Day 1, Session 1: Order of operations and negative numbers

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Learning objectives

By the end of this session, you should be able to

- **use** the order of operations to answer public health questions
- **determine** the relative ordering of two numbers
- **use** algebra and fractions to answer public health questions

Example: kidney stones (from Katie Kerr's BIOST 514, Autumn 2014)

A study compared the success rates of two different procedures for removing kidney stones: open surgery (OS) and percutaneous nephrolithotomy (PCNL), a minimally invasive technique. Here are the numbers of procedures that were successful or not at getting rid of patients' kidney stones, by type of procedure. The data are separated by patients with small kidney stones and large kidney stones.

Patients with Small Stones:

	OS	PCNL
Success	81	234
Failure	6	36

Patients with Large Stones:

	OS	PCNL
S	192	55
F	71	25

Example: kidney stones

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Combined data:	S	273	289
	F	77	61

We can ask a few questions using these data:

- What is the percentage of kidney stones successfully removed for each procedure?

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- What is the percentage of small kidney stones successfully removed? The percentage of large kidney stones? Which type of stones seem easier to treat?

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We can ask a few questions using these data:

- What is the percentage of kidney stones successfully removed for each procedure?
- What is the percentage of small kidney stones successfully removed? The percentage of large kidney stones? Which type of stones seem easier to treat?
- What is the percentage of successful procedures of each type for small kidney stones only, and for large stones only?

Example: kidney stones

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- fraction manipulation: percentages are fractions!
- the order of operations: make sure that we get correct denominators for the fractions
- reading 2x2 tables: get the correct numbers for each question
- parsing sentences: which information is relevant?

We will cover each of these tools in more detail!

Example: statistics in medical research (from Katie Kerr's BIOST 514, Autumn 2014)

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(Note: a paper is "submitted" when it is sent to a journal for consideration for publication. Not all submitted papers are accepted by the journal editors and published in the journal.)

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- Is this an observational study or a randomized trial?

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- Determine the proportion of papers rejected without review when a statistician is and is not involved.
- Give a 95% CI for this proportion, and interpret it.
- Is this an observational study or a randomized trial?
- Write a paragraph summarizing the conclusions of your analysis, making sure to comment on the ability of the study to address the question of interest and on any important limitations of the study.

Example: statistics in medical research

These questions also involve a variety of tools:

- fraction manipulation
- parsing sentences
- interpreting results

Outline for Session 1

- Order of operations
- Negative numbers
- Fractions
- Algebra

Evaluating expressions

- Example expression: $3(1 + 2) + 5$
- How do we evaluate the above expression? In other words:

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- How do we evaluate the above expression? In other words:
  - Which terms to we compute first?
  - Are there rules for evaluating expressions?

Order of operations

- Rules for evaluating expressions:
  1. Parentheses
  2. Exponents
  3. Multiplication and division (evaluate left to right)
  4. Addition and subtraction (evaluate left to right)

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  1. Parentheses
  2. Exponents
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  4. Addition and subtraction (evaluate left to right)

- A handy memory device: PEMDAS – Please Excuse My Dear Aunt Sally

Example: order of operations in action!

- Example from slide 10: $3(1+2)+5$
- This notation is equivalent to $3 \times (1+2)+5$

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  1. Parentheses: add 1 and 2

Current Expression
$3(3)+5$

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- Apply PEMDAS:
  1. Parentheses: add 1 and 2
  2. Exponents: none

Current Expression
$3(3)+5$
$3(3)+5$

Example: order of operations in action!

- Example from slide 10: $3(1+2)+5$
- This notation is equivalent to $3 \times (1+2)+5$
- Apply PEMDAS:
  1. Parentheses: add 1 and 2
  2. Exponents: none
  3. Multiplication: multiply 3 and 3

Current Expression
$3(3)+5$
$3(3)+5$
$9+5$

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  1. Parentheses: add 1 and 2
  2. Exponents: none
  3. Multiplication: multiply 3 and 3
  4. Division: none

Current Expression
$3(3)+5$
$3(3)+5$
$9+5$
$9+5$

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- This notation is equivalent to $3 \times (1+2)+5$
- Apply PEMDAS:
  1. Parentheses: add 1 and 2
  2. Exponents: none
  3. Multiplication: multiply 3 and 3
  4. Division: none
  5. Addition: add 9 and 5

Current Expression
$3(3)+5$
$3(3)+5$
$9+5$
$9+5$
14

Example: order of operations in action!

