have an extra layer on top of their syntactic category and on top of their semantic value. For example, below is a simplistic lexical entry for *everyone*.

(18)
$$\begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}} \\ \textit{everyone} \\ \dfrac{\forall y.\,[\ ]}{y} \end{array}$$

The syntactic category can be read counterclockwise, starting below the horizontal line:

(19)
$$\dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}} \quad \text{means} \quad \dfrac{\text{. . . to form an S.} \;\Big|\; \text{and takes scope at an S. . .}}{\text{The expression functions in local syntax as a DP,}}$$

Saying that a DP like *everyone* "takes scope at an S" means that its nuclear scope is formed from an enclosing expression of category S.

We can derive a simple quantificational sentence as follows.

(20)
$$\left(\begin{array}{cc} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}} & \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}\backslash\mathrm{S}} \\ \textit{everyone} & \textit{left} \\ \dfrac{\forall y.\,[\ ]}{y} & \dfrac{[\ ]}{\mathbf{left}} \end{array}\right) = \begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{S}} \\ \textit{everyone left} \\ \dfrac{\forall y.\,[\ ]}{\mathbf{left}\,y} \end{array}$$

In the general case, we have the following modes of combination.

(21)
$$\left(\begin{array}{c} C \,|\, \boldsymbol{D} \\ \hline A/\boldsymbol{B} \\ \textit{left-exp} \\ g[\ ] \\ \hline f \end{array} \quad \begin{array}{c} \boldsymbol{D} \,|\, E \\ \hline \boldsymbol{B} \\ \textit{right-exp} \\ h[\ ] \\ \hline x \end{array}\right) = \begin{array}{c} C \,|\, E \\ \hline A \\ \textit{left-exp right-exp} \\ g[h[\ ]] \\ \hline f(x) \end{array}$$

$$\left(\begin{array}{c} C \,|\, \boldsymbol{D} \\ \hline \boldsymbol{B} \\ \textit{left-exp} \\ g[\ ] \\ \hline x \end{array} \quad \begin{array}{c} \boldsymbol{D} \,|\, E \\ \hline \boldsymbol{B}\backslash A \\ \textit{right-exp} \\ h[\ ] \\ \hline f \end{array}\right) = \begin{array}{c} C \,|\, E \\ \hline A \\ \textit{left-exp right-exp} \\ g[h[\ ]] \\ \hline f(x) \end{array}$$

Below the horizontal lines, combination proceeds simply as in combinatory categorial grammar: in the syntax, B combines with A/B or $B\backslash A$ to form A; in the semantics, x combines with f to form $f(x)$.

Above the lines is where the combination machinery for continuations kicks in. The syntax combines the two pairs of categories by a kind of cancellation: the D on the left cancels with the D on the right. The semantics combines the two expressions with holes by a kind of composition: we plug $h[\ ]$ to the right into the hole of $g[\ ]$ to the left, to form $g[h[\ ]]$. The expression with a hole on the left, $g[\ ]$, always surrounds the expression with a hole on the right, $h[\ ]$, no matter which side supplies the function and which side supplies the argument below the lines. This fact expresses the generalization that the default order of semantic evaluation is left-to-right.

Type-shifter 1 of 3: Lift Comparing the analysis above of *John left* in (17) with that of *Everyone left* in (20) reveals that *left* has been given two distinct values. The first, simpler value is the basic lexical entry, and we derive the more complex value through the standard type-shifter Lift, proposed by Partee & Rooth (1983), Jacobson (1999), Steedman (2000), and many others.

(22)
$$\begin{array}{c} \mathrm{DP}\backslash\mathrm{S} \\ \textit{left} \\ \textbf{left} \end{array} \quad \begin{array}{c} \text{Lift} \\ \Rightarrow \end{array} \quad \begin{array}{c} \mathrm{S} \,|\, \mathrm{S} \\ \hline \mathrm{DP}\backslash\mathrm{S} \\ \textit{left} \\ [\ ] \\ \hline \textbf{left} \end{array}$$

In general, for any categories A and B and any value x, the following type-shifter is available.

(23)

$$\boxed{\begin{array}{ccc} & & \dfrac{B \mid B}{A} \\ A & \text{Lift} & \\ \textit{expression} & \Rightarrow & \textit{expression} \\ x & & \dfrac{[\ ]}{x} \end{array}}$$

Syntactically, Lift adds a layer with arbitrary (but matching!) syntactic categories. Semantically, it adds a layer with empty brackets.

Type-shifter 2 of 3: Lower The semantic value given above for *Everyone left* was $\dfrac{\forall x.\,[\ ]}{\textbf{left}\,x}$, which corresponds to the syntactic category $\dfrac{S \mid S}{S}$. To derive the syntactic category S and a semantic value with no horizontal line, we introduce the type-shifter Lower. In general, for any category A, any value x, and any semantic expression $f[\ ]$ with a hole $[\ ]$, the following type-shifter is available.

(24)

$$\boxed{\begin{array}{ccc} \dfrac{A \mid S}{S} & \text{Lower} & A \\ \textit{expression} & \Rightarrow & \textit{expression} \\ \dfrac{f[\ ]}{x} & & f[x] \end{array}}$$

Syntactically, Lower cancels an S above the line to the right with an S below the line. Semantically, Lower collapses a two-level meaning into a single level by plugging the value x below the line into the hole $[\ ]$ in the expression $f[\ ]$ above the line.[4] For example, applying Lower to the analysis above for

4 As the following examples show, this insertion may capture bound variables. This capture should not cause concern, since the equivalent system in Shan & Barker 2006 is presented entirely without the tower notation, and does not use this variable-capturing device. In linear notation, the semantics of the Lower type-shifter is simply $\lambda F.\, F(\lambda x.x)$. See the appendix for further details.

Everyone left gives

(25)
$$\begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{S}} \\ \textit{everyone left} \\ \dfrac{\forall y.\,[\;]}{\mathbf{left}\; y} \end{array} \quad \begin{array}{c}\text{Lower}\\ \Rightarrow\end{array} \quad \begin{array}{c} \mathrm{S} \\ \textit{everyone left} \\ \forall y.\,\mathbf{left}\; y \end{array}$$

As discussed in section 7, this type-shifter resembles a type-shifting rule proposed by Groenendijk & Stokhof (1989), and is characteristic of continuation-based systems in general (such as in the simulation theorem in Plotkin 1975).

We can now derive a sentence that contains more than one quantifier. Like the intransitive verb *left* above, the transitive verb *loves* is Lifted to match the levels of *someone* and *everyone*.

(26)
$$\begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}} \\ \textit{someone} \\ \dfrac{\exists x.\,[\;]}{x} \end{array} \left(\begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{(\mathrm{DP}\backslash \mathrm{S})/\mathrm{DP}} \\ \textit{loves} \\ \dfrac{[\;]}{\mathbf{loves}} \end{array} \quad \begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}} \\ \textit{everyone} \\ \dfrac{\forall y.\,[\;]}{y} \end{array} \right)$$

$$= \begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{S}} \\ \textit{Someone loves everyone} \\ \dfrac{\exists x.\,\forall y.\,[\;]}{\mathbf{loves}\; y\; x} \end{array} \quad \begin{array}{c}\text{Lower}\\ \Rightarrow\end{array} \quad \begin{array}{c} \mathrm{S} \\ \textit{Someone loves everyone} \\ \exists x.\,\forall y.\,\mathbf{loves}\; y\; x \end{array}$$

Note that this derivation gives linear scope.

The lexical entry for *someone* just used generalizes to an entry for the indefinite determiner *a*.

(27)
$$\begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}} \Big/ \mathrm{N} \\ \mathrm{a} \\ \lambda P.\, \dfrac{\exists x.\, Px \wedge [\;]}{x} \end{array}$$

This generalization shows how a tower can occur as a subpart of a syntactic category or semantic value, because a tower is just shorthand for a category or value. (Section 3.1 shows *a* in action.)

2.2 Multiple layers and inverse scope

Understanding how inverse scope works will turn out to be important later for handling examples involving multiple donkey pronouns.

In order to arrive at inverse scope, we must apply the Lift operator to lower levels of an expression. For example, beginning with the lexical entry for *someone*, there are two distinct ways that we can apply Lift. The first way targets the entire category $\frac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}}$ and the entire meaning $\frac{\exists x.\,[\;]}{x}$, and contributes the bold S’s and brackets in the result below, on the top level. The existential quantifier ends up on the middle level of the semantic tower.

(28)
$$\begin{array}{c} \mathrm{S}\,|\,\mathrm{S} \\ \hline \mathrm{DP} \\ \textit{someone} \\ \exists x.\,[\;] \\ \hline x \end{array} \quad \overset{\text{Lift}}{\Rightarrow} \quad \begin{array}{c} \mathbf{S}\,|\,\mathbf{S} \\ \hline \mathrm{S}\,|\,\mathrm{S} \\ \hline \mathrm{DP} \\ \textit{someone} \\ \mathbf{[\;]} \\ \hline \exists x.\,[\;] \\ \hline x \end{array}$$

The second way targets only the lower-level category DP in the syntax and the lower-level meaning x in the semantics, replacing them with Lifted versions without disturbing the rest of the expression. This way contributes the bold S’s and brackets in the result below, on the middle level. This time, crucially, the existential quantifier ends up on the top level of the semantic tower.[5]

(29)
$$\begin{array}{c} \mathrm{S}\,|\,\mathrm{S} \\ \hline \mathrm{DP} \\ \textit{someone} \\ \exists x.\,[\;] \\ \hline x \end{array} \quad \overset{\text{Lift}}{\Rightarrow} \quad \begin{array}{c} \mathrm{S}\,|\,\mathrm{S} \\ \hline \mathbf{S}\,|\,\mathbf{S} \\ \hline \mathrm{DP} \\ \textit{someone} \\ \exists x.\,[\;] \\ \hline \mathbf{[\;]} \\ \hline x \end{array}$$

5 More technically, if $A = \dots A_0 \dots$ and $B = \dots B_0 \dots$ are two tower categories that differ only in the categories A_0 and B_0 at their bottoms, and some type-shifter T shifts A_0 to B_0, then T also shifts A to B. Analogously, if $x = \dots x_0 \dots$ and $y = \dots y_0 \dots$ are two tower meanings that differ only in the expressions x_0 and y_0 at their bottoms, and some type-shifter T shifts x_0 to y_0, then T also shifts x to y.

Other type-shifters can also target lower levels of an expression. For example, Lower can apply to the bottom two levels of a three-level expression.

