Assignment No. 12

Due: 13:15 on Tuesday 31 March 2015 via email

There is no word limit/requirement for these exercises. Your responses may be in English, French, Spanish, German, Arabic, or any other language you are comfortable writing in. The grammar, spelling, and prescriptive conventions are not evaluated for the assignment. You do not need to edit, revise a number of times, or attend in any special way to form or language. You should just write in a way that is clear to you. You are welcome to use bullet points. You do not need to write complete sentences or in paragraph form complete with transitions.

Homework should be submitted by 15:15 on the day it is due. There is no late homework accepted. All written assignments must be typed using 12 pt Times New Roman or 11 pt Arial font with 1" margins. All assignments must be send in one of the following formats: .doc, .docx, .txt, .tex, .pdf, .rtf, .odt, .dot. Remember to cite all sources and use APA guidelines for the citations. Homework must also include your name, class, date, and assignment.

1 Readings

1.1 Quantification

Read section 1.5 'Quantifiers' of chapter 1 'Logical Foundations' from Sam Vendervelde (2010). *Bridge to Higher Mathematics* `https://myslu.stlawu.edu/~svanderv/chapone.pdf`.

1.2 Predication

Read subsection 3.1.1 'Semantic Valency' of chapter 3 'Some basic linguistic relations' from Beatrice Santorini, and Anthony Kroch (2007-). *The syntax of natural language: An online introduction using the Trees program.* `http://www.ling.upenn.edu/~beatrice/syntax-textbook/ch3.html#argumenthood`

1.3 Formula & Logic [Optional Reading]

Additionally, if you would like to know more about functions and the foundational lecture that established them as a system of understanding meaning in natural language, read a translation of Gottlob Frege's 1891 lecture 'Funktion und Begriff', Vortrag, gehalten in der Sitzung vom 9. Januar 1891 der Jenaischen Gesellschaft fr Medizin und Naturwissenschaft, Jena: Hermann Pohle. Translated as 'Function and Concept' by P. Geach in *Translations from the Philosophical Writings of Gottlob Frege*, P. Geach and M. Black (eds. and trans.), Oxford: Blackwell, third edition, 1980. `http://fitelson.org/proseminar/frege_fac.pdf`

1.4 Set Theory [Optional Reading]

A really great book for learning about core mathmatical principles is *Bridge to Higher Mathematics* by Sam Vendervelde (2010). Four chapters and the exercise key are freely available on his personal website. The First two chapters (chapter 1 'Logical Foundations' `https://myslu.stlawu.edu/~svanderv/chapone.pdf` and chapter 2 'Set Theory' `https://myslu.stlawu.edu/~svanderv/chaptwo.pdf`) are a great introduction to logic and set theory which we have been using in this class. The examples come from both math but also language which is particularly relevant to this class.

2 Predicate Logic – Expansion

For homework no. 10, you were to have translated English prose statements into predicate-argument notation and vice versa. In lecture, we introduced a notational system and set theoretic way of conceptualizing of meaning of predicates.

For sections 2.1 and 2.2, translate the predicate-argument statements into predicate-logic statements, and the English prose statements into predicate-logic statements. Declare the symbols used in your predicate-logic

statements. You can use any symbol you want for the constants and predicates. It will be easiest and most clear if you use the first letter of the noun and the first letter of the predicate. For each statement make a set U and using extension notation, list the entities $u \in U$. Additionally, define the constant symbols and predicate symbols you introduce using denotation notation, set-builder notation, and extension notation.

Examples are shown in **red** for two of the statements in each of the required section 2.1 and section 2.2. The steps for completing the task are: 1) translate the (English prose statement into) predicate-argument statement into a predicate-logic statement; 2) define a set U using extension notation which contains all the entities for the statement; 3) define the entities in U by declaring the constant symbol, using denotation notation, using set-builder notation, and extension notation; and 4) define the predicates in the predicate-logic statement by declaring the predicate letter and the number of number of arguments, using denotation notation, using set-builder notation, and extension notation.