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- Apply PEMDAS:
  1. Parentheses: add 1 and 2
  2. Exponents: none
  3. Multiplication: multiply 3 and 3
  4. Division: none
  5. Addition: add 9 and 5
  6. Subtraction: none

Current Expression
$3(3)+5$
$3(3)+5$
$9+5$
$9+5$
14

Example: order of operations in action!

- Example from slide 10: $3(1+2)+5$
- This notation is equivalent to $3 \times (1+2)+5$
- Apply PEMDAS:
  1. Parentheses: add 1 and 2
  2. Exponents: none
  3. Multiplication: multiply 3 and 3
  4. Division: none
  5. Addition: add 9 and 5
  6. Subtraction: none

Current Expression
$3(3)+5$
$3(3)+5$
$9+5$
$9+5$
14

- The final answer is 14!

Example: order of operations with exponents!

- Expression: $\dfrac{(2^2+5)^2}{3\times 3}+5$

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Current Expression
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1. Parentheses: 2^2+5.

Example: order of operations with exponents!

- Expression: $\dfrac{(2^2+5)^2}{3\times 3}+5$

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  1. Parentheses: 2^2+5.
     Need to apply PEMDAS again!

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Example: order of operations with exponents!

- Expression: $\dfrac{(2^2+5)^2}{3\times 3}+5$

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     Need to apply PEMDAS again!

     1.1 Parentheses: none

Current Expression
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Example: order of operations with exponents!

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- Apply PEMDAS:

  1. Parentheses: 2^2+5.
     Need to apply PEMDAS again!
     - 1.1 Parentheses: none
     - 1.2 Exponents: $2^2=4$

Current Expression
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(4+5)^2}{3\times 3}+5$

Example: order of operations with exponents!

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  1. Parentheses: 2^2+5.
     Need to apply PEMDAS again!
     - 1.1 Parentheses: none
     - 1.2 Exponents: $2^2=4$
     - 1.3 Multiplication/division: none

Current Expression
$\frac{(2^2+5)^2}{3\times 3}+5$
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  1. Parentheses: 2^2+5.
     Need to apply PEMDAS again!
     - 1.1 Parentheses: none
     - 1.2 Exponents: $2^2=4$
     - 1.3 Multiplication/division: none
     - 1.4 Addition/subtraction: $4+5=9$

Current Expression
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(4+5)^2}{3\times 3}+5$
$\frac{(4+5)^2}{3\times 3}+5$
$\frac{(9)^2}{3\times 3}+5$

Example: order of operations with exponents!

- Expression: $\dfrac{(2^2+5)^2}{3\times 3}+5$

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  1. Parentheses: 2^2+5.
     Need to apply PEMDAS again!
     - 1.1 Parentheses: none
     - 1.2 Exponents: $2^2=4$
     - 1.3 Multiplication/division: none
     - 1.4 Addition/subtraction: $4+5=9$
  2. Exponents: $9^2=81$

Current Expression
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(4+5)^2}{3\times 3}+5$
$\frac{(4+5)^2}{3\times 3}+5$
$\frac{(9)^2}{3\times 3}+5$
$\frac{81}{3\times 3}+5$

Example: order of operations with exponents!

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     - 1.3 Multiplication/division: none
     - 1.4 Addition/subtraction: $4+5=9$
  2. Exponents: $9^2=81$
  3. Multiplication: $3\times 3=9$

Current Expression
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(2^2+5)^2}{3\times 3}+5$
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$\frac{(9)^2}{3\times 3}+5$
$\frac{81}{3\times 3}+5$
$\frac{81}{9}+5$

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	Current Expression
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1. Parentheses: 2^2+5. Need to apply PEMDAS again!	
1.1 Parentheses: none	$\frac{(2^2+5)^2}{3\times 3}+5$
1.2 Exponents: $2^2=4$	$\frac{(4+5)^2}{3\times 3}+5$
1.3 Multiplication/division: none	$\frac{(4+5)^2}{3\times 3}+5$
1.4 Addition/subtraction: $4+5=9$	$\frac{(9)^2}{3\times 3}+5$
2. Exponents: $9^2=81$	$\frac{81}{3\times 3}+5$
3. Multiplication: $3\times 3=9$	$\frac{81}{9}+5$
4. Division: $81/9=9$	$9+5$

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  2. Exponents: $9^2=81$
  3. Multiplication: $3\times 3=9$
  4. Division: $81/9=9$
  5. Addition/subtraction: $9+5=14$!