(30)
$$\begin{array}{c} \begin{array}{c|c} B & C \\ \hline A & \mathbf{S} \\ \hline \end{array} \\ \mathbf{S} \\ \textit{expression} \\ \begin{array}{c} g[\;] \\ \hline f[\;] \\ \hline x \end{array} \end{array} \quad \overset{\text{Lower}}{\Rightarrow} \quad \begin{array}{c} \begin{array}{c|c} B & C \\ \hline \end{array} \\ A \\ \textit{expression} \\ \begin{array}{c} g[\;] \\ \hline f[x] \end{array} \end{array}$$

Furthermore, binary combination can also target lower levels of a pair of expressions. In other words, binary combination generalizes to multilevel derivations:

- At the bottom level, the syntax cancels a slash while the semantics applies a function. The category of the argument must match the category under the slash (shown as ***B*** below).
- At each level above, the syntax cancels adjacent categories while the semantics composes expressions with holes. The adjacent categories must match at each level (shown as ***D*** and ***G*** below in the case of two levels).

(31)
$$\left(\begin{array}{cc} \begin{array}{c} \begin{array}{c|c} F & \boldsymbol{G} \\ \hline C & \boldsymbol{D} \\ \hline \end{array} \\ A/\boldsymbol{B} \\ \textit{left-exp} \\ \begin{array}{c} i[\;] \\ \hline g[\;] \\ \hline f \end{array} \end{array} & \begin{array}{c} \begin{array}{c|c} \boldsymbol{G} & H \\ \hline \boldsymbol{D} & E \\ \hline \end{array} \\ \boldsymbol{B} \\ \textit{right-exp} \\ \begin{array}{c} j[\;] \\ \hline h[\;] \\ \hline x \end{array} \end{array} \end{array}\right) = \begin{array}{c} \begin{array}{c|c} F & H \\ \hline C & E \\ \hline \end{array} \\ A \\ \textit{left-exp right-exp} \\ \begin{array}{c} i[j[\;]] \\ \hline g[h[\;]] \\ \hline f(x) \end{array} \end{array}$$

(32)

$$\left(\begin{array}{c} \begin{array}{c|c} F & \mathbf{G} \\ \hline C & \mathbf{D} \\ \hline \end{array} \\ \mathbf{B} \\ \textit{left-exp} \\ i[\ ] \\ \hline g[\ ] \\ \hline x \end{array} \quad \begin{array}{c} \begin{array}{c|c} \mathbf{G} & H \\ \hline \mathbf{D} & E \\ \hline \end{array} \\ \mathbf{B}\backslash A \\ \textit{right-exp} \\ j[\ ] \\ \hline h[\ ] \\ \hline f \end{array}\right) = \begin{array}{c} \begin{array}{c|c} F & H \\ \hline C & E \\ \hline \end{array} \\ A \\ \textit{left-exp right-exp} \\ i[j[\ ]] \\ \hline g[h[\ ]] \\ \hline f(x) \end{array}$$

As long as *someone* uses the first Lifting method and *everyone* uses the second, we end up with inverse scope.

(33)

$$\begin{array}{c} \begin{array}{c|c} \mathbf{S} & \mathbf{S} \\ \hline \mathrm{S} & \mathrm{S} \\ \hline \end{array} \\ \mathrm{DP} \\ \text{someone} \\ [\ ] \\ \hline \exists x.[\ ] \\ \hline x \end{array} \left(\begin{array}{c} \begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \mathrm{S} & \mathrm{S} \\ \hline \end{array} \\ (\mathrm{DP}\backslash\mathrm{S})/\mathrm{DP} \\ \text{loves} \\ [\ ] \\ \hline [\ ] \\ \hline \textbf{loves} \end{array} \quad \begin{array}{c} \begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \mathbf{S} & \mathbf{S} \\ \hline \end{array} \\ \mathrm{DP} \\ \text{everyone} \\ \forall y.[\ ] \\ \hline [\ ] \\ \hline y \end{array}\right) = \begin{array}{c} \begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \mathrm{S} & \mathrm{S} \\ \hline \end{array} \\ \mathrm{S} \\ \text{someone loves everyone} \\ \forall y.[\ ] \\ \hline \exists x.[\ ] \\ \hline \textbf{loves}\ y\ x \end{array}$$

$$\xRightarrow{\text{Lower (twice)}} \begin{array}{c} \mathrm{S} \\ \text{someone loves everyone} \\ \forall y.\exists x.\textbf{loves}\ y\ x \end{array}$$

To match the additional level produced by Lifting *someone* and *everyone*, we Lift the verb *loves* twice: first using the first Lifting method, then using either Lifting method. To reduce the combined three-level meaning to a single level, we first apply Lower to the bottom two levels, then to the resulting two-level meaning in its entirety.

In general, quantifiers on higher levels outscope lower quantifiers. Within a given level, as demonstrated in section 2.1, quantifiers on the left outscope quantifiers on the right.

2.3 Binding

There are two halves to any binding relationship: the pronoun must create a need to be bound, and the binder must satisfy that need. We accomplish the first half by giving pronouns a lexical entry that announces a functional dependence on an entity-type argument:

(34)
$$\begin{array}{c} \dfrac{\mathrm{DP} \rhd B \,\big|\, B}{\mathrm{DP}} \\ \textit{he} \\ \dfrac{\lambda y.\,[\;]}{y} \end{array}$$

Here B is any category, and the category $\mathrm{DP} \rhd B$ denotes functions from DP to B. For instance, we derive the sentence *He left* below.

(35)
$$\left(\begin{array}{c} \dfrac{\mathrm{DP} \rhd \mathrm{S} \,\big|\, \mathrm{S}}{\mathrm{DP}} \\ \textit{he} \\ \dfrac{\lambda y.\,[\;]}{y} \end{array} \quad \begin{array}{c} \dfrac{\mathrm{S} \,\big|\, \mathrm{S}}{\mathrm{DP}\backslash\mathrm{S}} \\ \textit{left} \\ \dfrac{[\;]}{\textbf{left}} \end{array} \right) = \begin{array}{c} \dfrac{\mathrm{DP} \rhd \mathrm{S} \,\big|\, \mathrm{S}}{\mathrm{S}} \\ \textit{He left} \\ \dfrac{\lambda y.\,[\;]}{\textbf{left}\, y} \end{array} \quad \begin{array}{c} \text{Lower} \\ \Rightarrow \end{array} \quad \begin{array}{c} \mathrm{DP} \rhd \mathrm{S} \\ \textit{He left} \\ \lambda y.\,\textbf{left}\, y \end{array}$$

On this view, sentences with free pronouns do not have the same category as sentences without pronouns (e.g., *John left*). This difference captures the fact that a sentence containing a free pronoun does not express a complete thought until the value of the pronoun has been specified, whether by binding or by the pragmatic context. However, the syntactic commonality of the two sentence types is still captured: below the lowest horizontal line, they are both S's, and it is only above the line that their semantic differences are recorded.[6]

Type-shifter 3 of 3: Binding The Bind type-shifter provides the second half of the binding relationship: it allows an arbitrary DP to control the value of a subsequent pronoun. For any categories A and B, any value x, and any semantic expression $f[\;]$ with a hole $[\;]$, the following type-shifter is available.

6 Like Jacobson (e.g., 1999), but unlike Dowty (2007), we assume that pronouns denote identity functions. Like Dowty, but unlike Jacobson, we explicitly recognize that pronouns literally take scope.

(36) $$\boxed{\begin{array}{ccc} \dfrac{A \mid B}{\text{DP}} & \text{Bind} & \dfrac{A \mid \text{DP} \rhd B}{\text{DP}} \\ \textit{expression} & \Rightarrow & \textit{expression} \\ \dfrac{f[\ ]}{x} & & \dfrac{f([\ ]x)}{x} \end{array}}$$

Syntactically, Bind annotates the top right syntactic category with “DP $\rhd$”, offering to bind a following pronoun. Semantically, Bind copies the value of the DP and feeds it to the pronoun. For instance, applying Bind to *everyone*, we have

(37) $$\begin{array}{ccc} \dfrac{\text{S} \mid \text{S}}{\text{DP}} & \text{Bind} & \dfrac{\text{S} \mid \text{DP} \rhd \text{S}}{\text{DP}} \\ \textit{everyone} & \Rightarrow & \textit{everyone} \\ \dfrac{\forall x.\,[\ ]}{x} & & \dfrac{\forall x.\,([\ ]x)}{x} \end{array}$$

Note the extra copy of x in the semantics of the shifted (binding) version.

This move lets us complete the following derivation. (To simplify the exposition, we treat *his* like *him* and assign *mother* the functional category DP\DP.)

(38) $$\begin{array}{c} \dfrac{\text{S} \mid \text{DP} \rhd \text{S}}{\text{DP}} \\ \textit{everyone} \\ \dfrac{\forall x.\,([\ ]x)}{x} \end{array} \left(\begin{array}{c} \dfrac{\text{DP} \rhd \text{S} \mid \text{DP} \rhd \text{S}}{(\text{DP}\backslash\text{S})/\text{DP}} \\ \textit{loves} \\ \dfrac{[\ ]}{\mathbf{loves}} \end{array} \left(\begin{array}{cc} \dfrac{\text{DP} \rhd \text{S} \mid \text{S}}{\text{DP}} & \dfrac{\text{S} \mid \text{S}}{\text{DP}\backslash\text{DP}} \\ \textit{his} & \textit{mother} \\ \dfrac{\lambda y.\,[\ ]}{y} & \dfrac{[\ ]}{\mathbf{mother}} \end{array} \right) \right)$$

$$= \begin{array}{ccc} \dfrac{\text{S} \mid \text{S}}{\text{S}} & \text{Lower} & \text{S} \\ \textit{Everyone loves his mother} & \Rightarrow & \textit{Everyone loves his mother} \\ \dfrac{\forall x.\,((\lambda y.\,[\ ])x)}{\mathbf{loves}\,(\mathbf{mother}\,y)\,x} & & \forall x.\,((\lambda y.\,\mathbf{loves}\,(\mathbf{mother}\,y)\,x)x) \end{array}$$

This lowered value reduces to $\forall x.\,\mathbf{loves}\,(\mathbf{mother}\,x)\,x$, as desired for the bound reading. This derivation Lifts the verb *loves* from the category (DP\S)/DP to $\dfrac{\text{DP} \rhd \text{S} \mid \text{DP} \rhd \text{S}}{(\text{DP}\backslash\text{S})/\text{DP}}$ rather than $\dfrac{\text{S} \mid \text{S}}{(\text{DP}\backslash\text{S})/\text{DP}}$, so as to cancel first against *his mother* on the right and then against *everyone* on the left. Our Lift type-shifter allows this move because its schematic category B can be instantiated as DP $\rhd$ S or any other category, not just the S used to lift *mother* above.