In section 2.9, you will make a master list of all of the entities and predicates that you wrote for section 2.1 and section 2.2. When symbols have are identical, make use of subscripts to distinguish them. The result of this section will be a long list of all of the entities and predicates in the world for the homework. I have started the three lists for you.

Optional exercises and examples of them in **blue** are included to provide additional practice and extend the material beyond what was covered in lecture. Optional exercises are not necessarily an indication of what we will cover in the class, but merely provided for those wishing to explore the topic at greater depth and for their diversion.

2.1 One Place Predicates

1. "Rodrigo slept"
    1. sleep(rodrigo) $\rightarrow S(r)$
    2. $U = \{r\}$
    3. $r = [\![\text{Rodrigo}]\!] = \{x : x \text{ is Rodrigo}\} = \{rodrigo\}$
    4. $S(x) = [\![\text{sleep}]\!] = \{x : x \text{ sleeps}\} = \{s\}$
2. "Sally had been swimming"
    1. swim(sally) $\rightarrow S(s)$
    2. $U = \{s\}$
    3. $s = [\![\text{Sally}]\!] = \{x : x \text{ is Sally}\} = \{sally\}$
    4. $S(x) = [\![\text{swim}]\!] = \{x : x \text{ swims}\} = \{s\}$
3. 'Hawai'i is exciting'
4. 'Karen is a genius'
5. 'Cerberus barks'
6. 'Nishi is a secretary'
7. fun(noora)
8. awesome(euna)

2.2 Two Place Predicates

1. "Reza loves John"
    1. love(reza,john) $\rightarrow L(r, j)$
    2. $U = \{r, j\}$
    3. $r = [\![\text{Reza}]\!] = \{x : x \text{ is Reza}\} = \{reza\}$

$j = [\![\text{John}]\!] = \{x : x \text{ is John}\} = \{john\}$

4. $L(x, y) = [\![\text{love}]\!] = \{< x, y >: x \text{ loves } y\} = \{< r, j >\}$

2. "John likes Mary"

1. like(john, mary) $\rightarrow L(j, m)$
2. $U = \{j, m\}$
3. $m = [\![\text{Mary}]\!] = \{x : x \text{ is Mary}\} = \{mary\}$
   $j = [\![\text{John}]\!] = \{x : x \text{ is John}\} = \{john\}$
4. $L(x, y) = [\![\text{like}]\!] = \{< x, y >: x \text{ likes } y\} = \{< j, m >\}$

3. 'Mahmoud admires Fairouz'
4. 'Fairouz admires Mahmoud'
5. 'Dana is taller than Janelle'
6. 'Tina Fey wrote *Bossypants*'
7. learn(sean, latin)
8. father_of(parley, christen)
9. square_of(9, 3)
10. play(martina, tennis)
11. capital_of(beirut, lebanon)
12. in(tasmania, australia)
13. near(the_falkland_islands, argentina)

2.3 Three Place Predicates [Optional Practice]

1. 'Graham introduced Christen to David'

- introduce(graham,christen,david) $\rightarrow I(g, c, d)$
- $U = \{g, c, d\}$
- $g = [\![\text{Graham}]\!] = \{x : x \text{ is Graham}\} = \{graham\}$
- $c = [\![\text{Christen}]\!] = \{x : x \text{ is Christen}\} = \{christen\}$
- $d = [\![\text{David}]\!] = \{x : x \text{ is David}\} = \{david\}$
- $I(x, y, z) = [\![\text{introduce}]\!] = \{< x, y, z >: x \text{ introduces } y \text{ to } z\} = \{< g, c, d >\}$

2. 'Bertha cooked Christen pozole'

