

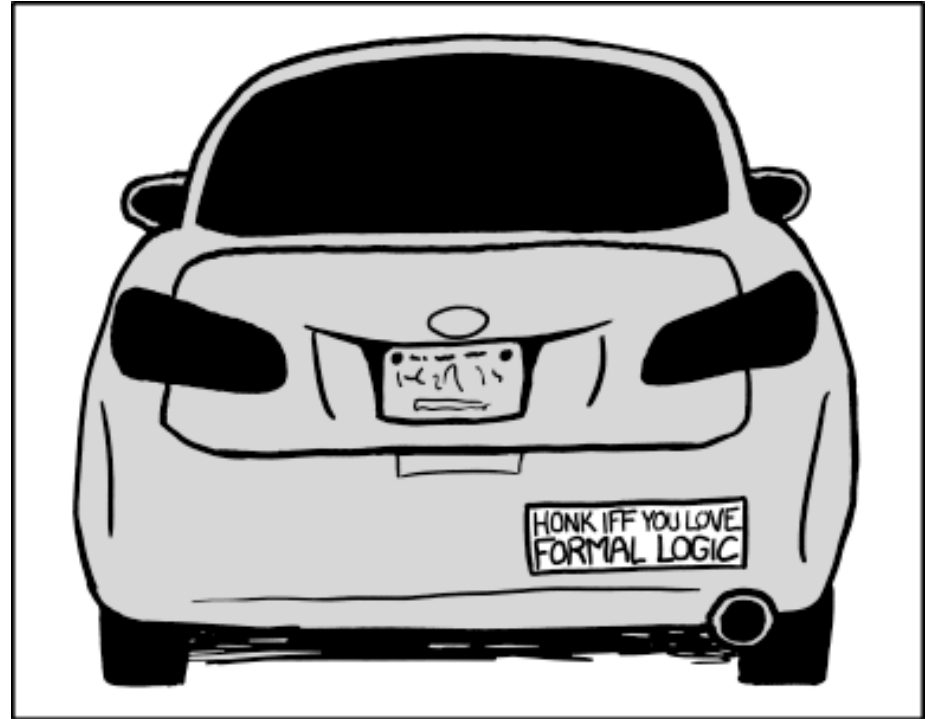
# Here Early?

Here for CSE 311?

Welcome! You're early!

Want a copy of these slides to take notes?

You can download them from the calendar webpage [cs.uw.edu/311](https://cs.uw.edu/311)



# Logistics and Propositional Logic

CSE 311: Foundations of  
Computing I  
Lecture 1

# Outline

Course logistics

What is the goal of this course?

Start of Propositional Logic

# Staff



Instructor: Robbie Weber

Ph.D. from UW CSE in theory  
Third year as teaching faculty  
Fourth time teaching 311

Office: CSE2 311

Email: [rtweber2@cs.washington.edu](mailto:rtweber2@cs.washington.edu)

## TAs

Jacob Berg

Grace Chen

Yusuf Hanafy

Kenny Ma

Robert Stevens

Aria Tang

Davin Tjia

Yadi Wang

Alice Hoyer

# This is where syllabus information would go

If we had time...

Since it's Winter, we have fewer lectures than normal.

So detailed information is in an extra recording on panopto. Part of HW1 is watching that video.

# What you need to know right now

We'll have a mix of zoom and in-person office hours.

We'll have a **take-home** "mini-midterm" (weekend of Feb 10-12)

We'll have an **in-person** final (Wed March 15, 8:30 AM)

Section participation is **required**.

The course is designed to give you high-level ideas here and practice in section. Details on the syllabus (including what to do if you can't make the occasional section).

Sections aren't recorded, but resources are available.

Lecture attendance won't be tracked (and recordings go on panopto).

# We're (still) in a pandemic...

Things have generally been improving [knock on wood]

I've put as much into the syllabus as I can, but fundamentally ヽ(๑)ノ

Now is a great time to:

Ask DRS for accommodations if you think you might need formal ones.

Start looking for a study group!