2.4 Binding without c-command; the dynamics of weak crossover

Binding without c-command is crucial to our account of donkey anaphora. Since c-command has no special status in our theory of binding, it is perfectly possible to have binding without c-command:

(39)
$$\left(\begin{array}{c|c} \mathrm{S} & \mathrm{DP} \rhd \mathrm{S} \\ \hline \multicolumn{2}{c}{\mathrm{DP}} \\ \multicolumn{2}{c}{\text{everyone's}} \end{array} \quad \begin{array}{c|c} \mathrm{DP} \rhd \mathrm{S} & \mathrm{DP} \rhd \mathrm{S} \\ \hline \multicolumn{2}{c}{\mathrm{DP}\backslash\mathrm{DP}} \\ \multicolumn{2}{c}{\text{mother}} \end{array}\right) \left(\begin{array}{c|c} \mathrm{DP} \rhd \mathrm{S} & \mathrm{DP} \rhd \mathrm{S} \\ \hline \multicolumn{2}{c}{(\mathrm{DP}\backslash\mathrm{S})/\mathrm{DP}} \\ \multicolumn{2}{c}{\text{loves}} \end{array} \quad \begin{array}{c|c} \mathrm{DP} \rhd \mathrm{S} & \mathrm{S} \\ \hline \multicolumn{2}{c}{\mathrm{DP}} \\ \multicolumn{2}{c}{\text{him}} \end{array}\right)$$

This derivation yields the final interpretation $\forall y.\, \mathbf{loves}\, y\, (\mathbf{mother}\, y)$.

In contrast, the order of the binder and the pronoun is crucial.

(40)
$$\left(\begin{array}{c|c} \mathrm{DP} \rhd \mathrm{S} & \mathrm{S} \\ \hline \multicolumn{2}{c}{\mathrm{DP}} \\ \multicolumn{2}{c}{\text{his}} \end{array} \quad \begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \multicolumn{2}{c}{\mathrm{DP}\backslash\mathrm{DP}} \\ \multicolumn{2}{c}{\text{mother}} \end{array}\right) \left(\begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \multicolumn{2}{c}{(\mathrm{DP}\backslash\mathrm{S})/\mathrm{DP}} \\ \multicolumn{2}{c}{\text{loves}} \end{array} \quad \begin{array}{c|c} \mathrm{S} & \mathrm{DP} \rhd \mathrm{S} \\ \hline \multicolumn{2}{c}{\mathrm{DP}} \\ \multicolumn{2}{c}{\text{everyone}} \end{array}\right)$$
$$= \begin{array}{c|c} \mathrm{DP} \rhd \mathrm{S} & \mathrm{DP} \rhd \mathrm{S} \\ \hline \multicolumn{2}{c}{\mathrm{S}} \\ \multicolumn{2}{c}{\text{his mother loves everyone}} \end{array}$$

In this weak crossover configuration, syntactic cancellation goes through without any difficulty up until the point at which we would like to apply Lower. But the schema for triggering the Lower rule isn't met, since lowering requires the top right category to be S, not DP $\rhd$ S. At best, the pronoun mournfully looks left for an antecedent, while the binder looks right for a pronoun to bind. Thus we correctly predict that there is no complete derivation for sentences in which the pronoun is evaluated before its binder.

3 Donkey anaphora in conditionals

Typical donkey anaphora in conditionals involves an indefinite in the antecedent clause covarying with a pronoun in the consequent.

As discussed in section 1, we need to articulate the denotation of *if* into an in-situ part and a scope-taking part:

(41)
$$\begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{S}}{(\mathrm{S/S})/\mathrm{S}} \\ \textit{if} \\ \dfrac{\neg[\ ]}{\lambda p \lambda q.\, p \wedge \neg q} \end{array}$$

Crucially, in the semantic value the outer negation is above the line, where it can take scope over the entire conditional. The conjunction and the inner negation are below the line, where they can distinguish the antecedent from the consequent.

(42)
$$\begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{S}}{(\mathrm{S/S})/\mathrm{S}} \\ \textit{if} \\ \dfrac{\neg[\ ]}{\lambda p \lambda q.\, p \wedge \neg q} \end{array} \left(\begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{DP} \rhd \mathrm{S}}{\mathrm{DP}} \\ \textit{someone} \\ \dfrac{\exists y.\, ([\ ]\, y)}{y} \end{array} \quad \begin{array}{c} \dfrac{\mathrm{DP} \rhd \mathrm{S} \mid \mathrm{DP} \rhd \mathrm{S}}{\mathrm{DP\backslash S}} \\ \textit{knocked} \\ \dfrac{[\ ]}{\textbf{knocked}} \end{array} \right) \left(\begin{array}{c} \dfrac{\mathrm{DP} \rhd \mathrm{S} \mid \mathrm{S}}{\mathrm{DP}} \\ \textit{she} \\ \dfrac{\lambda x.\, [\ ]}{x} \end{array} \quad \begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{S}}{\mathrm{DP\backslash S}} \\ \textit{left} \\ \dfrac{[\ ]}{\textbf{left}} \end{array} \right)$$

The indefinite takes scope over the consequent and binds the pronoun, which accounts for covariance. The outer negation contributed by the *if* takes even wider scope. After combination, we have

(43)
$$\begin{array}{c} \dfrac{\mathrm{S} \mid \mathrm{S}}{\mathrm{S}} \\ \dfrac{\neg\exists y.\, ((\lambda x.\, [\ ])\, y)}{(\textbf{knocked}\, y) \wedge \neg(\textbf{left}\, x)} \end{array} \quad \overset{\text{Lower}}{\Rightarrow} \quad \begin{array}{c} \mathrm{S} \\ \neg\exists y.\, (\textbf{knocked}\, y) \wedge \neg(\textbf{left}\, y) \end{array}$$

These truth conditions say that there is no one who knocked without leaving, which is a reasonable approximation in Predicate Logic of the truth conditions of a donkey conditional.

In the absence of donkey anaphora, our lexical entry for *if* increases the potential for spurious ambiguity. For example, we can analyze *someone* in (44) as taking scope either just over *knocked* or just under *if*, with the same truth condition.

(44) If someone knocked, the lobby was open.

This kind of ambiguity is present in all theories that allow wide-scope indefinites to take intermediate scope.

Apart from the lexical entry for *if*, all of the mechanisms for scope and binding were developed entirely independently of any concerns for donkey anaphora!

In fact, even the idea that a lexical item could introduce an outer negation that takes separate scope has been proposed in other empirical domains, though it is controversial (Jacobs 1980, Geurts 1996, de Swart 2000, Penka & Zeijlstra 2005, among others). Most notably, Jacobs (1980) advocates decomposing German *kein* 'no' into negation plus existential quantification in such a way that other quantificational elements can take intermediate scope between the negation and the existential. Geurts (1996) criticizes lexical decomposition as implemented by Jacobs as an unwelcome extension of the expressive power of the formal system. In the current context, however, Geurts' criticism does not apply, since the analysis proposed here for *if* does not rely on any formal resources beyond those already required for basic quantification.

3.1 Multiple indefinites

The prototypical donkey sentence contains more than one indefinite (namely, *a farmer* and *a donkey*). In most treatments of binding, multiple binders are distinguished by means of different subscript indices, e.g., x_i versus x_j. Since our framework is variable-free, we don't use variables, let alone indices!

In our framework, each binder can occupy a different scope-taking level. We don't need to say anything special to achieve this, however, since multiple levels are required independently in order to provide inverse scope, as discussed above in section 2.2. With access to multiple levels, it is easy to handle multiple binders.

Analyzing pronouns as two-level rules is the same thing as claiming that pronouns take scope (see Dowty 2007, who also advocates treating pronouns as scope-takers). Then, roughly speaking, a pronoun chooses its binder by choosing where to take scope. In more practical terms, distinct scope-taking levels correspond to different binders, so layers play the role of indices in some sense: a binder and the pronoun it binds must take effect at the same layer in the compositional tower. One pleasant consequence of this fact is that (as usual for variable-free treatments) a single lexical entry for each pronoun will do, rather than needing an unbounded number of pronouns distinguished by inaudible indices.

We'll compose the donkey sentence (1a) from its parts, beginning with the antecedent clause. We first apply the function in (27) denoted by the indefinite determiner *a* to each of the two common nouns *farmer* and *donkey*, illustrated below for *farmer*.

(45)
$$\begin{array}{c}\dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}}\Big/\mathrm{N}\\ \text{a}\\ \lambda P.\,\dfrac{\exists x.\,Px \wedge [\;]}{x}\end{array}\quad \begin{array}{c}\mathrm{N}\\ \text{farmer}\\ \textbf{farmer}\end{array}\quad = \quad\begin{array}{c}\dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}}\\ \text{a farmer}\\ \dfrac{\exists x.\,(\textbf{farmer}\,x) \wedge [\;]}{x}\end{array}$$

We then apply Bind and Lift to each of the two indefinite DPs *a farmer* and *a donkey*, so that they occupy different binding levels.

(46)
$$\begin{array}{c}\text{Bind}\\ \Rightarrow\end{array}\quad\begin{array}{c}\dfrac{\mathrm{S}\,|\,\mathrm{DP} \rhd \mathrm{S}}{\mathrm{DP}}\\ \text{a farmer}\\ \dfrac{\exists x.\,(\textbf{farmer}\,x) \wedge ([\;]x)}{x}\end{array}\quad\begin{array}{c}\text{Lift}\\ \Rightarrow\end{array}\quad\begin{array}{c}\dfrac{\mathrm{S}\,|\,\mathrm{DP} \rhd \mathrm{S}}{\dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}}}\\ \text{a farmer}\\ \dfrac{\exists x.\,(\textbf{farmer}\,x) \wedge ([\;]x)}{\dfrac{[\;]}{x}}\end{array}$$

We build the antecedent clause from three three-level meanings.