- cook(bertha,pozole,christen) $\rightarrow C(b, p, c)$
- $U = \{b, c, p\}$
- $b = [\![\text{Bertha}]\!] = \{x : x \text{ is Bertha}\} = \{bertha\}$
- $c = [\![\text{Christen}]\!] = \{x : x \text{ is Christen}\} = \{christen\}$
- $p = [\![\text{pozole}]\!] = \{x : x \text{ is a red mexican soup}\} = \{pozole\}$
- $C(x, y, z) = [\![\text{cook}]\!] = \{< x, y, z >: x \text{ cooks } y \text{ for } z\} = \{< b, p, c >\}$

3. 'the North Koreans leaked the movie to the internet'

4. 'Jorge volunteered his expertise at GMHC'
5. 'Janelle sang the aria for the prince'
6. give(christen, ernesto, flowers)
7. bake(nora, pablo, hamantashen)
8. send(dani, sarah, arkansas)

2.4 Four-plus Place Predicates [Optional Practice]

1. 'Dani bought Bertha the flowers at Walmart
   - buy(dani,flowers,bertha,walmart) $\rightarrow B(d, f, b, w)$
   - $U = \{b, d, f, w\}$
   - $b = [\![\text{Bertha}]\!] = \{x : x \text{ is Bertha}\} = \{bertha\}$
   - $d = [\![\text{Dani}]\!] = \{x : x \text{ is Dani}\} = \{dani\}$
   - $f = [\![\text{flowers}]\!] = \{x : x \text{ is a flower}\} = \{flowers\}$
   - $w = [\![\text{Walmart}]\!] = \{x : x \text{ is the store Walmart}\} = \{walmart\}$
   - $B(x, y, z, w) = [\![\text{buy}]\!] = \{< x, y, z, w >: x \text{ buys } y \text{ for } z \text{ at } w\} = \{< d, f, b, w >\}$
2. 'Reza made Bryan the cake at home with gluten-free flour'
   - make(reza,cake,bryan,gluten-free_flour,home) $\rightarrow M(r, c, b, g, h)$
   - $U = \{b, c, g, h, r\}$
   - $b = [\![\text{Bryan}]\!] = \{x : x \text{ is Bryan}\} = \{bryan\}$
   - $c = [\![\text{cake}]\!] = \{x : x \text{ is a cake}\} = \{cake\}$
   - $g = [\![\text{Gluten-free flour}]\!] = \{x : x \text{ is gluten-free wheat flour}\} = \{gluten - free\_flour\}$
   - $h = [\![\text{home}]\!] = \{x : x \text{ is a domicile}\} = \{home\}$
   - $r = [\![\text{Reza}]\!] = \{x : x \text{ is Reza}\} = \{reza\}$
   - $M(x, y, z, w, v) = [\![\text{make}]\!] = \{< x, y, z, w, v >: x \text{ makes } y \text{ for } z \text{ with } w \text{ at } v\} = \{< r, c, b, g, h >\}$
3. 'Graham poured the drink in the kitchen for Christen'
4. 'Nena bought the rice at the store for the family'
5. 'Tensing cooked the meal in the tent with the stove'
6. watch(noora,TV,laptop,Hawai'i)
7. run(golnesa,5k,breast_cancer,romania)
8. tutor(karen,christen,semantics,graduate_center)

