Philosophy 12A: Introduction to Logic

UC Berkeley, Summer Session A, 2013

The Team

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Course Description

This course is a gentle introduction to symbolic logic. Our primary goal is to determine when an argument is *logically valid*—that is, to determine when the conclusion of an argument follows from its premises by virtue of their logical form. In pursuit of this goal, we'll learn a new formal language, the *language of first-order logic*, in stages. At each stage, we'll define logical validity and related logical concepts in terms of the truth values of sentences in the language. In addition, we'll learn a useful method for demonstrating that an argument is logically valid: *natural deduction proofs* in a Fitch-style system.

Lectures are held Tuesday, Wednesday, and Thursday from 1-3:30 in 156 Dwinelle. Sections meet Monday and Friday from 1-3:30 in 156 and 279 Dwinelle (exception: lecture will replace section on Monday, July 1). If your last name begins with A-M, then you'll be meeting with Jeff in 156 Dwinelle. If your last name begins with N-Z, then you'll be meeting with Russell in 279 Dwinelle. Justin, Jeff, and Russell will also hold weekly office hours on Wednesday, Thursday, and Friday respectively from 4-6 in 301 Moses where you can receive individual attention. Feel free to attend any office hours that suit your schedule.

Schedule

Here is the tentative schedule for the course. It is subject to revision as the summer progresses.

Unit I. Sentential Logic

May 28	What is logic? Language of sentential logic.
May 29	More on the language of sentential logic.
May 30	Semantics for sentential logic.
Jun 4	More semantics for sentential logic. Truth-functional completeness.
Jun 5	Fitch-style proofs. Conjunction rules.
Jun 6	Disjunction rules.
Jun 11	Negation rules.
Jun 12	Conditional rules.
Jun 13	Soundness and completeness. Review.
Jun 18	**Midterm Exam.**

Unit II. Predicate Logic

Jun 19	Language of predicate logic.
Jun 20	Semantics for predicate logic.
Jun 25	Mixed quantifiers.

Jun 26 Easy quantifier rules.
Jun 27 Hard quantifier rules.

Unit III. First-Order Logic

Jul 1 Language of first-order logic. Semantics for first-order logic.
Jul 2 Identity Rules. Review.
Jul 3 **Final Exam.**

Requirements

There are three kinds of assignment:

- Weekly exercise sets, worth 40% of your final grade.
- Midterm exam, worth 25% of your final grade.
- Final exam, worth 35% of your final grade.

The midterm exam will be held in lieu of lecture on **June 18**. The final exam will be held on the last day of the session in lieu of lecture on **July 3**. Exercises will be assigned on every Wednesday of the session and are to be submitted in section on the following Monday—for example, the first exercise set will be assigned on **May 29** and will be due in section on **June 3**.

Book

The official text for the course is:

Jon Barwise and John Etchemendy. *Language, Proof and Logic*. CSLI Publications, 1999.

However, your primary source of information will be the lectures. The Barwise and Etchemendy text covers the lecture material in more depth—though in a different sequence—so it is a useful secondary resource.

Students are typically required to buy a new copy of Barwise and Etchemendy so they can submit assignments using the software that comes along with the text. We will *not* be using the software; exercise sets will be submitted on paper. So you *needn't* buy a new copy of the text.

Attendance

Attendance is not a component of your final grade, but it can play an important role in determining your grade in borderline cases. In any case, attending lecture and section is *strongly* encouraged. Summer sessions at UC Berkeley are short and intense, and the course material is cumulative, building on itself over the course of the session. It is crucial that you stay on top of the material.

Group Work

You are encouraged to discuss the weekly exercise sets in groups. Logic is best enjoyed with others! However, you should write up your solutions independently. Also, you should attempt the exercises on your own before meeting with your group. If you cannot do the exercises, you will not do well on the exams.

Academic Integrity

Please do not cheat. This would be depressing. Students caught cheating will receive an F in the course and can face direr consequences in extreme cases.

Disabled Students

If you have a disability and require special accommodation, please contact the Disabled Students' Program to obtain a letter from a disability specialist: http : //dsp.berkeley.edu/. Then pass on the letter to Justin, Jeff, or Russell.

Enjoy the course!

What is Logic?

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Suppose that my twin brother Dave stole a chocolate chip cookie from the cookie jar, and I like chocolate chip cookies, dislike oatmeal raisin cookies, and didn't steal a cookie. Consider the following arguments:

(1) Somebody stole a cookie. I didn't steal a cookie. So, somebody other than me stole a cookie.

(2) The stolen cookie was chocolate chip. After all, the stolen cookie was either chocolate chip or oatmeal raisin.

(3) Nobody stole a cookie. Hence, it's not the case that somebody stole a cookie.