# CSE 390Z

390Z is:  
Practice with concepts  
Lessons on study skills  
Place to find study groups

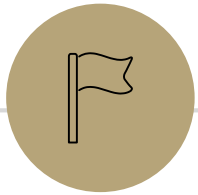
390Z is NOT:  
Extra office hours  
Homework help

CSE 390Z is a **workshop** designed to provide academic support to students enrolled concurrently in CSE 311. During each 2-hour workshop, students will reinforce concepts through:

- collaborative problem solving
- practice study skills and effective learning habits
- build community for peer support

All students enrolled in CSE 311 are welcome to register for this class.

Contact Anjali Agarwal for more information



**What is this course?**

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# What is this course?

In this course, you will learn how to make and communicate rigorous and formal arguments.

Why? Because you'll have to do technical communication in real life.

If you become a PM – you'll have to convert non-technical requirements from experts into clear, unambiguous statements of what is needed.

If you become an engineer – you'll have to justify to others exactly why your code works, and interpret precise requirements from your PM.

If you become an academic – to explain to other academics how your algorithms and ideas improve on everyone else's.

# What is this course?

In this course, you will learn how to make and communicate rigorous and formal arguments.

Two verbs

Make arguments – what kind of reasoning is allowed and what kind of reasoning can lead to errors?

Communicate arguments – using one of the common languages of computer scientists (no one is going to use your code if you can't tell them what it does or convince them it's functional)

# Course Outline

Symbolic Logic (training wheels; lectures 1-7)

Just make arguments in mechanical ways.

- Using notation and rules a computer could understand.

Understand the rules that are allowed, without worrying about pretty words.

Set Theory/Arithmetic (bike in your backyard; lectures 8-19)

Make arguments, and communicate them to humans

Arguments about numbers and sets, objects you already know

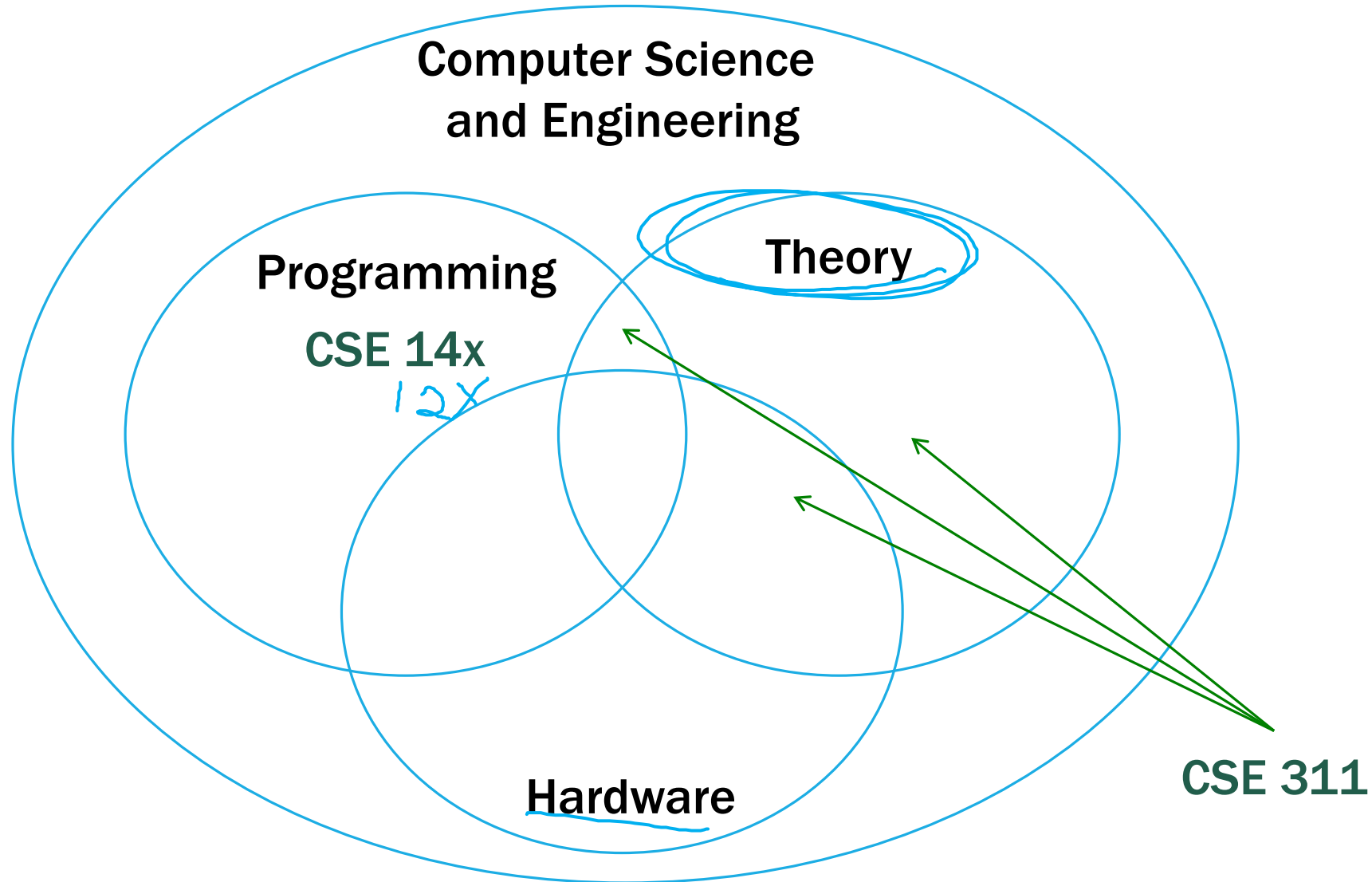
Models of computation (biking in your neighborhood; lectures 20-27)