2.5 Embedding & Predication [Optional Practice]

1. 'Bertha claims that Mexican cuisine is the best'
   - claim(bertha,best(mexican_cuisine)) $\rightarrow C(b, B(m))$
   - $U = \{b, m\}$
   - $b = [\![\text{Bertha}]\!] = \{x : x \text{ is Bertha}\} = \{bertha\}$
   - $m = [\![\text{Mexican cuisine}]\!] = \{x : x \text{ is Mexican food}\} = \{mexican\_cuisine\}$
   - $B(x) = [\![\text{the best}]\!] = \{x : x \text{ is the best}\} = \{m\}$
   - $C(x, y) = [\![\text{claim}]\!] = \{< x, y >: x \text{ claims } y\} = \{b, B(m)\}$
2. 'Nora heard Pablo call Omer'
   - hear(nora,call(pablo,omer)) $\rightarrow H(n, C(p, o))$
   - $U = \{n, o, p\}$
   - $n = [\![\text{Nora}]\!] = \{x : x \text{ is Nora}\} = \{nora\}$
   - $o = [\![\text{Omer}]\!] = \{x : x \text{ is Omer}\} = \{omer\}$
   - $p = [\![\text{Pablo}]\!] = \{x : x \text{ is Pablo}\} = \{pablo\}$
   - $C(x, y) = [\![\text{call}]\!] = \{< x, y >: x \text{ calls } y\} = \{< p, o >\}$
   - $H(x, y) = [\![\text{hear}]\!] = \{< x, y >: x \text{ hears } y\} = \{< n, C(p, o) >\}$
3. 'Nate thinks that Keith is handsome'
4. 'Graciela told Bertha that Sandra thinks that Maria Elena stole Eduardo from Rosa'
5. 'The cat saw the mouse run'
6. see(tamara,dance(farah))
7. think(carlos,pretty(euna))
8. cause(christen,learn(rodrigo))

2.6 Multiple Expressions & Predication [Optional Practice]

1. 'Marta and Erik dance'
   - dance(marta) $\wedge$ dance(erik)$\rightarrow D(m) \wedge D(e)$
   - $U = \{m, e\}$
   - $e = [\![\text{Erik}]\!] = \{x : x \text{ is Erik}\} = \{erik\}$
   - $m = [\![\text{Marta}]\!] = \{x : x \text{ is Marta}\} = \{marta\}$
   - $D(x) = [\![\text{dance}]\!] = \{x : x \text{ dances}\} = \{e, m\}$
2. 'If Graciela cooked chorizo then she ate it'
   - cook(graciela,chorizo) $\rightarrow$ eat(graciela,chorizo) $\rightarrow C(g, c) \rightarrow E(g, c)$
   - $U = \{c, g\}$
   - $c = [\![\text{chorizo}]\!] = \{x : x \text{ is a loose spicy Mexican sausage}\} = \{chorizo\}$
   - $g = [\![\text{Graciela}]\!] = \{x : x \text{ is Graciela}\} = \{graciela\}$
   - $C(x, y) = [\![\text{cook}]\!] = \{< x, y >: x \text{ cooks } y\} = \{< g, c >\}$
   - $E(x, y) = [\![\text{eat}]\!] = \{< x, y >: x \text{ eats } y\} = \{< g, c >\}$

3. 'Karen smokes or drinks'
4. 'Jorge teaches biology or does research'
5. 'Nena is old but fun'
6. 'Sandra is beautiful but nice'
7. 'If Reza drinks then he is fun'
8. 'Golnesa makes pozole if and only if Eduardo buys chiles'

2.7 Quantification [Optional Practice]

2.7.1 Existential Quantification

1. "Some students swim"
   - swim(some_student) $\rightarrow \exists x(S_i(x) \wedge S_j(x))$
   - $U = \{\emptyset\}$
   - $S_i(x) = [\![\text{student}]\!] = \{x : x \text{ is a student}\} = \{???\}$
   - $S_j(x) = [\![\text{swims}]\!] = \{x : x \text{ swims}\} = \{???\}$
2. 'Some Mexicans are American'
   - american(some_mexican) $\rightarrow \exists x(A(x) \wedge M(x))$
   - $U = \{\emptyset\}$
   - $A(x) = [\![\text{American}]\!] = \{x : x \text{ is a American}\} = \{???\}$
   - $M(x) = [\![\text{Mexican}]\!] = \{x : x \text{ is a Mexican}\} = \{???\}$
3. 'Sandra ate a banana'
   - eat(sandra,some_banana) $\rightarrow \exists x(E(s, x) \wedge B(x))$
   - $U = \{s\}$
   - $s = [\![\text{Sandra}]\!] = \{x : x \text{ is Sandra}\} = \{Sandra\}$
   - $B(x) = [\![\text{banana}]\!] = \{x : x \text{ is a banana}\} = \{???\}$
   - $E(x, y) = [\![\text{eat}]\!] = \{< x, y >: x \text{ eats } y\} = \{< s, ??? >\}$
4. 'Bertha was cooking something'
   - cook(bertha,thing) $\rightarrow \exists x(C(b, x) \wedge T(x))$
   - $U = \{b\}$
   - $b = [\![\text{Bertha}]\!] = \{x : x \text{ is Bertha}\} = \{bertha\}$
   - $C(x, y) = [\![\text{cook}]\!] = \{< x, y >: x \text{ cooks } y\} = \{< b, ??? >\}$
   - $T(x) = [\![\text{thing}]\!] = \{x : x \text{ is a thing}\} = \{???\}$
5. 'There is a cloud in the sky'
   - there_is(cloud_in_the_sky) $\rightarrow \exists x(C(x))$
   - $U = \{\emptyset\}$
   - $C(x) = [\![\text{cloud in the sky}]\!] = \{x : x \text{ is a cloud in the sky}\} = \{???\}$
6. 'There is a woman'