(47)
$$\begin{array}{c}\dfrac{\mathrm{S}\,|\,\mathrm{DP} \rhd \mathrm{S}}{\dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}}}\\ \textit{a farmer}\\ \dfrac{\exists x.\,(\textbf{farmer}\,x) \wedge ([\;]x)}{\dfrac{[\;]}{x}}\end{array}\quad\begin{array}{c}\dfrac{\mathrm{DP} \rhd \mathrm{S}\,|\,\mathrm{DP} \rhd \mathrm{S}}{\dfrac{\mathrm{S}\,|\,\mathrm{S}}{(\mathrm{DP}\backslash \mathrm{S})/\mathrm{DP}}}\\ \textit{owns}\\ \dfrac{[\;]}{\dfrac{[\;]}{\textbf{owns}}}\end{array}\quad\begin{array}{c}\dfrac{\mathrm{DP} \rhd \mathrm{S}\,|\,\mathrm{DP} \rhd \mathrm{S}}{\dfrac{\mathrm{S}\,|\,\mathrm{DP} \rhd \mathrm{S}}{\mathrm{DP}}}\\ \textit{a donkey}\\ \dfrac{[\;]}{\dfrac{\exists y.\,(\textbf{donkey}\,y) \wedge ([\;]y)}{y}}\end{array}$$

Next, we build the consequent by Lifting two pronouns from (34), waiting to be bound at two different levels.

(48)
$$\begin{array}{ccc}
\begin{array}{c} \begin{array}{c|c} \mathrm{DP} \triangleright \mathrm{S} & \mathrm{S} \\ \hline \mathrm{DP} \triangleright \mathrm{S} & \mathrm{DP} \triangleright \mathrm{S} \\ \hline \end{array} \\ \mathrm{DP} \\ \textit{he} \\ \begin{array}{c} \lambda z.[\ ] \\ \hline [\ ] \\ \hline z \end{array} \end{array}
&
\begin{array}{c} \begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \mathrm{DP} \triangleright \mathrm{S} & \mathrm{DP} \triangleright \mathrm{S} \\ \hline \end{array} \\ (\mathrm{DP}\backslash \mathrm{S})/\mathrm{DP} \\ \textit{beats} \\ \begin{array}{c} [\ ] \\ \hline [\ ] \\ \hline \mathbf{beats} \end{array} \end{array}
&
\begin{array}{c} \begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \mathrm{DP} \triangleright \mathrm{S} & \mathrm{S} \\ \hline \end{array} \\ \mathrm{DP} \\ \textit{it} \\ \begin{array}{c} [\ ] \\ \hline \lambda w.[\ ] \\ \hline w \end{array} \end{array}
\end{array}$$

We finish the derivation using the lexical entry for *if* given in (41) above (adjusted by an application of Lift).

(49)
$$\begin{array}{ccc}
\begin{array}{c} \begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \mathrm{S} & \mathrm{S} \\ \hline \end{array} \\ (\mathrm{S}/\mathrm{S})/\mathrm{S} \\ \textit{if} \\ \begin{array}{c} \neg[\ ] \\ \hline [\ ] \\ \hline \lambda p \lambda q.\, p \wedge \neg q \end{array} \end{array}
&
\begin{array}{c} \begin{array}{c|c} \mathrm{S} & \mathrm{DP} \triangleright \mathrm{S} \\ \hline \mathrm{S} & \mathrm{DP} \triangleright \mathrm{S} \\ \hline \end{array} \\ \mathrm{S} \\ \textit{a farmer owns a donkey} \\ \begin{array}{c} \exists x.\, (\mathbf{farmer}\, x) \wedge ([\ ]x) \\ \hline \exists y.\, (\mathbf{donkey}\, y) \wedge ([\ ]y) \\ \hline \mathbf{owns}\, y\, x \end{array} \end{array}
&
\begin{array}{c} \begin{array}{c|c} \mathrm{DP} \triangleright \mathrm{S} & \mathrm{S} \\ \hline \mathrm{DP} \triangleright \mathrm{S} & \mathrm{S} \\ \hline \end{array} \\ \mathrm{S} \\ \textit{he beats it} \\ \begin{array}{c} \lambda z.[\ ] \\ \hline \lambda w.[\ ] \\ \hline \mathbf{beats}\, w\, z \end{array} \end{array}
\end{array}$$

$$= \begin{array}{c} \begin{array}{c|c} \mathrm{S} & \mathrm{S} \\ \hline \mathrm{S} & \mathrm{S} \\ \hline \end{array} \\ \mathrm{S} \\ \textit{If a farmer owns a donkey he beats it} \\ \begin{array}{c} \neg\exists x.\, (\mathbf{farmer}\, x) \wedge ((\lambda z.[\ ])x) \\ \hline \exists y.\, (\mathbf{donkey}\, y) \wedge ((\lambda w.[\ ])y) \\ \hline (\mathbf{owns}\, y\, x) \wedge \neg(\mathbf{beats}\, w\, z) \end{array} \end{array}$$

With two applications of Lower and some routine lambda conversion, we have the following analysis of the standard donkey sentence:

(50) If a farmer owns a donkey, he beats it.
$\neg\exists x.\, (\mathbf{farmer}\, x) \wedge \exists y.\, (\mathbf{donkey}\, y) \wedge (\mathbf{owns}\, y\, x) \wedge \neg(\mathbf{beats}\, y\, x)$

These truth conditions require that every farmer beats every donkey that he owns, which is the standard interpretation of the donkey anaphora interpretation of the sentence.

There is much discussion in the literature of so-called ‘weak’ readings, which require only that each farmer beats at least one of the donkeys that he owns. We follow Barker (1996) and Schein (2003), who argue that weak readings are a pragmatic domain narrowing effect that do not correspond to a distinct set of truth conditions. Weak versus strong readings for quantificational determiners seem to behave differently (Kanazawa 1994); in section 4, we show how to arrive at either weak or strong readings for each determiner.

3.2 Unwanted uniqueness implications don't arise

The D-type situation-based account first proposed by Heim (1990) (adapting ideas in Berman 1987) and further developed by Elbourne (2005) provides truth conditions for the standard donkey sentence that say, roughly, that every minimal situation of a farmer owning a donkey can be extended to a situation in which the (unique) farmer in that situation beats the (unique) donkey in that situation. These truth conditions are compatible with situations in which a farmer owns more than one donkey, since given a theory of situations like that in Kratzer 1989, we can choose each minimal situation so small that it contains only one farmer and only one donkey (provided we also stipulate suitable persistence behavior, as discussed by Zweig 2006).

However, as pointed out by Kamp (according to the lore in Heim 1990), sometimes even the minimal situation must contain more than one entity that matches the descriptive content of a D-type pronoun.

(51) If a bishop meets a bishop, he blesses him. (= (8))

The problem with (51) is that any situation in which a bishop meets a bishop, no matter how minimal, contains two bishops. If we take the pronoun *he* as a D-type pronoun expressing the content *the bishop* or even *the bishop who meets a bishop*, the uniqueness implication due to the definiteness of the description fails, since there is no unique bishop in any of the relevant minimal situations.

Elbourne (2005: 147) explains how to rescue the situation-based account. The key is to recognize that the compositional semantics treats the two bishops asymmetrically. Under Elbourne's assumptions, quantifier raising creates an LF with the following structure:

(52) [a bishop x [a bishop y [x meets y]$_\gamma$]$_\beta$]$_\alpha$

His truth conditions for interpreting LFs require the existence of a situation γ within which two thin particulars (call them x and y) meet; γ must be contained within a slightly larger situation, β, in which we learn that one of the thin particulars (say, y) happens to be a bishop; and β must be contained within a still larger situation α in which we finally learn that the other thin particular happens to also be a bishop. As Elbourne (2005: 147) puts it, "the inclusion relations among the situations ... mirror the inclusion relations among the syntactic constituents of the sentence".

We can now construct a semantic property that can tell the bishops apart. Elbourne proposes a property he calls "distinguished", without specifying what that property is, but we can easily choose a suitable property. Let us say that a bishop x is distinguished relative to another bishop y in a given set of situations S just in case there is some $s \in S$ that contains both x and y and the fact that x is a bishop, but not the fact that y is a bishop. Then if S is the set of situations provided by the D-type analysis in the previous paragraph, β will be the member of S that distinguishes one of the bishops.[7]

Elbourne then proposes that "he" and "him" are D-type pronouns both containing the silent NP *bishop*. Pragmatic enrichment then delivers truth conditions equivalent to the definite descriptions *the distinguished bishop* and *the undistinguished bishop*. In summary, Elbourne solves the bishop problem by positing a particular kind of pragmatic enrichment of silent descriptive content.

On the present proposal, of course, bishop sentences are perfectly straightforward and require no special assumptions. The derivation is identical to the one given above for the farmer/donkey sentence (after substituting the appropriate words), giving the following truth conditions (compare with (50) above):

(53) If a bishop meets a bishop, he blesses him.
$\neg\exists x.\,(\mathbf{bishop}\,x) \wedge \exists y.\,(\mathbf{bishop}\,y) \wedge (\mathbf{meets}\,y\,x) \wedge \neg(\mathbf{blesses}\,y\,x)$

Thus bishop sentences pose no special difficulties on our account.

Although donkey pronouns do not entail uniqueness (as we have just seen), Kadmon (1987) and others persistently report that for some speakers donkey pronouns nevertheless contribute a flavor of uniqueness. For instance, many people report that the standard donkey sentences only clearly apply to farmers who own one donkey, and that the status of farmers who

7 Nick Kroll and Anna Szabolcsi have independently pointed out that something more needs to be said about cases in which the two indefinites accidentally pick out the same individual. For instance, consider *If a scholar cites a scholar, she spells her name carefully* in a situation in which a scholar cites her own work. Perhaps equality among thin particulars, like bishophood, can be omitted in subsituations.

own more than one donkey is problematic. Barker (1996) argues that these residual uniqueness effects are due to a presupposition that each farmer either beats all or none of his donkeys. In the absence of a reason to suppose that farmers treat their donkeys uniformly, one way to accommodate the presupposition is to limit attention to farmers that have only one donkey. In contrast, in situations in which the homogeneity presupposition is entailed, all uniqueness implications disappear entirely, as in Heim's famous sage-plant sentence.

(54) Most women who buy a sage plant here buy eight others along with it.

In (54), there is no temptation to claim that the generalization only applies to women who buy a single sage plant.

3.3 Extending the account to modal treatments of conditionals

Our analysis approximates the semantics of the conditional using quantification only over individuals. But conditionals display bewildering modal behavior that is not captured in our fragment. It is far from trivial to combine a dynamic account of modality and of binding in a single system (though see Brasoveanu 2007 for a recent example), and we will not work out the details of such an endeavor here. Nevertheless, we give enough details to make it plausible that our overall strategy is compatible with a more nuanced account of conditionals.