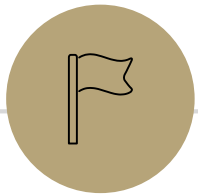
Still make and communicate rigorous arguments

But now with objects you haven't used before.

- A first taste of how we can argue rigorously about computers.

# Some Perspective





# Symbolic Logic



# What is symbolic logic and why do we need it?

Symbolic Logic is a language, like English or Java, with its own words and rules for combining words into sentences (syntax)  
ways to assign meaning to words and sentences (semantics)

Symbolic Logic will let us mechanically simplify expressions and make arguments.

The new language will let us focus on the (sometimes familiar, sometimes unfamiliar) rules of logic.

Once we have those rules down, we'll be able to apply them "intuitively" and won't need the symbolic representation as often

but we'll still go back to it when things get complicated.

# Propositions: building blocks of logic

## Proposition

A statement that has a truth value (i.e. is true or false) and is “well-formed”

Propositions are the basic building blocks in symbolic logic.  
Here are two propositions.

All cats are mammals

True, (and a proposition)

All mammals are cats

False, but is well-formed and has a truth value, so still a proposition.

# Analogy

In 142/143 you talked about a variable type that could be either true or false.

You called it a “Boolean”

Boolean variables are a useful analogy for propositions.  
They aren't identical, but they're very similar.

# Are These Propositions?

$2 + 2 = 5$  ✓ is a proposition

~~$x + 2 = 5$~~  not a prop.

Akjsdf! not a prop

Who are you? not a prop

{ There is life on Mars. is a proposition

# Are These Propositions?

$2 + 2 = 5$  This is a proposition. It's okay for propositions to be false.

$x + 2 = 5$  Not a proposition. Doesn't have a fixed truth value

Akjsdf! Not a proposition because it's gibberish.

Who are you?

This is a question which means it doesn't have a truth value.

There is life on Mars.

This is a proposition. We don't know if it's true or false, but we know it's one of them!

# Propositions

$P$  there is life on Mars

We need a way of talking about *arbitrary* ideas...