- there_is(woman) $\rightarrow \exists x(W(x))$
- $U = \{\emptyset\}$
- $W(x) = [\![\text{woman}]\!] = \{x : x \text{ is a woman}\} = \{???\}$

7. 'Some actors are rich'
8. 'Some men are handsome'
9. 'A grad student defended'
10. 'Ofra saw a person'
11. 'Sameer ate something'
12. 'Yulia stole a car'
13. 'There is a shah of Iran'
14. 'There is a cat in the box'

2.8 Universal Quantification

1. "Every person is friendly"
   - friendly(every_person) $\rightarrow \forall x(P(x) \rightarrow F(x))$
   - $U = \{\emptyset\}$
   - $P(x) = [\![\text{person}]\!] = \{x : x \text{ is a person}\} = \{???\}$
   - $F(x) = [\![\text{friendly}]\!] = \{x : x \text{ is friendly}\} = \{???\}$
2. "All Parisians in the room smoke cigarettes"
   - smoke(all_parisians_in_the_room,cigarettes) $\rightarrow \forall x(P(x) \rightarrow S(x, c))$
   - $U = \{c\}$
   - $c = [\![\text{cigarettes}]\!] = \{x : x \text{ is a cigarette}\} = \{cigarettes\}$
   - $P(x) = [\![\text{Parisian in the room}]\!] = \{x : x \text{ is a Parisian in the room}\} = \{???\}$
   - $S(x, y) = [\![\text{smoke}]\!] = \{< x, y >: x \text{ smokes } y\} = \{<???, c >\}$
3. 'Sandra danced in all the clubs'
   - dance(sandra,all_clubs) $\rightarrow \forall x(C(x) \rightarrow D(s, x))$
   - $U = \{s\}$
   - $s = [\![\text{Sandra}]\!] = \{x : x \text{ is Sandra}\} = \{Sandra\}$
   - $C(x) = [\![\text{club}]\!] = \{x : x \text{ is a club}\} = \{???\}$
   - $D(x, y) = [\![\text{dance in}]\!] = \{< x, y >: x \text{ dances in } y\} = \{< s, ??? >\}$
4. 'Pablo made all the money'
   - make(pablo,all_money) $\rightarrow \forall x(M_i(x) \rightarrow M_j(p, x))$
   - $U = \{p\}$
   - $p = [\![\text{Pablo}]\!] = \{x : x \text{ is Pablo}\} = \{pablo\}$
   - $M_j(x) = [\![\text{money}]\!] = \{x : x \text{ is money}\} = \{???\}$
   - $M_j(x, y) = [\![\text{make}]\!] = \{< x, y >: x \text{ makes } y\} = \{< p, ??? >\}$

5. "All actors are rich'
6. 'All Mexicans are amazing'
7. 'Every man kissed Reza'
8. 'Reza kissed every man'
9. 'Bertha made every meal'
10. 'Jorge completed all the exams