One popular strategy for handling conditionals due to Kratzer (e.g., 1991) is to view the *if* clause as a restriction on the accessibility relation of some modal operator. The modal operator in question can be supplied by an adverbial element in the main clause (e.g., *might* in *If a farmer owns a donkey, he might beat it*). If no modal operator is overt, a silent one is assumed to be present. For instance, Heim (1982) suggests that the prototypical donkey sentence (1a) means roughly *If a farmer owns a donkey, he* ***usually*** *beats it.*

Once we have a modal operator, the truth condition of the conditional depends on a modal base f and an ordering source g, both supplied by pragmatic context. In the usual treatment, f and g are functions mapping each world to a set of propositions, and propositions, in turn, are modeled as sets of worlds.

We can then use the following semantic value for *if*.

(55)
$$\frac{\lambda w \lambda w'.\, \neg[\;]}{\lambda p \lambda q.\, (w' \in \max(g(w))(\cap(f(w) + p))) \wedge (w' \notin q)}$$

This value maps each evaluation world w onto a set of possible worlds which is constructed according to the following recipe: take the set of propositions provided by $f(w)$. Add the antecedent (p) to that set.[8] Treating propositions as sets of worlds, intersect them. This gives the set of accessible worlds in which the antecedent is true. Next, eliminate all of these worlds that are less than ideal with respect to the partial order induced by the ordering source g applied to w. Now remove all the worlds in which the consequent is true. Finally (the outermost negation, above the line), return the complement of this set.

This complement set will provide the input to the semantics of the governing modal. For instance, we might have either of the following modals:

(56)

$$\begin{array}{c} \mathrm{S} \mid \mathrm{S} \\ \hline (\mathrm{DP}\backslash\mathrm{S})\,/\,(\mathrm{DP}\backslash\mathrm{S}) \\ \textit{might} \\ \lambda w.\, \exists w'.\, ([\ ]\; w\; w') \\ \hline \lambda f.\, f \end{array} \qquad \begin{array}{c} \mathrm{S} \mid \mathrm{S} \\ \hline (\mathrm{DP}\backslash\mathrm{S})\,/\,(\mathrm{DP}\backslash\mathrm{S}) \\ \textit{must} \\ \lambda w.\, \forall w'.\, ([\ ]\; w\; w') \\ \hline \lambda f.\, f \end{array}$$

Notice that *might* and *must* differ only in their modal force: *might* existentially quantifies over worlds, and *must* universally quantifies over worlds.

Then we would have the following analysis for *If a donkey eats, it might sleep*:

(57)

$$\begin{array}{c} \lambda w.\, \exists w'.\, ([\ ]\; w\; w') \\ \hline \lambda w.\, \lambda w'.\, \neg\exists d.\, (\mathbf{donkey}\, d) \wedge [\ ] \\ \hline (w' \in \max(g(w))(\cap(f(w) + (\mathbf{eats}\, d)))) \wedge (w' \notin \mathbf{sleep}\, d) \end{array}$$

After lowering (twice) and lambda-conversion, we have

(58) $\lambda w.\, \exists w'.\, \neg\exists d.\, (\mathbf{donkey}\, d)$

$$\wedge\ (w' \in \max(g(w))(\cap(f(w) + (\mathbf{eats}\, d)))) \wedge (w' \notin \mathbf{sleep}\, d)$$

If f is an epistemic modal base, and g is a stereotypical ordering source (in which worlds are more ideal if things happen normally), then the prediction is that the sentence will be true in a world w just in case there is some world w' consistent with what we know, and there is no way to pick a donkey d such that

8 For instance, for counterfactuals, the + operation would have to start with the antecedent and add as many propositions in $f(w)$ as possible without creating inconsistency; for anankastic conditionals such as *If you want to get to Harlem, you should take the A train*, the + operation will have to be complex in a different way (von Fintel & Iatridou 2005).

- d eats in w',
- w' is a maximally normal world (at least compared to other worlds compatible with what we know in which a donkey eats), and
- d fails to sleep in w'.

We're ignoring the possibility that there are no donkeys, or that supposing that some donkey eats is incompatible with our knowledge.

In order for this scheme to work, expressions with category S will have to denote sets of worlds, but nothing we have said prevents this. We would also have to adjust the syntax of *if* and the modals to require that modals must take scope over an *if* clause. Other refinements would be necessary, but we will not pursue any here.

What is important for present purposes is that we have arrived at an analysis which exhibits donkey anaphora: the interaction of the modal, the *if*, the indefinite, and the pronoun is such that the donkey that is doing the eating must be the same donkey that is doing the sleeping. In sum, we are not aware of any reason why the approach suggested here would be incompatible with a more refined analysis of conditionals.

3.4 Why does *every* disrupt donkey anaphora?

If a universal occurs in the antecedent, donkey anaphora is no longer possible:

(59) If everyone owns a donkey, it brays.

More precisely, there is no interpretation on which the indefinite takes narrow scope with respect to the universal and still binds the pronoun.

As discussed below in section 7, previous dynamic accounts such as Dynamic Predicate Logic and Dynamic Montague Grammar define *everyone* in terms of static negation, which is stipulated to be dynamically closed, i.e., to block anaphora between an indefinite taking scope inside the negation and a pronoun outside the scope of negation.

Our account needs no such stipulation: the binding relationships follow immediately from getting the scope of the quantifiers right. Recall from (2) that unlike indefinites, the scope of *every* is generally limited to its minimal clause. In this case, the minimal clause is the antecedent. That means that the only possible analysis of the antecedent in (59) must close off the scope of *every* by applying Lower before the antecedent combines with *if*:

(60)

$$\begin{array}{c} \dfrac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{S}} \\ \textit{Everyone owns a donkey} \\ \dfrac{\forall x.\,\exists y.\,(\mathbf{donkey}\,y) \wedge [\;]}{\mathbf{owns}\,y\,x} \end{array} \quad \begin{array}{c} \text{Lower} \\ \Rightarrow \end{array} \quad \begin{array}{c} \mathrm{S} \\ \textit{Everyone owns a donkey} \\ \forall x.\,\exists y.\,(\mathbf{donkey}\,y) \wedge (\mathbf{owns}\,y\,x) \end{array}$$

Because eliminating the quantificational level at which *everyone* takes scope also eliminates any other quantifier on the same level and lower levels, whenever the indefinite takes narrow scope with respect to the universal, the scope of the indefinite must also be limited to the antecedent clause.

There is no obvious semantic reason why universals can't take wide scope beyond their minimal clause, so their scope limitations are presumably purely syntactic. Like most leading accounts of donkey anaphora (including Elbourne 2005), we provide no formal mechanism here that bounds the scope-taking of universals.

4 Donkey anaphora from relative clauses

We turn now from donkey anaphora in conditionals to the other classic case of donkey anaphora, which involves indefinites embedded within a relative clause.

(61) Every farmer who owns a donkey beats it. (= (1b))

To provide a lexical entry for quantifiers such as *every*, we proceed by analogy with conditionals. Just as we distinguish taking scope under *if* from taking scope in its antecedent or consequent, we distinguish taking scope under a quantifier from taking scope in its restrictor or nuclear scope.

(62) Every passenger who had no money received a warning note.

(63) Every passenger with no money received a warning note.

(64) An official from every country attended the ceremony.

For example, on the most natural interpretation of (62) and (63), the quantifier *no* takes scope in the restrictor of *every*, and the quantifier *a* takes scope in the nuclear scope of *every*. In the QR approach developed in Heim & Kratzer 1998: 221, the scope of *no* in (63) motivates a proposal (following May) that prepositional phrases have covert clause-like structure involving a semantically vacuous PRO. As long as quantifiers are allowed to take scope at any constituent of type `t`, (63) will be assigned the same meaning as (62). In (64), the quantifier *every* takes wide scope over *an*.

In contrast to these three examples, we will analyze *a* in (61) as taking scope under *every* yet over its restrictor and nuclear scope. We will also treat linear scope in (65) as an instance of spurious ambiguity in the absence of donkey anaphora, because the same truth condition obtains whether *a* takes scope just in the restrictor of *every*, as in (62) and (63), or also over the nuclear scope of *every*, as in (61).

(65) Every farmer who owns a donkey left.

We refer the reader to other papers (Barker & Shan 2006; Shan & Barker 2006) for detailed analyses of sentences such as (62)–(65) without donkey anaphora. Those analyses are compatible with the machinery for scope and binding in this paper, because they essentially extend it with a natural treatment of relative clauses and prepositional phrases. The end result is that the nominal *farmer who owns a donkey* has two meanings, one where *a* takes scope inside the relative clause and one where it takes wider scope. Both meanings are shown in (66).

(66)

$$\begin{array}{c} \mathrm{N} \\ \text{farmer who owns a donkey} \\ \lambda z.\,(\mathbf{farmer}\ z) \wedge \exists y.\,(\mathbf{donkey}\ y) \wedge (\mathbf{owns}\ y\ z) \end{array} \qquad \begin{array}{c} \frac{\mathrm{S} \mid \mathrm{S}}{\mathrm{N}} \\ \text{farmer who owns a donkey} \\ \frac{\exists y.\,(\mathbf{donkey}\ y) \wedge [\ ]}{\lambda z.\,(\mathbf{farmer}\ z) \wedge (\mathbf{owns}\ y\ z)} \end{array}$$

By applying the Bind type-shifter to *a donkey*, we can derive another meaning in which the donkey y is ready to bind a later pronoun.

(67)

$$\begin{array}{c} \frac{\mathrm{S} \mid \mathrm{DP} \rhd \mathrm{S}}{\mathrm{N}} \\ \text{farmer who owns a donkey} \\ \frac{\exists y.\,(\mathbf{donkey}\ y) \wedge ([\ ]y)}{\lambda z.\,(\mathbf{farmer}\ z) \wedge (\mathbf{owns}\ y\ z)} \end{array}$$

Below we present lexical entries for quantifiers like *every* that take scope over this last meaning and yield the right truth conditions compositionally.

The usual notion of a quantificational determiner is that it takes a nominal and returns a generalized quantifier, so it has the category $\frac{\mathrm{S} \mid \mathrm{S}}{\mathrm{DP}} / \mathrm{N}$. In the present framework, we provide an extra layer to the translation of *every*, as used in the following derivation of (61).