Current Expression
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(2^2+5)^2}{3\times 3}+5$
$\frac{(4+5)^2}{3\times 3}+5$
$\frac{(4+5)^2}{3\times 3}+5$
$\frac{(9)^2}{3\times 3}+5$
$\frac{81}{3\times 3}+5$
$\frac{81}{9}+5$
$9+5$

Order of operations: nesting

- Earlier, we needed to apply PEMDAS a second time, within the evaluation of the parentheses
- This is common!
- Apply PEMDAS as many times as necessary within each sub-expression, like $(2^2 + 5)$ in the previous example

Exercise: order of operations

Kidney stone data:

Patients with Small Stones:

	OS	PCNL
Success	81	234
Failure	6	36

Patients with Large Stones:

	OS	PCNL
S	192	55
F	71	25

Combined data:

	OS	PCNL
S	273	289
F	77	61

Try to work out these examples alone or in pairs:

1. 273/(273+77) and 289/(289+61). What proportions do these correspond to?
2. What is the percentage of small kidney stones successfully removed? Large kidney stones?
3. Which type of kidney stones seem easier to treat?
4. PEMDAS example: $\{(2+1)^2+1\}^2$

Negative numbers: what are they?

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  - A positive number subtracted from zero
  - Opposites of positive numbers: $-4 + 4 = 0$
  - Movement left on the number line
- When might we see them?
  - Comparing two proportions
  - Decreasing trend (e.g., lung capacity for smokers vs. non-smokers)

The number line

- Movement on the number line:

The number line

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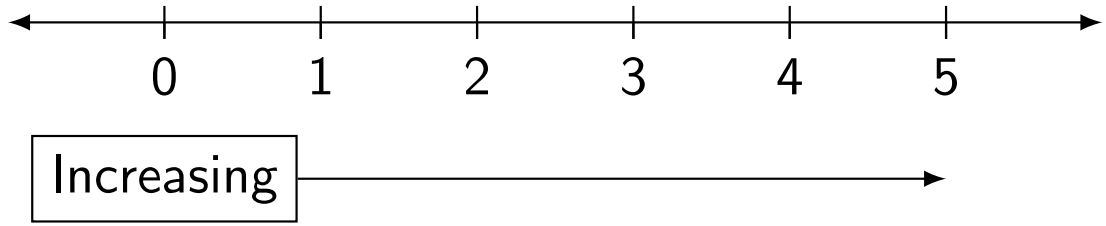
  - Right (positive numbers):



The number line

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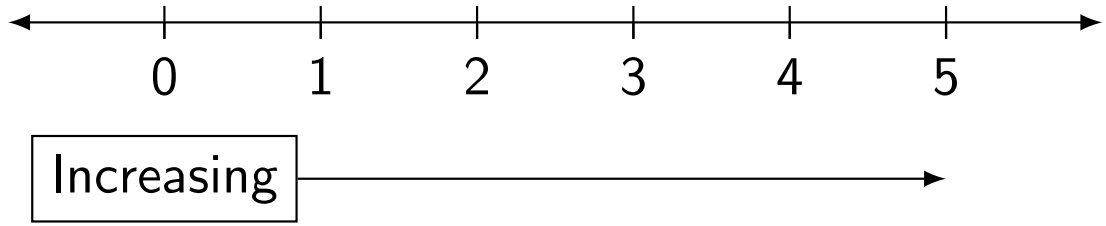

