int.1 Sentences

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Ok, now we have a (sketch of a) definition of satisfaction ("true in") for structures and formulas. But it needs this additional bit—a variable assignment—and what we wanted is a definition of sentences. How do we get rid of assignments, and what are sentences?

You probably remember a discussion in your first introduction to formal logic about the relation between variables and quantifiers. A quantifier is always followed by a variable, and then in the part of the sentence to which that quantifier applies (its "scope"), we understand that the variable is "bound" by that quantifier. In formulas it was not required that every variable has a matching quantifier, and variables without matching quantifiers are "free" or "unbound." We will take sentences to be all those formulas that have no free variables.

Again, the intuitive idea of when an occurrence of a variable in a formula φ is bound, which quantifier binds it, and when it is free, is not difficult to get. You may have learned a method for testing this, perhaps involving counting parentheses. We have to insist on a precise definition—and because we have defined formulas by induction, we can give a definition of the free and bound occurrences of a variable x in a formula φ also by induction. E.g., it might look like this for our simplified language:

1. If φ is atomic, all occurrences of x in it are free (that is, the occurrence of x in $P(x)$ is free).
2. If φ is of the form $\neg\psi$, then an occurrence of x in $\neg\psi$ is free iff the corresponding occurrence of x is free in ψ (that is, the free occurrences of variables in ψ are exactly the corresponding occurrences in $\neg\psi$).
3. If φ is of the form $(\psi \land \chi)$, then an occurrence of x in $(\psi \land \chi)$ is free iff the corresponding occurrence of x is free in ψ or in χ.
4. If φ is of the form $\exists x\, \psi$, then no occurrence of x in φ is free; if it is of the form $\exists y\, \psi$ where y is a different variable than x, then an occurrence of x in $\exists y\, \psi$ is free iff the corresponding occurrence of x is free in ψ.

Once we have a precise definition of free and bound occurrences of variables, we can simply say: a sentence is any formula without free occurrences of variables.

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Bibliography