(68)
$$\left(\begin{array}{cc} \dfrac{\mathrm{S} \,\big|\, \mathrm{S}}{\dfrac{\mathrm{S}|\mathrm{S}}{\mathrm{DP}}\Big/\mathrm{N}} & \dfrac{\mathrm{S} \,|\, \mathrm{DP} \rhd \mathrm{S}}{\mathrm{N}} \\ \textit{every} & \textit{farmer who owns a donkey} \\ \dfrac{\neg\exists x.\,[\;]}{\lambda P.\, \dfrac{Px \wedge \neg[\;]}{x}} & \dfrac{\exists y.\,(\mathbf{donkey}\,y) \wedge ([\;]\,y)}{\lambda z.\,(\mathbf{farmer}\,z) \wedge (\mathbf{owns}\,y\,z)} \end{array}\right) \begin{array}{c} \dfrac{\mathrm{DP} \rhd \mathrm{S} \,|\, \mathrm{S}}{\dfrac{\mathrm{S} \,|\, \mathrm{S}}{\mathrm{DP}\backslash \mathrm{S}}} \\ \textit{beats it} \\ \dfrac{\lambda w.\,[\;]}{\dfrac{[\;]}{\mathbf{beats}\,w}} \end{array}$$

This derivation gives the truth condition

(69) $$\neg\exists x \exists y.\, \mathbf{donkey}\,y \wedge \big((\mathbf{farmer}\,x \wedge \mathbf{owns}\,y\,x) \wedge \neg(\mathbf{beats}\,y\,x)\big)\,,$$

as desired. The indefinite makes its usual contribution to the compositional truth conditions: on the one hand, it restricts the generalization to farmers who own a donkey; on the other hand, it binds the pronoun in the verb phrase.

This analysis extends to proportional quantificational determiners. For instance, we can assign *most* the denotation

(70) $$\dfrac{\textsc{most}(\lambda x \lambda p.\,[\;])}{\lambda P.\, \dfrac{Px \wedge (p \vee [\;])}{x}}\,,$$

where MOST is defined by

(71) $$\textsc{most}(F) = \big(|\{x : Fxt\}| < 2 \times |\{x : Fxf\}|\big),$$

writing t and f for the two truth values. In the standard treatment, *most* takes as arguments a pair of sets; here, it takes instead a set of pairs such that $\langle x, t\rangle$ is in the set iff x satisfies the restriction, and $\langle x, f\rangle$ is in the set iff x satisfies both the restriction and the nuclear scope (cf. Pietroski's 2006 analysis of quantifiers in terms of Frege-pairs). The net result is that at least half of the entities that satisfy the restriction must also satisfy the nuclear scope. Clearly, we can accommodate any conservative two-place quantificational determiner by replacing MOST with a different function.

The lexical entry for *most* as given delivers weak truth conditions (each farmer in the witness set need only beat one of his donkeys). We can provide strong truth conditions by replacing $p \vee [\ ]$ with $p \vee \neg[\ ]$ in (70), and $<$ with $>$ in (71).

We note in passing a difference in how indefinites interact with conditionals versus with quantificational determiners like *every*. As (15a) above and (72) below show, an indefinite in the consequent of *if* takes scope immediately under *if* as easily as an indefinite in the antecedent does.

(72) A donkey runs for shelter if it is raining.

As we discuss further in section 7.3, our formal system already generates the attested reading of (72) in which every donkey runs for shelter if it is raining. In contrast, an indefinite in the nuclear scope of *every* cannot take scope immediately under *every*.

(73) a. Every academic witnessed a raucous debate.
b. $^*\neg\exists x \exists y.\, \textbf{academic}\, x \wedge \textbf{raucous-debate}\, y \wedge \textbf{witness}\, y\, x$

(74) ??Every academic enjoys a raucous debate.

It is impossible for the truth condition of (73) to be that every academic witnessed every raucous debate, and it is dubious whether (74) can mean that every academic enjoys every raucous debate. It appears, then, that *a raucous debate* can take either narrow scope in the nuclear scope of *every*, or wide scope beyond *every*, but not in between. Such unavailability of intermediate scope has been observed elsewhere (Fodor & Sag 1982; Kratzer 1998; Lin 2004), but is not accounted for by our formal system.

5 Coordination and donkey anaphora

As noted by Stone (1992), disjunction constitutes a challenge for at least some dynamic theories of anaphora, including DPL.

(75) If a farmer owns a donkey or a goat, he beats it.

The problem for DPL is that the indefinites *a donkey* and *a goat* introduce two distinct discourse referents, neither of which is a suitable antecedent for *it*. This challenge is hardly insurmountable, but does seem to require assumptions that go beyond the mechanisms provided by the basic theory of DPL.

The D-type analysis has no trouble with disjunction: every situation that verifies the antecedent will either have a donkey in it or a goat, so there will always be a suitable object for the pronoun *it* to describe. The descriptive content of the pronoun will be something neutral between the two descriptions, something like *the animal*, or perhaps *the donkey or goat*.[9] Elbourne (2005: 19) concludes that disjunction provides an argument in favor of the D-type approach over DPL.

Partee & Rooth (1983) suggest allowing phrases like *John or Bill* to introduce new variables. The treatment of generalized disjunction proposed in Barker 2002 achieves the desired result without any stipulation.

(76)
$$\left(A\Big\backslash \frac{\mathrm{S}\,|\,\mathrm{S}}{A}\right)\Big/A$$
$$\textit{or}$$
$$\lambda R\lambda L.\ \frac{(\lambda\kappa.(\kappa L)\vee(\kappa R))(\lambda x.[\ ])}{x}$$

This lexical entry is polymorphic: A can be any category.[10]

In particular, we can choose A = DP:

(77)
$$\begin{pmatrix} \mathrm{DP} & \left(\mathrm{DP}\Big\backslash \frac{\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}}\right)\Big/\mathrm{DP} & \mathrm{DP} \\ \textit{John} & \textit{or} & \textit{Bill} \end{pmatrix} \begin{pmatrix} \frac{\mathrm{DP}\rhd\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}\backslash\mathrm{S}} \\ \textit{called his mother} \end{pmatrix}$$
$$\overset{\text{Bind}}{\Rightarrow} \begin{pmatrix} \frac{\mathrm{S}\,|\,\mathrm{DP}\rhd\mathrm{S}}{\mathrm{DP}} \\ \textit{John or Bill} \end{pmatrix} \begin{pmatrix} \frac{\mathrm{DP}\rhd\mathrm{S}\,|\,\mathrm{S}}{\mathrm{DP}\backslash\mathrm{S}} \\ \textit{called his mother} \end{pmatrix}$$

This derivation gives the truth condition

(78)
$$(\mathbf{called}\ (\mathbf{mother}\,\mathbf{j})\ \mathbf{j}) \vee (\mathbf{called}\ (\mathbf{mother}\,\mathbf{b})\ \mathbf{b}).$$

In other words, the disjunction of *John* and *Bill* is perfectly able to serve as the antecedent of a singular pronoun without any stipulation.

A similar derivation goes through for donkey anaphora, i.e., when the disjunction is in the antecedent and the pronoun is in the consequent: *If John*

9 Leu (2005) argues that in the general case, the content of the D-type pronoun will have to be essentially contentless, roughly *the entity*.

10 There is no restriction to “conjoinable” types, since that is implicit in the claim that disjunction takes scope over an S, i.e., eventually yielding a result of type `t`. The semantic value is expressed slightly awkwardly as a redex in order to avoid multiple holes [ ]. This awkwardness is purely expository, however; it is perfectly straightforward to compute the denotations of derivations involving *or* using the linear notation from Shan & Barker 2006, in which the value of *or* is $\lambda R\lambda L\lambda\kappa.\, L\kappa \vee R\kappa$.

or Bill left, he called. In order to bind the pronoun, the disjunction must scope over the consequent, in which case the truth conditions come out equivalent to

(79) $$((\textbf{left}\,\textbf{j}) \to (\textbf{called}\,\textbf{j})) \wedge ((\textbf{left}\,\textbf{b}) \to (\textbf{called}\,\textbf{b})).$$

Crucially, this truth condition requires whoever left to call.

If the disjuncts are indefinites rather than names, we can choose $A = \frac{S \mid S}{DP}$ (the category of a generalized quantifier) to get appropriate truth conditions for sentences such as *If a farmer owns a donkey or a goat, he beats it.*

Stone and Elbourne claim that similar anaphora can occur with disjoined sentences (as opposed to disjoined DPs):

(80) If Mary hasn't seen John lately, or Ann misses Bill, she calls him.

On the D-type analysis, all that is required is that each minimal situation involved in the antecedent of (80) contains a man. On our system, we simply choose $A = \frac{S \mid DP \rhd S}{S}$, which allows each disjoined clause to provide its own binder independently of the other disjunct.

Thus, although disjunction poses difficulties for some specific dynamic theories of meaning, it by no means poses difficulties for all dynamic theories. In particular, it seems to work out fine in the analysis proposed here.

It is a notable virtue of the D-type analysis that it correctly fails to predict donkey anaphora for conjoined DPs.

(81) If a bishop and a bishop meet, he blesses him.

In contrast with the standard bishop sentence above in (53) in which *meet* is used transitively, it is difficult to interpret the pronouns in (81) as taking the indefinites as antecedents. On the D-type account, this contrast is supposed to be because the two indefinites are treated symmetrically in the intransitive case, at least as far as the construction of the situations characterized by the antecedent is concerned. Hence the covert definite descriptions contributed by the pronouns cannot be enriched to distinguish the two bishops, and the example is rendered infelicitous by the failed uniqueness presupposition of the definite descriptions.

In applying our account to (81), there are two points to be made. The first is that the way described above in which disjunction automatically gives rise in effect to a joint discourse referent does not apply to this kind of conjunction. As noted by Elbourne, the *meet* in (81) requires a plural entity as its argument, so this is sum-forming conjunction, not generalized conjunction. In any case, the conjunction must mark the conjoined DP as syntactically plural, in which case it cannot serve as the antecedent to a singular pronoun.[11] So the conjunction as a whole cannot provide an antecedent for either pronoun.

The second point is to admit that our account predicts that the conjuncts can serve as separate antecedents. But in the general case, this is necessary:

(82) If a woman and a man meet, she asks him for his number.

The D-type account can also explain the availability of anaphora in this case, since the content of each conjunct provides plenty of leverage for the pronouns to distinguish between the participants in the antecedent situation on the basis of their semantic properties.