To make statements easier to read we'll use propositional variables like  $p, q, r, s, \dots$

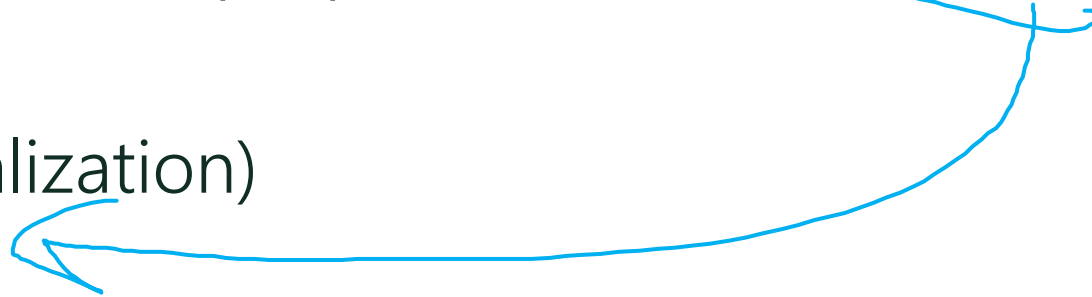
Lower-case letters are standard.

Usually start with  $p$  (for proposition), and avoid  $t, f$ , because...

Truth Values:

$T$  for true (note capitalization)

$F$  for false



# Analogy

We said propositions were a lot like Booleans...

How did you connect Booleans in code?

& &

| |

!



# Logical Connectives

And (& &) works exactly like it did in code.

But with a different symbol  $\wedge$

And

$\wedge$

Or (| |) works exactly like it did in code.

But with a different symbol  $\vee$

Or

$\vee$

Not (!) works exactly like it did in code.

But with a different symbol  $\neg$

Not

$\neg$

# Some Truth Tables

| $p$ | $\neg p$ |
|-----|----------|
|     |          |
|     |          |

| $p$ | $q$ | $p \wedge q$ |
|-----|-----|--------------|
|     |     |              |
|     |     |              |
|     |     |              |
|     |     |              |

| $p$ | $q$ | $p \vee q$ |
|-----|-----|------------|
|     |     |            |
|     |     |            |
|     |     |            |
|     |     |            |

Truth tables are the simplest way to describe how logical connectives operate.

# Some Truth Tables

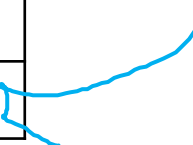


| $p$ | $\neg p$ |
|-----|----------|
| T   | F        |
| F   | T        |



| $p$ | $q$ | $p \wedge q$ |
|-----|-----|--------------|
| T   | T   | T            |
| T   | F   | F            |
| F   | T   | F            |
| F   | F   | F            |

| $p$ | $q$ | $p \vee q$ |
|-----|-----|------------|
| T   | T   | T          |
| T   | F   | T          |
| F   | T   | T          |
| F   | F   | F          |



Truth tables are the simplest way to describe how logical connectives operate.

# Implication

Another way to connect propositions

If  $p$  then  $q$ .

"If it is raining, then I have my umbrella."