2.9 Our world

2.9.1 Superset of all entities in our world

- $U_{<w,t,>} = \{j, m, r_1, r_2, s_1, b_1, b_2, c_1, c_2, c_3, c_4, d_1, d_2, e, f, g_1, g_2, g_3, h, m_2, m_3, n, o, p_1, p_2, s_2, w \dots\}$

2.9.2 Entities in our world

- $j = [\![\text{John}]\!] = \{x : x \text{ is John}\} = \{john\}$
- $m_1 = [\![\text{Mary}]\!] = \{x : x \text{ is Mary}\} = \{mary\}$
- $r_1 = [\![\text{Rodrigo}]\!] = \{x : x \text{ is Rodrigo}\} = \{rodrigo\}$
- $r_2 = [\![\text{Reza}]\!] = \{x : x \text{ is Reza}\} = \{reza\}$
- $s_1 = [\![\text{Sally}]\!] = \{x : x \text{ is Sally}\} = \{sally\}$
- $b_1 = [\![\text{Bertha}]\!] = \{x : x \text{ is Bertha}\} = \{bertha\}$
- $b_2 = [\![\text{Bryan}]\!] = \{x : x \text{ is Bryan}\} = \{bryan\}$
- $c_1 = [\![\text{cake}]\!] = \{x : x \text{ is a cake}\} = \{cake\}$
- $c_2 = [\![\text{Christen}]\!] = \{x : x \text{ is Christen}\} = \{christen\}$
- $c_3 = [\![\text{chorizo}]\!] = \{x : x \text{ is a loose spicy Mexican sausage}\} = \{chorizo\}$
- $c_4 = [\![\text{cigarettes}]\!] = \{x : x \text{ is a cigarette}\} = \{cigarettes\}$
- $d_1 = [\![\text{Dani}]\!] = \{x : x \text{ is Dani}\} = \{dani\}$
- $d_2 = [\![\text{David}]\!] = \{x : x \text{ is David}\} = \{david\}$
- $e = [\![\text{Erik}]\!] = \{x : x \text{ is Erik}\} = \{erik\}$
- $f = [\![\text{flowers}]\!] = \{x : x \text{ is a flower}\} = \{flowers\}$
- $g_1 = [\![\text{Graham}]\!] = \{x : x \text{ is Graham}\} = \{graham\}$
- $g_2 = [\![\text{Gluten-free flour}]\!] = \{x : x \text{ is gluten-free wheat flour}\} = \{gluten - free\_flour\}$
- $g_3 = [\![\text{Graciela}]\!] = \{x : x \text{ is Graciela}\} = \{graciela\}$
- $h = [\![\text{home}]\!] = \{x : x \text{ is a domicile}\} = \{home\}$
- $m_2 = [\![\text{Mexican cuisine}]\!] = \{x : x \text{ is Mexican food}\} = \{mexican\_cuisine\}$
- $m_3 = [\![\text{Marta}]\!] = \{x : x \text{ is Marta}\} = \{marta\}$
- $n = [\![\text{Nora}]\!] = \{x : x \text{ is Nora}\} = \{nora\}$

- $o = [\![\text{Omer}]\!] = \{x : x \text{ is Omer}\} = \{omer\}$
- $p_1 = [\![\text{Pablo}]\!] = \{x : x \text{ is Pablo}\} = \{pablo\}$
- $p_2 = [\![\text{pozole}]\!] = \{x : x \text{ is a red mexican soup}\} = \{pozole\}$
- $s_2 = [\![\text{Sandra}]\!] = \{x : x \text{ is Sandra}\} = \{Sandra\}$
- $w = [\![\text{Walmart}]\!] = \{x : x \text{ is the store Walmart}\} = \{walmart\}$
- et cetera...