However, it is possible to find cases in which the conjuncts are semantically distinct, yet the overall situation is symmetric enough that donkey anaphora becomes infelicitous:

(83) a. #If John and Bill meet, he falls asleep.
b. #If a butcher and a baker meet, he pays him.
c. #If a man walking a dog and a woman walking a dog meet, it barks at it.

The D-type and continuations accounts both predict that these sentences have various readings involving donkey anaphora, yet anaphoric interpretations are difficult in a way that we feel is just like the difficulty of (81). Independently of any grammatical theory of anaphora, we need an account of anaphora resolution. Anaphora resolution is a notoriously difficult area of research (see, e.g., Kehler 2002), in part because so many factors seem to influence the process. The difficulty with the sentences in (83) is that they provide no traction for deciding which of the possible anaphoric relations is the intended one. Since even the D-type account needs some principle of this sort to explain the infelicity of the sentences in (83), we suggest that this is all that is necessary to explain any difficulty associated with (81): the various donkey anaphoric analyses are perfectly grammatical, but pragmatically unresolvable.

11 Kanazawa (2001) argues compellingly against Neale's (1990) suggestion that donkey pronouns are semantically number-neutral.

6 Donkey weak crossover

In our system, binders must be evaluated before the expressions they bind. In the examples considered in this paper, evaluation order corresponds to linear word order. The prediction is that the same mechanism that rules out weak crossover also rules out examples in which a donkey pronoun precedes its antecedent.

(84) (Weak crossover)
   a. Everyone$_i$'s mother loves his$_i$ father.
   b. *His$_i$ father loves everyone$_i$'s mother.

(85) (Donkey weak crossover) (= (12))
   a. If a farmer owns a donkey, he beats it.
   b. *?If he owns it, a farmer beats a donkey.

Because our system embodies a default of processing from left to right, we correctly rule in the (a) examples, and correctly rule out the binding in the (b) examples.

Crucially, the same sensitivity to evaluation order obtains when the order of the antecedent and the consequent are reversed.

(86) (Donkey weak crossover) (= (15))
   a. A farmer beats a donkey if he owns it.
   b. *He beats it if a farmer owns a donkey.

We assume that the order of the clauses does not affect the semantics of the conditional. Then *if* does not differ between (85) and (86), except in one minor syntactic detail, the direction of a slash: $\frac{\mathrm{S} \mid \mathrm{S}}{(\mathrm{S}/\mathrm{S})/\mathrm{S}}$ for (85), $\frac{\mathrm{S} \mid \mathrm{S}}{(\mathrm{S}\backslash\mathrm{S})/\mathrm{S}}$ for (86).[12]

Most importantly for our purposes here, there is no donkey anaphora derivation of (86b). We take this as strong evidence that donkey anaphora, like all quantificational anaphora, is sensitive to order, favoring a dynamic account. We also take (86) to show that donkey anaphora is independent of the semantics of the conditional, contrary to the predictions of situation-based accounts such as Elbourne 2005.

(87) *His$_i$ father loves most women who have a son$_i$. (= (11b))

12 There are processing differences between the two clause orders, however. For instance, in order for the outer negation of the conditional to take inverse scope over the existentials in (86a), an inner application of Lift is necessary that was not necessary for the derivation given in section 3.1 for (85a).

Similarly, we correctly predict that an indefinite in a relative clause, such as *a son* in (87), can only bind a donkey pronoun that is evaluated after it.

7 Comparisons with other dynamic accounts

So far we have concentrated on comparisons with Elbourne's D-type analysis as a well-known modern theory of donkey anaphora with broad empirical coverage. We are now ready to compare our system with other explicitly dynamic accounts. We first explain how our system treats binding and scope uniformly by comparing it to Dynamic Montague Grammar. We then discuss the compositional flexibility that results from this uniformity and that extends our empirical coverage.

7.1 Dynamic Montague Grammar

The dynamic approach to donkey anaphora is deep and rich, including Kamp 1981, Heim 1982, Groenendijk & Stokhof 1989, 1991, and many more. We concentrate here on Groenendijk & Stokhof's (1989) Dynamic Montague Grammar (DMG), since it is a paradigm example of a dynamic and compositional treatment that has some striking similarities to our approach, yet significant technical, empirical, and philosophical differences, as it turns out.

DMG introduces a type-shifter '↑' to turn a static clause meaning q into its dynamic counterpart $\uparrow q$. In this definition, the down operator $^\vee$ from intensional logic deals in assignments ('states') rather than worlds.

(88) $$\uparrow q = \lambda p.\, q \wedge {}^\vee p$$

The connective ';' conjoins two dynamic sentence meanings.

(89) $$\phi;\psi = \lambda p.\, \phi({}^\wedge\psi(p))$$

For example, *John walks and John talks* translates as

(90) $$(\uparrow \mathbf{walk}(\mathbf{j}))\,;(\uparrow \mathbf{talk}(\mathbf{j})) = \lambda p.\, \mathbf{walk}(\mathbf{j}) \wedge \mathbf{talk}(\mathbf{j}) \wedge {}^\vee p.$$

An additional type-shifter '↓' extracts a static truth condition from a dynamic sentence meaning.

(91) $$\downarrow \phi = \phi({}^\wedge\mathbf{true})$$

For example, applying ↓ to (90) yields the truth condition

(92) $$\mathbf{walk}(\mathbf{j}) \wedge \mathbf{talk}(\mathbf{j}) \wedge {}^{\vee\wedge}\mathbf{true} = \mathbf{walk}(\mathbf{j}) \wedge \mathbf{talk}(\mathbf{j}).$$

These elements of DMG manage the proposition p in (88) and (89) much as the elements of our system manage continuations: roughly, DMG's '↑' corresponds to (a special case of) our LIFT; DMG's ';' corresponds to (a special case of) our combination schema (21) and (likewise) stipulates left-to-right evaluation; and DMG's '↓' corresponds to our LOWER. Indeed, when Groenendijk & Stokhof (1989) write that "we can look upon the propositions which form the extension of a sentence as something giving the truth conditional contents of its possible continuations", they use the word 'continuation' in a sense very similar to the way we use it.

Is DMG a continuation semantics, then? For binding, DMG only lifts clause meanings: from $\mathbf{walks}(\mathbf{j})$ to $\uparrow \mathbf{walks}(\mathbf{j})$. Analogously, for quantification, Montague's PTQ only lifts noun-phrase meanings: from the individual $\mathbf{j}$ to the continuation consumer $\lambda\kappa.\, \kappa(\mathbf{j})$ (Barker 2002). In contrast to DMG and PTQ, our grammar allows lifting any constituent, not just sentences or noun phrases. This uniformity cashes out our claim that the mechanism by which quantifiers find their scopes is one and the same as the mechanism by which pronouns find their antecedents.

7.2 Binding requires scope

Whereas the point of our system is to bring scope and binding together, the point of DMG is to pull scope and binding apart, as is necessitated by the assumption (which we reject) that the indefinites in (1) cannot take scope over their donkey pronouns. DMG thus sports *two* binding strategies. On the one hand, it provides a stock of variables that are evaluated with respect to an assignment function in the usual way. On the other, it provides a separate system in which the role of variables is played by discourse markers, which are evaluated with respect to a state. The translation of *a* mediates between the states and the continuations, so that A_i *man walks* reduces to

(93) $$\lambda p.\, \exists x.\, \mathbf{man}(x) \wedge \mathbf{walk}(x) \wedge \{x/d_i\}^{\vee} p,$$

which is equivalent in DMG to

(94) $$\mathcal{E} d_i((\uparrow \mathbf{man}(d_i))\, ;\, (\uparrow \mathbf{walk}(d_i)))$$

in terms of the dynamic version $\mathcal{E}$ of the existential quantifier. The static existential quantifier $\exists$ in (93) binds the variable x in the normal way, which supplies an object to the state switcher $\{x/d_i\}$, so that the discourse marker d_i evaluates to that object wherever it occurs (free) in the continuation p. Thus dynamic binding arises from the interaction between a special case of continuations and a special kind of variables.

A famous fact about DMG is that

(95) $$(\mathcal{E}d\phi)\,;\psi = \mathcal{E}d(\phi;\psi).$$

This equation says that, even if a (dynamic) existential quantifier takes scope only over the first element ϕ in a sequence, it can nevertheless bind discourse markers in subsequent elements ψ. Crucially, this equation finds no counterpart in our system. Our only binding operators are $\exists$, $\forall$, and λ, all of which require scope. Thus, in our system, whenever a quantifier binds a pronoun, it takes scope over the pronoun.

But pulling scope and binding apart complicates DMG. DMG provides two kinds of negation, both operating on dynamic clause meanings, that differ in whether an indefinite that takes scope within the negation can nevertheless bind a discourse marker outside the negation: the static negation $\sim_s\phi$ of a dynamic clause meaning ϕ is the closure $\uparrow\downarrow\sim_d\phi$ of the dynamic negation $\sim_d\phi$ of ϕ. In contrast, it is inconceivable on our account for a quantifier that takes scope inside some negation to bind a pronoun outside that negation, because any pronoun outside that negation must also be outside the scope of that quantifier, and a quantifier can only bind a pronoun within its scope. It is for the same reason in section 3.4 that *every* blocks donkey anaphora.

Because DMG allows an existential operator to bind pronouns outside its scope, it must take special steps to ensure that other operators, including negation, block that ability. Our account refrains from the allowing and obviates the blocking.

7.3 Other accounts based on continuations

As we have just seen, ours is not the only account of donkey anaphora that can be viewed as depending to some extent on continuations. The account of de Groote (2006) reformulates DMG in an elegant continuation-based system. He takes the meaning of a clause to be a relation between its *left context*, which contains individuals introduced so far, and its *right context*, a continuation. A clause that introduces a discourse referent does so by adding an individual to the left context and passing the result to the right context. Similarly, Shan (2001) uses *monads*, closely related to continuations (Wadler 1994), to implement a variable-free dynamic semantics and to predict donkey weak crossover.[13]

We are naturally sympathetic to continuation-based theories of donkey anaphora. However, like DMG, neither de Groote's theory nor Shan's lets indefinites, other quantifiers, and pronouns interact in a uniform system of scope taking. Since we argue that binding exploits the same scope-taking mechanisms required for quantification, we believe that a complete understanding of quantificational binding must be situated within a uniform theory of scope. Our greater empirical coverage relies on the fact that this uniformity provides two kinds of compositional flexibility: first, to let an indefinite take existential scope outside an enclosing operator; second, to manipulate the dynamic meaning of a clause as a semantic value.