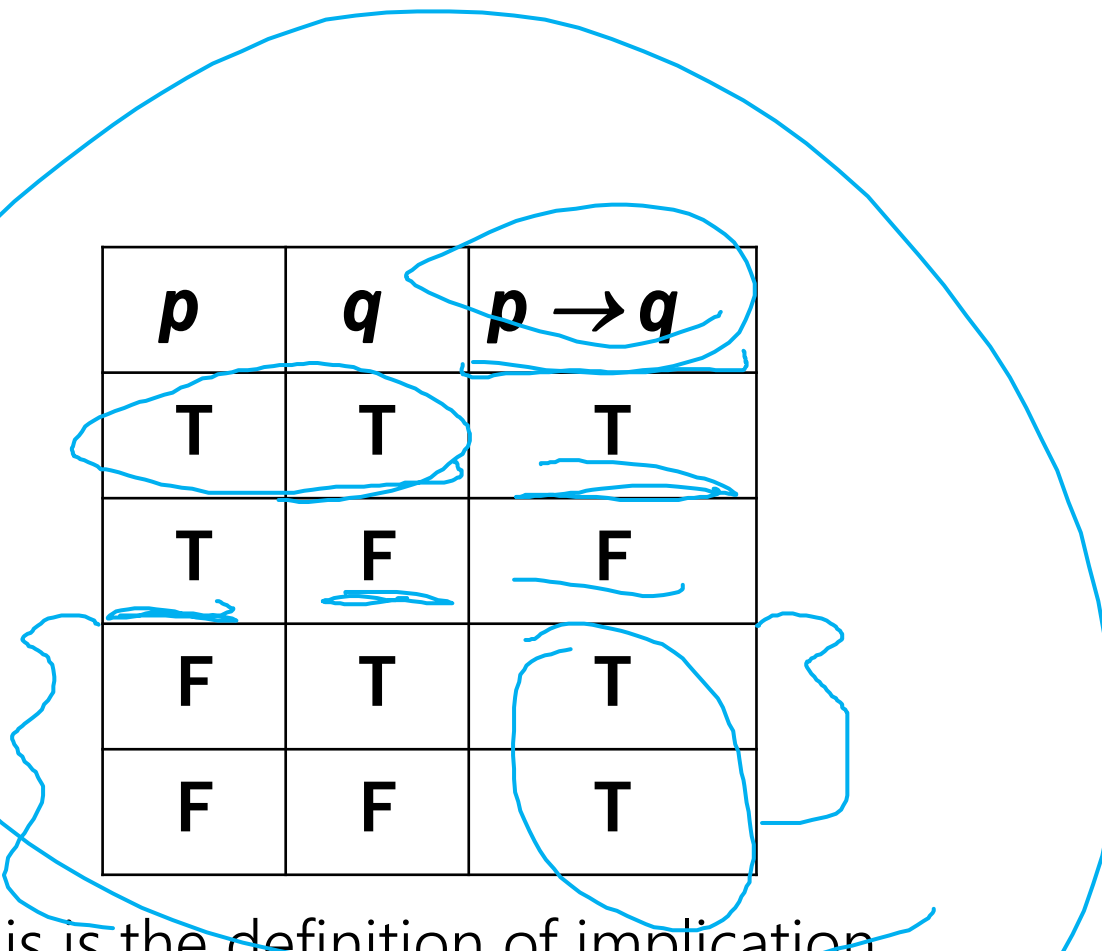
$p \rightarrow q$

Think of an implication as a promise.

# Implication

The first two lines should match your intuition.

The last two lines are called “vacuous truth.” For now, they’re the definition. We’ll explain why in a few lectures.



| $p$ | $q$ | $p \rightarrow q$ |
|-----|-----|-------------------|
| T   | T   | T                 |
| T   | F   | F                 |
| F   | T   | T                 |
| F   | F   | T                 |

This is the definition of implication. When you write “if...then...” in a piece of mathematical English, this is how you will be interpreted.

# Implication ( $p \rightarrow q$ )

*"If it's raining, then I have my umbrella"*

*It's useful to think of implications as promises. An implication is false exactly when you can **demonstrate** I'm lying.*

|                           | It's raining | It's not raining |
|---------------------------|--------------|------------------|
| I have my umbrella        |              |                  |
| I do not have my umbrella |              |                  |

| $p$ | $q$ | $p \rightarrow q$ |
|-----|-----|-------------------|
| T   | T   | T                 |
| T   | F   | F                 |
| F   | T   | T                 |
| F   | F   | T                 |

# Implication ( $p \rightarrow q$ )

*"If it's raining, then I have my umbrella"*

*It's useful to think of implications as promises. An implication is false exactly when you can **demonstrate** I'm lying.*

|                           | It's raining                | It's not raining |
|---------------------------|-----------------------------|------------------|
| I have my umbrella        | No lie.<br>True             | No lie.<br>True  |
| I do not have my umbrella | <b>LIE!</b><br><b>False</b> | No lie.<br>True  |



| $p$ | $q$ | $p \rightarrow q$ |
|-----|-----|-------------------|
| T   | T   | T                 |
| T   | F   | F                 |
| F   | T   | T                 |
| F   | F   | T                 |

$$p \rightarrow q$$

$p \rightarrow q$  and  $q \rightarrow p$  are different implications!

