Mixed quantifiers

- The order of quantifiers makes a difference:
  - $\forall x \exists y(\text{Hates}(x,y))$ vs $\exists x \forall y(\text{Hates}(x,y))$
  - $\forall x \exists y(\text{SameCol}(x,y))$ vs $\exists x \forall y(\text{SameCol}(x,y))$

The step-by-step method of translation

- This is very useful for sentences that contain several quantified noun phrases.
- EG: 'Every dog lives in some kennel'
  - Step one: $\forall x(Dog(x) \rightarrow$ lives-in-some-kennel$(x))$
  - Step two: $\forall x(Dog(x) \rightarrow \exists y(Kennel(y) \wedge LivesIn(x,y))$

- EG: ‘Every dog who lives in a kennel has an owner who lives in a house’.
  - Step One: $\forall x(Dog(x) \wedge$lives-in-a-kennel$(x) \rightarrow$ has-an-owner-who-lives-in-a-house$(x))$.
  - Step Two: $\forall x(Dog(x) \wedge \exists y(Kennel(y) \wedge LivesIn(x,y)) \rightarrow \exists z(Owns(x,z) \wedge$ lives-in-a-house$(z))$.
  - Step Three: $\forall x(Dog(x) \wedge \exists y(Kennel(y) \wedge LivesIn(x,y)) \rightarrow \exists z(Owns(x,z) \wedge \exists y(House(y) \wedge LivesIn(z,y))))$.

Ambiguity

- Quantifiers in English are a rich source of ambiguity.
  - ‘Some poor sucker is mugged every minute’.
    - ? $\exists x(Poor(x) \wedge Sucker(x) \wedge mugged\text{-}every\text{-}minute(x))$
    - $\forall x(Minute(x) \rightarrow some\text{-}poor\text{-}sucker\text{-}is\text{-}mugged\text{-}during(x))$
- Often this ambiguity is resolved by context.