The first flexibility is introduced in section 2.2, where we use multiple layers of continuation lifting in order to generate inverse scope. For example, to generate the inverse-scope reading of *everyone loves someone*, we use two layers of lifting: *someone* takes effect in the outer layer (higher level) whereas *everyone* takes effect in the inner layer (lower level). Precisely the same machinery turns out to support multiple donkey indefinites (section 3.1) with good results on bishop sentences (section 3.2), and to predict donkey weak crossover (section 6). In particular, we exploit multiple layers of lifting to generate the intended reading of (86a). Similarly, our compositional semantics offers three ways to interpret (96):

(96) A farmer sells lemonade if it is sunny.

It is easy for a dynamic semantics to generate the reading in which *a farmer* takes narrowest scope: the farmers take turns selling lemonade on sunny days. Using multiple layers of lifting, the indefinites in (86a) and (96) can take scope outside their enclosing negation, so we generate two other readings for (96) as desired: the farmers all sell lemonade on sunny days; a certain farmer sells lemonade on sunny days.

The second flexibility is that a lifted meaning in our system is a semantic value that can be fed to and returned from functions just like any other value. For example, the lexical meaning for *a* in (27) is a function that returns a lifted individual when combined with a common-noun property by ordinary

13 Like Jacobson (1999), Shan (2001) does not deal with binding out of a possessor (see Barker 2005), whereas we do.

function application. The denotations of *every* in (68) and *or* in (76) also involve functions that return lifted meanings, and we can use *or* to coordinate indefinites and binders as usual. Another example of the second flexibility is how the lexical meaning for *he* in (34) uses $\lambda y.[\ ]$ on the higher level to abstract over a propositional meaning where indefinites and other quantifiers may take scope (as in *he loves someone*). Such abstractions play a crucial role in our modal meaning for *if* ($\lambda w \lambda w'. \neg[\ ]$ in (55)) and our proportional meaning for *most* ($\lambda x \lambda p.[\ ]$ in (70)).

8 Conclusion

The picture that we have drawn is very simple: a quantifier can only bind a pronoun that it takes scope over. But since indefinites can take scope over more than their minimal clause, they can bind donkey pronouns. The fact that they fail to c-command those pronouns is irrelevant, because c-command is not a requirement for binding. However, since evaluation order is a requirement for binding, donkey indefinites must be evaluated before the pronouns that they bind, which in the examples discussed here means they must linearly precede those pronouns. If the pronoun comes first, donkey weak crossover results.

We have presented a formal fragment implementing these ideas that involves three type-shifters that apply freely: Lift, Lower, and Bind. Given independently motivated lexical entries for quantifiers and pronouns, along with an innovative lexical entry for *if*, we derive a wide range of predictions about donkey anaphora.

To be sure, we leave many questions unanswered. For instance, we have limited the discussion above to quantificational binding. What about other types of anaphora? Because our Bind type-shifter applies to proper names such as *John* just as it applies to quantifiers such as *everyone*, the sentence *John*$_i$ *loves his*$_i$ *mother* has a derivation on which *John* grammatically binds *his*. Therefore our system has something to say about at least some non-quantificational anaphora. But there are other cases of non-quantificational anaphora that cannot be handled by our system, such as *He has to offer her an apology if John wants Mary to talk to him again* (cf. the ungrammatical (15b) with quantificational DPs instead of proper names). Our working assumption is that quantificational binding may be subject to different grammatical constraints than anaphora in general. In fact, we suspect that one of the factors that may have lead Reinhart (e.g., 1983) and others to impose what we have argued to be an erroneous c-command requirement on quantificational anaphora was a valiant but ultimately futile attempt to unify quantificational anaphora with anaphora in general.

We have also limited ourselves to intrasentential binding. But like other dynamic treatments (Heim 1982, Groenendijk & Stokhof 1991, etc.), nothing prevents us from defining a convention for dynamically combining sequences of sentences. And in general, it is easy to imagine how our system could allow an expression to give rise to a side effect in one sentence that affects the evaluation of some expression in a different sentence. But just like our predecessors, we have nothing to say about how to understand what is going on when a side effect persists across different types of speech acts, let alone across different speakers (*Did you see a man*$_i$ *run past? Yes, he*$_i$ *turned left.*).

At several points we have emphasized that our theory predicts that relative scope and binding potential depends on the order in which expressions are evaluated. One of the virtues of our system is that it makes it natural for a quantifier to be able to take inverse scope (that is, to get evaluated before some quantifier that linearly precedes it, by occupying a higher level in the tower) without necessarily allowing a pronoun to be evaluated before its binder. But there are well-known cases of quantificational binding in which the pronoun does linearly precede its binder:

(97) Which of his$_i$ relatives does every man$_i$ love _ the most?

Perhaps surprisingly, these so-called reconstruction cases fall out without special stipulation given certain independently motivated assumptions about the syntax and semantics of *wh*-expressions. The basic idea is that, as a result of its syntactic displacement, the evaluation of the fronted *wh*-phrase *which of his relatives* is postponed until after the quantifier *every man* has already been evaluated (Shan & Barker 2006: 123, Barker 2008).

It bears mentioning that although we have argued that donkey pronouns are the most ordinary type of pronouns, and therefore that donkey anaphora does not justify resorting to a D-type analysis, there are many other uses of pronouns that appear to argue in favor of an E-type or D-type analysis.

(98) After everyone dropped his paycheck on the floor, everyone picked it up again.

There is a salient reading of (98) on which the pronoun appears to mean something like *his paycheck*, with the virtual *his* bound by *everyone*. As long as we generalize the lexical entry for pronouns as in Shan & Barker 2006 and

Barker 2008, our system is perfectly able to bind into a functional pronoun in the style of, e.g., Jacobson 1999. However, it remains as much a mystery for us as for everyone else how that functional pronoun comes to have the content of the **paycheck** function.

None of these open questions diminishes our belief that understanding quantificational binding requires a theory that unifies scope-taking with binding. We have proposed just such a theory, one based on continuations, which allows expressions to dynamically manipulate their semantic context. To what degree this approach will provide useful insights into further mysteries remains to be discovered.

9 Appendix: converting to lambda terms

This appendix illustrates how to convert semantic towers into lambda terms in the linear notation of Shan & Barker 2006. Recall that $\dfrac{f[\ ]}{x}$ is shorthand for $\lambda\kappa.\, f[\kappa(x)]$. Accordingly, our type shifters correspond to lambda terms as follows.

(23) $$\mathbf{L} = \text{Lift} = \lambda x.\, \lambda\kappa.\, \kappa x$$

(24) $$\text{Lower} = \lambda F.\, F(\lambda x.\, x)$$

(36) $$\mathbf{B} = \text{Bind} = \lambda X.\, \lambda\kappa. X(\lambda x.\, \kappa x x)$$

These type shifters are called Up, Down, and Bind in Shan & Barker 2006. Tower combination can also be expressed in linear notation, whether the lifted function (f) finds its lifted argument (x) to the right ($\mathbf{S}_{/}$) or to the left ($\mathbf{S}_{\backslash}$):

(21) $$\mathbf{S}_{/} = \lambda L.\, \lambda R.\, \lambda\kappa.\, L(\lambda f.\, R(\lambda x.\, \kappa(f x)))$$
$$\mathbf{S}_{\backslash} = \lambda L.\, \lambda R.\, \lambda\kappa.\, L(\lambda x.\, R(\lambda f.\, \kappa(f x)))$$

In Shan & Barker 2006, $\mathbf{S}_{/}$ is posited as a primitive called Scope, whereas $\mathbf{S}_{\backslash}$ can be derived as $\text{Scope} \circ (\text{Scope}\,(\text{Up}\,\text{Lift}))$, where $\circ$ denotes function composition and Lift is as defined in that paper.

Thus we can compute the semantics of the donkey sentence from (42) as follows.

(42)

$$
\begin{aligned}
\mathbf{B}\text{ someone} &= \lambda\kappa.\,\exists y.\,\kappa y y\\
\mathbf{L}\text{ knocked} &= \lambda\kappa.\,\kappa(\mathbf{knocked})\\
\mathbf{S}_{\backslash}\ (\mathbf{B}\text{ someone})\ (\mathbf{L}\text{ knocked}) &= \lambda\kappa.\,\exists y.\,\kappa(\mathbf{knocked}\,y)y\\
\text{she} &= \lambda\kappa.\,\lambda x.\,\kappa x\\
\mathbf{L}\text{ left} &= \lambda\kappa.\,\kappa(\mathbf{left})\\
\mathbf{S}_{\backslash}\ \text{she}\ (\mathbf{L}\text{ left}) &= \lambda\kappa.\,\lambda x.\,\kappa(\mathbf{left}\,x)\\
\text{if} &= \lambda\kappa.\,\neg\kappa(\lambda p\lambda q.\,p\wedge\neg q)\\
\mathbf{S}_{/}\ \text{if} &= \lambda R.\,\lambda\kappa.\,\neg R(\lambda p.\,\kappa(\lambda q.\,p\wedge\neg q))\\
\mathbf{S}_{/}\ \text{if}\ (\mathbf{S}_{\backslash}\ (\mathbf{B}\text{ someone})\ (\mathbf{L}\text{ knocked})) &= \lambda\kappa.\,\neg\exists y.\,\kappa(\lambda q.\,(\mathbf{knocked}\,y)\wedge\neg q)y\\
\mathbf{S}_{/}\ (\mathbf{S}_{/}\ \text{if}\ (\mathbf{S}_{\backslash}\ (\mathbf{B}\text{ someone})\ (\mathbf{L}\text{ knocked})))\ (\mathbf{S}_{\backslash}\ \text{she}\ (\mathbf{L}\text{ left}))&\\
&= \lambda\kappa.\,\neg\exists y.\,\kappa((\mathbf{knocked}\,y)\wedge\neg(\mathbf{left}\,y))\\
\text{Lower}\ (\mathbf{S}_{/}\ (\mathbf{S}_{/}\ \text{if}\ (\mathbf{S}_{\backslash}\ (\mathbf{B}\text{ someone})\ (\mathbf{L}\text{ knocked})))\ (\mathbf{S}_{\backslash}\ \text{she}\ (\mathbf{L}\text{ left})))&\\
&= \neg\exists y.\,(\mathbf{knocked}\,y)\wedge\neg(\mathbf{left}\,y)
\end{aligned}
$$

Checking each step in this derivation is a good way to appreciate the convenience of the tower notation.

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