"If the sun is out, then we have class outside."

"If we have class outside, then the sun is out."

Only the first is useful to you when you see the sun come out.

Only the second is useful if you forgot your umbrella.

$$p \rightarrow q$$

Implication:

$p$  implies  $q$

whenever  $p$  is true  $q$  must be true

if  $p$  then  $q$

$q$  if  $p$

$p$  is sufficient for  $q$

$p$  only if  $q$

$q$  is necessary for  $p$

| $p$ | $q$ | $p \rightarrow q$ |
|-----|-----|-------------------|
| T   | T   | T                 |
| T   | F   | F                 |
| F   | T   | T                 |
| F   | F   | T                 |

Implications are super useful, so there are LOTS of translations.  
You'll learn these in detail in section.

# A More Complicated Statement

“Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry.”

Is this a proposition?

We'd like to *understand* what this proposition means.

In particular, is it true?

# A Compound Proposition

“Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry.”

We'd like to *understand* what this proposition means.

First find the simplest (**atomic**) **propositions**:

$p$  “Robbie knows the Pythagorean Theorem”

$q$  “Robbie is a mathematician”

$r$  “Robbie took geometry”

$(p \text{ if } (q \text{ and } r)) \text{ and } (q \text{ or } (\text{not } r))$

$(p \text{ if } (q \wedge r)) \wedge (q \vee (\neg r))$

# A Compound Proposition

“Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry.”

$$(p \text{ if } (q \wedge r)) \wedge (q \vee (\neg r))$$

|     |                                        |
|-----|----------------------------------------|
| $p$ | “Robbie knows the Pythagorean Theorem” |
| $q$ | “Robbie is a mathematician”            |
| $r$ | “Robbie took geometry”                 |

How did we know where to put the parentheses?

- Subtle English grammar choices (top-level parentheses are independent clauses).
- Context/which parsing will make more sense.
- Conventions

A reading on this is coming soon!

# Back to the Compound Proposition...

“Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry.”

$$(p \text{ if } (q \wedge r)) \wedge (q \vee (\neg r))$$

|     |                                        |
|-----|----------------------------------------|
| $p$ | “Robbie knows the Pythagorean Theorem” |
| $q$ | “Robbie is a mathematician”            |
| $r$ | “Robbie took geometry”                 |

What promise am I making?

$$((q \wedge r) \rightarrow p) \wedge (q \vee (\neg r))$$

$$(p \rightarrow (q \wedge r)) \wedge (q \vee (\neg r))$$

The first one! Being a mathematician and taking geometry goes with the “if.” Knowing the Pythagorean Theorem is the consequence.

# A Compound Proposition

“Robbie knows the Pythagorean Theorem if he is a mathematician and took geometry, and he is a mathematician or did not take geometry.”

We'd like to *understand* what this proposition means.

First find the simplest (**atomic**) **propositions**:

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$(p \text{ if } (q \text{ and } r)) \text{ and } (q \text{ or } (\text{not } r))$

$(p \text{ if } (q \wedge r)) \wedge (q \vee (\neg r))$

# Analyzing the Sentence with a Truth Table

| $p$ | $q$ | $r$ | $\neg r$ | $q \vee \neg r$ | $q \wedge r$ | $(q \wedge r) \rightarrow p$ | $((q \wedge r) \rightarrow p) \wedge (q \vee \neg r)$ |
|-----|-----|-----|----------|-----------------|--------------|------------------------------|-------------------------------------------------------|
| F   | F   | F   | T        | T               | F            | T                            | T                                                     |
| F   | F   | T   | F        | F               | F            | T                            | F                                                     |
| F   | T   | F   | T        | T               | F            | T                            | T                                                     |
| F   | T   | T   | F        | T               | T            | F                            | F                                                     |
| T   | F   | F   | T        | T               | F            | T                            | T                                                     |
| T   | F   | T   | F        | F               | F            | T                            | F                                                     |
| T   | T   | F   | T        | T               | F            | T                            | T                                                     |
| T   | T   | T   | F        | T               | T            | T                            | T                                                     |

# Order of Operations

Just like you were taught PEMDAS

e.g.  $3 + 2 \cdot 4 = 11$  not 24.