(4) I like chocolate chip cookies. Therefore, I like oatmeal raisin cookies.

(5) Either I stole a cookie or I didn't steal one.

Ask yourself: Are any of these arguments *good*? If so, what makes them good?

Logicians have quite a lot to say about this.

Valid and Sound Arguments

First, let's be careful about what we mean by 'argument.'

Def 1. An *argument* is a series of claims, one of which—the *conclusion*—is supposed to follow from, or be supported by, the others—the *premises*—or to follow from no premises at all.

It might seem strange to call a single claim like (5) an 'argument.' But 'argument' as used here is a technical term and it is useful to include (5) in its extension.

It's helpful *not* to think of two people bickering back and forth. Instead, think of one person trying to convince another person (or herself) that some conclusion holds on the basis of mutually accepted premises.

Arguments can be found in many contexts: philosophy papers, newspaper articles, political debates, conversations at the dinner table, and so on.

Def 1 involves the admittedly vague term 'claim' so that we can remain neutral on whether logic is about sentences in context, the content of these sentences, and so on. This is a controversial issue in the philosophy of logic.

Now that we have a better grip on what arguments are, let's try to be more precise about what makes an argument 'good.' As you might have realized when you were reflecting on (1)-(5), there are different dimensions of goodness. Some of these arguments might have seemed good, in at least one sense, because they start from true premises—(1), (2), and (4) are good in this way. Some of the arguments might have seemed good because they end with a true conclusion—(1), (2), and (5) are good in this way. But—and this is where our course really gets going—there seems to be another sense of goodness altogether that doesn't depend on whether the premises and conclusion of an argument are true. This sense of goodness is concerned with an argument's *flow*.

Consider (1). It's got true premises and a true conclusion. So far so good. But it's got another nice feature. The conclusion of the argument *follows* from its premises. Given that somebody stole a cookie and I didn't steal a cookie, it *must* be the case that somebody other than me stole a cookie.

Compare this to (2). It's got a true premise and a true conclusion. So far so good. But unlike (1), the conclusion of (2) doesn't follow from its premise. Given that the stolen cookie was either chocolate chip or oatmeal raisin, it needn't be the case that the stolen cookie was chocolate chip. The stolen cookie might have been oatmeal raisin. So this argument has a true premise and a true conclusion but nevertheless has bad flow.

Logicians are interested in flow. So let's introduce some terminology for discussing it.

Def 2. An argument is *logically valid* if and only if it is *impossible* for each of its premises (if any) to be true and for its conclusion to be false by virtue of the *logical form* of the argument.

Def 3. An argument is *sound* if and only if it is both logically valid *and* has no false premises.

Def 2 aims to capture the vague idea of *good flow*—of the conclusion of an argument following from its premises. A logically valid argument has good flow. The premises of the argument needn't be true. Its conclusion needn't be true either. But it must be the case that *if* the premises of the argument are true, then the conclusion is also true. We can say: truth is *preserved* downstream in the argument. (We'll return to the business of 'logical form' in a moment.)

Def 3 combines all of the different kinds of goodness that we've discussed. A sound argument is *very* good. It has no false premises. It has good flow. So it has a true conclusion as well.

With this terminology in hand, let's revisit our examples:

• (1) is sound.

• (2) is neither logically valid nor sound. Though this argument has a true premise and a true conclusion, it's not the case that the conclusion must be true if the premise is true. Note that *all* logically invalid arguments are unsound.

• (3) is logically valid but unsound. This argument has a false premise and a false conclusion but still has good flow. While all logically invalid arguments are unsound, some logically valid arguments are sound—those with true premises or no premises—and some logically valid arguments are unsound—those with false premises.

• (4) is neither logically valid nor sound.

• (5) is sound. We'll treat arguments with no premises like arguments with premises that must be true. These arguments are sound if their conclusions must be true.

Our target in this course is logical validity. Admittedly, the question of whether the premises of an argument are true can be an interesting one. But usually this question lies outside the scope of logic (exception: when the premises of an argument are logically 'special' in some way—for example, when they're logical truths (see below)). If an argument is about numbers, then it's usually the mathematician's job to tell us whether its premises are true. If an argument is about spacetime, then it's usually the physicist's job to tell us whether its premises are true. The logician's job is to tell us whether these arguments have good flow.

Def 2 allows us to be more rigorous when talking and thinking about the flow of arguments. However, this definition isn't completely precise. When we say 'It is impossible for each of its premises to be true...,' what do we mean by 'impossible'? How should we interpret this expression? Is it logically/metaphysically/epistemically necessary that if the premises are true then the conclusion is true? Logicians sometimes say that the premises of a logically valid argument *guarantee* the truth of its conclusion. But in what sense exactly?