2.9.3 Predicates in our world

- $L_1(x, y) = [\![\text{like}]\!] = \{< x, y >: x \text{ likes } y\} = \{< j, m_1 >\}$
- $L_2(x, y) = [\![\text{love}]\!] = \{< x, y >: x \text{ loves } y\} = \{< r_2, j >\}$
- $S_1(x) = [\![\text{sleep}]\!] = \{x : x \text{ sleeps}\} = \{r_1\}$
- $S_2(x) = [\![\text{swim}]\!] = \{x : x \text{ swims}\} = \{s_1\}$
- $A(x) = [\![\text{American}]\!] = \{x : x \text{ is a American}\} = \{???\}$
- $B_1(x) = [\![\text{banana}]\!] = \{x : x \text{ is a banana}\} = \{???\}$
- $B_2(x) = [\![\text{the best}]\!] = \{x : x \text{ is the best}\} = \{m_2\}$
- $B_3(x, y, z, w) = [\![\text{buy}]\!] = \{< x, y, z, w >: x \text{ buys } y \text{ for } z \text{ at } w\} = \{< d_1, f, b_1, w >\}$
- $C_1(x, y) = [\![\text{call}]\!] = \{< x, y >: x \text{ calls } y\} = \{< p_1, o >\}$
- $C_2(x, y) = [\![\text{claim}]\!] = \{< x, y >: x \text{ claims } y\} = \{b_1, B(m_2)\}$
- $C_3(x) = [\![\text{cloud in the sky}]\!] = \{x : x \text{ is a cloud in the sky}\} = \{???\}$
- $C_4(x) = [\![\text{club}]\!] = \{x : x \text{ is a club}\} = \{???\}$
- $C_5(x, y, (z)) = [\![\text{cook}]\!] = \{< x, y, z >: x \text{ cooks } y \text{ for } z\} = \{< g_3, c_3 >, < b_1, p_2, c_2 >, < b_1, ??? >\}$
- $D_1(x) = [\![\text{dance}]\!] = \{x : x \text{ dances}\} = \{e, m_3\}$
- $D_2(x, y) = [\![\text{dance in}]\!] = \{< x, y >: x \text{ dances in } y\} = \{< s_2, ??? >\}$
- $E(x, y) = [\![\text{eat}]\!] = \{< x, y >: x \text{ eats } y\} = \{< g_3, c_3 >, < s_2, ??? >\}$
- $F(x) = [\![\text{friendly}]\!] = \{x : x \text{ is friendly}\} = \{???\}$
- $H(x, y) = [\![\text{hear}]\!] = \{< x, y >: x \text{ hears } y\} = \{< n, C(p_1, o) >\}$
- $I(x, y, z) = [\![\text{introduce}]\!] = \{< x, y, z >: x \text{ introduces } y \text{ to } z\} = \{< g_1, c_2, d_2 >\}$
- $M_1(x, y, (z), (w), (v)) = [\![\text{make}]\!] = \{< x, y, z, w, v >: x \text{ makes } y \text{ for } z \text{ with } w \text{ at } v\} = \{< p_1, ??? >, < r_2, c_1, b_2, g_2, h >\}$
- $M_2(x) = [\![\text{Mexican}]\!] = \{x : x \text{ is a Mexican}\} = \{???\}$
- $M_3(x) = [\![\text{money}]\!] = \{x : x \text{ is money}\} = \{???\}$
- $P_1(x) = [\![\text{Parisian in the room}]\!] = \{x : x \text{ is a Parisian in the room}\} = \{???\}$
- $P_2(x) = [\![\text{person}]\!] = \{x : x \text{ is a person}\} = \{???\}$
- $S_3(x, y) = [\![\text{smoke}]\!] = \{< x, y >: x \text{ smokes } y\} = \{<???, c_4 >\}$

- $S_4(x) = [\![\text{student}]\!] = \{x : x \text{ is a student}\} = \{???\}$
- $T(x) = [\![\text{thing}]\!] = \{x : x \text{ is a thing}\} = \{???\}$
- $W(x) = [\![\text{woman}]\!] = \{x : x \text{ is a woman}\} = \{???\}$
- et cetera...