Logic also has order of operations.

Parentheses

Negation

And

Or, exclusive or

Implication

Biconditional

For this class: each line is its own level!  
e.g. "and"s have precedence over "or"s

Within a level, apply from left to right.

Some textbooks place And, Or at the same level – it's good practice to use parentheses even if not required.

# Logical Connectives

**Negation (not)**  $\neg p$

**Conjunction (and)**  $p \wedge q$

**Disjunction (or)**  $p \vee q$

**Exclusive Or**  $p \oplus q$

**Implication (if-then)**  $p \rightarrow q$

**Biconditional**  $p \leftrightarrow q$

These ideas have been around for so long most have at least two names.

Two more connectives to discuss!

# Biconditional: $p \leftrightarrow q$

Think:  $(p \rightarrow q) \wedge (q \rightarrow p)$

$p$  if and only if  $q$

$p$  iff  $q$

$p$  is equivalent to  $q$

$p$  implies  $q$  and  $q$  implies  $p$

$p$  is necessary and sufficient for  $q$

| $p$ | $q$ | $p \leftrightarrow q$ |
|-----|-----|-----------------------|
|     |     |                       |
|     |     |                       |
|     |     |                       |
|     |     |                       |

# Biconditional: $p \leftrightarrow q$

Think:  $(p \rightarrow q) \wedge (q \rightarrow p)$

$p$  if and only if  $q$

$p$  iff  $q$

$p$  is equivalent to  $q$

$p$  implies  $q$  and  $q$  implies  $p$

$p$  is necessary and sufficient for  $q$

| $p$      | $q$      | $p \leftrightarrow q$ |
|----------|----------|-----------------------|
| <b>T</b> | <b>T</b> | <b>T</b>              |
| <b>T</b> | <b>F</b> | <b>F</b>              |
| <b>F</b> | <b>T</b> | <b>F</b>              |
| <b>F</b> | <b>F</b> | <b>T</b>              |

$p \leftrightarrow q$  is the proposition:  
" $p$ " and " $q$ " have the same  
truth value.

# Exclusive Or

Exactly one of the two is true.

$$p \oplus q$$

| $p$ | $q$ | $p \oplus q$ |
|-----|-----|--------------|
|     |     |              |
|     |     |              |
|     |     |              |
|     |     |              |

In English “either  $p$  or  $q$ ” is the most common, but be careful.

Often translated “ $p$  or  $q$ ” where you’re just supposed to understand that exclusive or is meant (instead of the normal inclusive or).

Try to say “either...or...” in your own writing.

# Exclusive Or

Exactly one of the two is true.

$$p \oplus q$$

| $p$ | $q$ | $p \oplus q$ |
|-----|-----|--------------|
| T   | T   | F            |
| T   | F   | T            |
| F   | T   | T            |
| F   | F   | F            |

In English “either  $p$  or  $q$ ” is the most common, but be careful.

Often translated “ $p$  or  $q$ ” where you’re just supposed to understand that exclusive or is meant (instead of the normal inclusive or).

Try to say “either...or...” in your own writing.

# Active learning!

We'll pause lectures for a few minutes

Why? It works!

<https://www.pnas.org/content/111/23/8410> a meta-analysis of 225 studies.

Just listening to me isn't as good for you as listening to me then trying problems on your own and with each other.

# Lecture 1 Activity

Introduce yourselves!

Go to [pollev.com/robbie](https://pollev.com/robbie)

You have to login, but no “points” are associated; these help me adjust explanation.

Break this sentence down into its smallest propositions and convert it into logical notation.

“If I read the book or watch the movie, then I’ll know the plot.”

# What's next?

A proof!

We want to be able to make iron-clad guarantees that something is true.

And convince others that we really have ironclad guarantees.

# Todo

## Tonight:

Make sure you can access the Ed discussion board.

## Thursday:

Go to section (in-person)

## Friday:

## Soon:

Form a study group! Threads to organize on the Ed board.