Also, consider the clause 'by virtue of the logical form...' in Def 2. This rider is included because of arguments like this:

(6) The chocolate chip cookies are bigger than the oatmeal raisin cookies. So, the oatmeal raisin cookies are smaller than the chocolate chip cookies.

Given the meaning of 'bigger' and 'smaller,' the conclusion of (6) follows from its premise: it is impossible for the chocolate chip cookies to be bigger than the oatmeal raisin cookies and for the oatmeal raisin cookies not to be smaller than the chocolate chip cookies. However, logicians do not think that (6) is *logically* valid. (1), (3), and (5) have good flow by virtue of the meaning of 'logical' terms like 'somebody,' 'nobody,' 'or,' and 'not.' When we do logic, we're interested in arguments that have good flow by virtue of their logical structure. This is, of course, another source of imprecision: what bits of language count as the logical ones? How to draw the divide between the logical and non-logical?

We're now in thorny terrain. The questions we've raised—How to interpret 'impossible' in Def 2? What is 'logical form'?—remain the subject of intense debate and we're not going to definitively answer these questions in this course. Our target—logical validity—will remain at the intuitive, *informal* level. But we'll try to sharpen this concept by developing a *formal* analysis of good flow (by virtue of logical form). As our course progresses, you should be asking yourself how well the formal analysis captures our informal target.

The Family

So what is logic about? So far our answer is: logical validity. This is more or less right, but there are other candidate answers. In fact, there is a large cluster of interrelated logical concepts surrounding logical validity.

Def 4. A claim ψ is a *logical consequence* of the possibly empty set of claims $\{\varphi_1, ..., \varphi_n\}$ if and only if the argument with premises $\varphi_1, ..., \varphi_n$ and conclusion ψ is logically valid.

That is, the conclusion of a logically valid argument is a logical consequence of the set of its premises.

Def 5. A claim φ is a *logical truth* if and only if the argument with no premises and conclusion φ is logically valid.

Examples:

(5) Either I stole a cookie or I didn't steal one.

(7) If I am in the pantry, then I am in the pantry.

Def 6. A claim φ is a *logical falsehood* if and only if the negation of this claim is a logical truth (where the negation of φ is the claim that is true when φ is false and false when φ is true).

Examples:

(8) I stole a cookie and I didn't steal one.

(9) It's not the case that if I am in the pantry, then I am in the pantry.

Def 7. Claims φ and ψ are *logically equivalent* if and only if the argument from φ to ψ is logically valid and the argument from ψ to φ is logically valid.

Examples:

(10) I like chocolate chip cookies.

(11) I like chocolate chip cookies and I like chocolate chip cookies.

(12) It's not the case that I don't like chocolate chip cookies.

Whereas logical validity is a property of arguments, logical consequence is a relation between a set of claims and a claim, logical truth and falsehood are properties of claims, and logical equivalence is a relation between claims.

In this course, we'll also investigate these different informal concepts. But since they're all definable in terms of logical validity, it still makes sense to say that logic is about logical validity.

Why Study Logic?

In the opening pages of Barwise and Etchemendy [1999], there are some grand claims about the import of logic:

> *All* rational inquiry depends on logic, on the ability of people to reason correctly most of the time, and, when they fail to reason correctly, on the ability of others to point out the gaps in their reasoning. (p. 1)

> [The concept of logical validity] is also used in disconfirming a theory. For if a particular claim is a logical consequence of a theory, and we discover that the claim is false, then we know the theory itself must be incorrect in some way or other. (p. 4)

> Rational inquiry, in our sense, is not limited to academic disciplines, and so neither are the principles of logic. If your beliefs about a close friend logically imply that he would never spread rumors behind your back, but you find out that he has, then your beliefs need revision. Logical consequence is central, not only to the sciences, but to virtually every aspect of everyday life. (p. 5)

These passages suggest that logic has a special role to play in rational inquiry, both about scientific theories and ordinary everyday situations. Now, it's fairly uncontroversial that logic has *some* connection to theoretical reasoning. But as we've been understanding our subject, logic is not *about* rational inquiry, or *about* how we ought to change our beliefs over time. Logic is about logical validity; it tells us what follows from what. If logic plays a special role in reasoning, this is because there is a special kind of bridge or connection between logical validity, on the one hand, and scientific theorizing, everyday decision making, and so forth, on the other.

One last introductory remark. At times, this course might seem difficult. But something to keep in mind when you find yourself confused about a tricky concept or stuck on a proof: the very fact that you've fed yourself breakfast, put clothes on, made it to the bus on time, and arrived in this classroom is evidence that you've already mastered a great deal of logic. If you weren't already proficient in logic, you'd have died a long time ago.