#8.1

- Male and female are disjoint categories:
  - $\forall x\ Male(x) \Leftrightarrow \neg Female(x)$

- A sibling is another child of one's parent:
  - $\forall x,y\ Sibling(x, y) \Leftrightarrow x \neq y\ \wedge\ \exists p\ Parent(p,x)\ \wedge\ Parent(p, y)$

#8.2

a) Some students took French in spring 2001.

$\exists x$ Student(x) $\wedge$ Takes(x, F, Spring2001).

b) Every student who takes French passes it.

$\forall$ x, s Student(x) $\wedge$ Takes(x, F, s) $\Rightarrow$ Passes(x, F, s).

c) Only one student took Greek in spring 2001.

$\exists x$ Student(x)$\wedge$Takes(x,G, Spring2001)$\wedge\forall y$ $y \neq x \Rightarrow \neg$Takes(y,G,Spring2001).

d) The best score in Greek is always higher than the best score in French.

$\forall s$ $\exists x$ $\forall y$ Score(x,G,s) > Score(y,F, s).

#8.3

- AsHighAs(Kilimanjaro, Everest)
- AsHighAs(Kilimajaro, Everest) and AsHighAs(BenNevis, Everest)

- It’s fine as long as you don’t reuse an existing constant

#8.4

1. x = A, y = B, z = B
2. Doesn’t exist
3. X = John, y = John
4. Doesn’t exist

#8.5

a. Horse, cows, and pigs are mammals.

- $Horse(x) \Rightarrow Mammal(x)$
- $Cow(x) \Rightarrow \mathrm{Mammal(x)}$
- $Pig(x) \Rightarrow \mathrm{Mammal(x)}$

b. An offspring of a horse is a horse.

- $Offspring(x,y) \wedge Horse(y) \Rightarrow Horse\mathrm{(x)}$

c. Bluebeard is a horse.

- $Horse(Bluebeard)$

d. Bluebeard is Charlie's parent.

- $Parent(Bluebeard, Charlie)$

e. Offspring and parent are inverse relations.

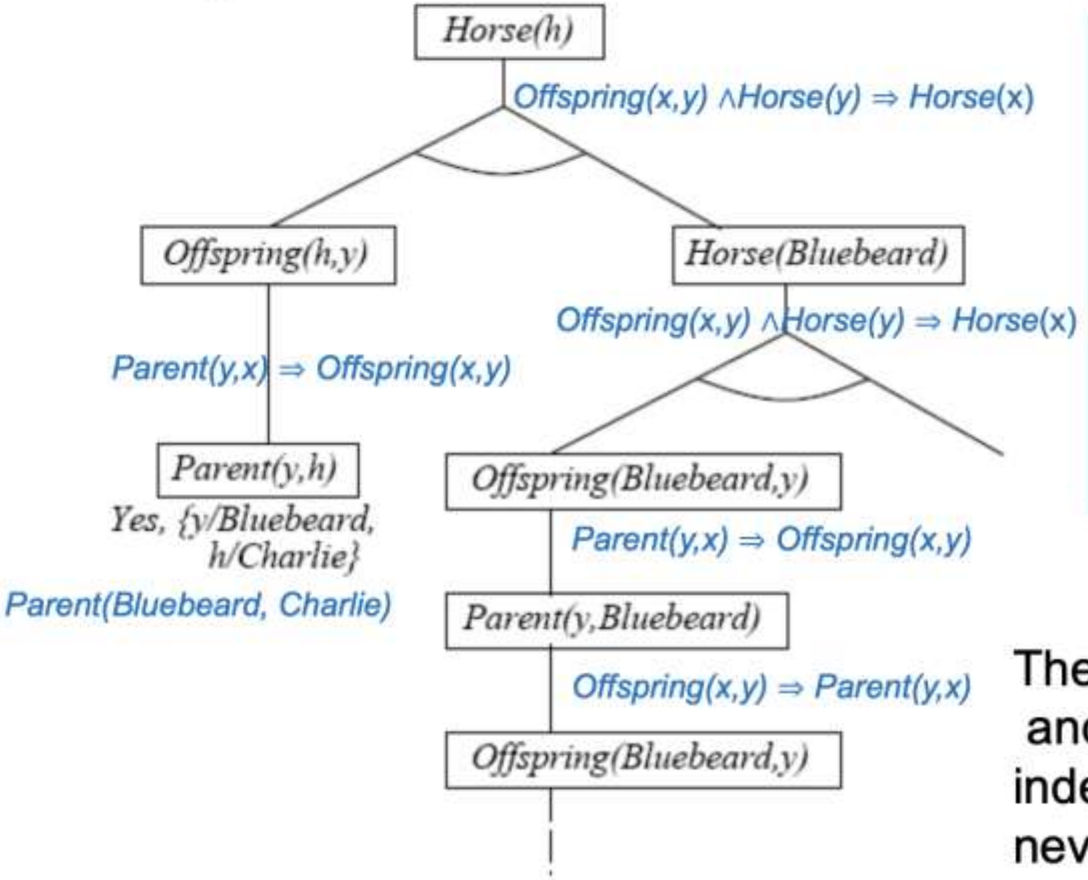
- $Offspring(x,y) \Rightarrow Parent(y,x)$
- $Parent(y,x) \Rightarrow Offspring(x,y)$

f. Every mammal has a parent.

- $Mammal(x) \Rightarrow \mathrm{Parent(G(x),x)}$

#8.5

Draw the proof tree generated by an exhaustive backward-chaining algorithm for the query ∃h Horse(h), where clauses are matched in the order given.



Horse(x) ⇒ *Mammal(x)*
Cow(x) ⇒ Mammal(x)
Pig(x) ⇒ Mammal(x)
Offspring(x,y) ∧*Horse(y)* ⇒ *Horse*(x)
Horse(Bluebeard)
Parent(Bluebeard, Charlie)
Offspring(x,y) ⇒ *Parent(y,x)*
Parent(y,x) ⇒ *Offspring(x,y)*
Mammal(x) ⇒ Parent(G(x),x)

The branch with *Offspring(Bluebeard,y)* and *Parent(y,Bluebeard)* repeats indefinitely, so the rest of the proof is never reached!

#11.1

Initial State:

At(Monkey,A)
At(Bananas,B)
At(Box,C)
Height(Monkey,Low)
Height(Box,Low)
Height(Bananas,High)
Pushable(Box)
Climbable(Box)
Graspable(Bananas)

Goal State:

Have(Monkey, Bananas)

Operators:

Go(x,y)
Precond: At(Monkey,x) AND Height(Monkey,Low)
Effect: At(Monkey,y) AND NOT At(Monkey,x)

Push(b,x,y)
Precond: At(Monkey,x) AND Height(Monkey,Low) AND At(b,x) AND Pushable(b) AND Height(b,Low)
Effect: At(b,y) AND At(Monkey,y) AND NOT At(b,x) AND NOT At(Monkey,x)

ClimbUp(b)
Precond: At(Monkey,x) AND Height(Monkey,Low) AND At(b,x) AND Climbable(x) AND Height(b,Low)
Effect: On(Monkey,b) AND NOT Height(Monkey,Low) AND Height(Monkey,High)

Grasp(b)
Precond: At(Monkey,x) AND Height(Monkey,h) AND At(b,x) AND Graspable(b) AND Height(b,h)
Effect: Have(Monkey,b)

Plan: Go(A, C), Push(Box, C, B), ClimbUp(Box), Grasp(Banana)

#11.2

- See pages 6-7 of our planning lecture notes.

#11.3

- Removing negative effects will not remove any positive states in the world, and thus make the goal easier to achieve.