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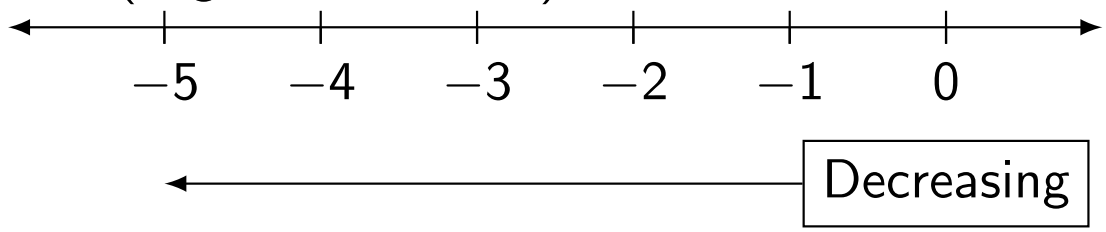

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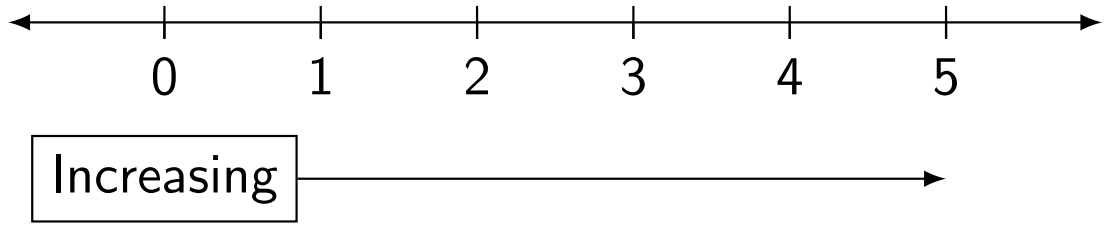

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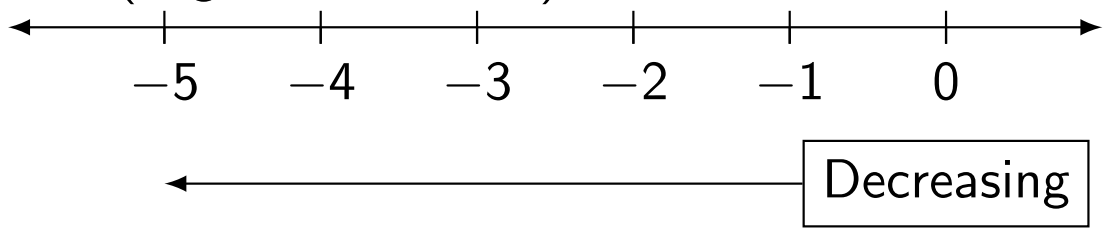

- Example: move left 3, starting at 100?

The number line

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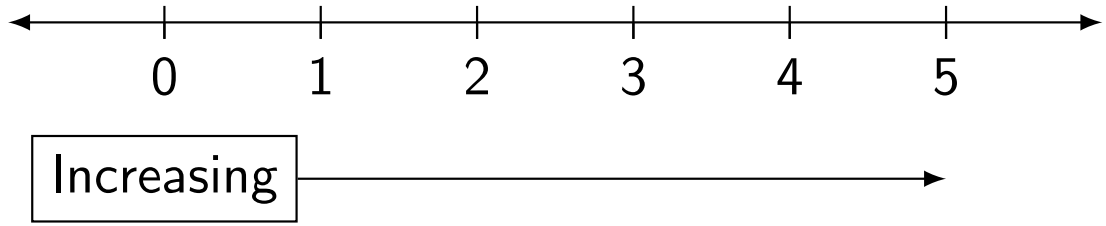
  - Right (positive numbers):



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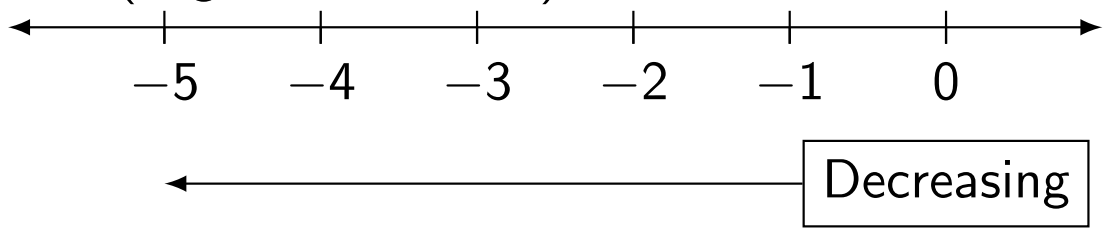
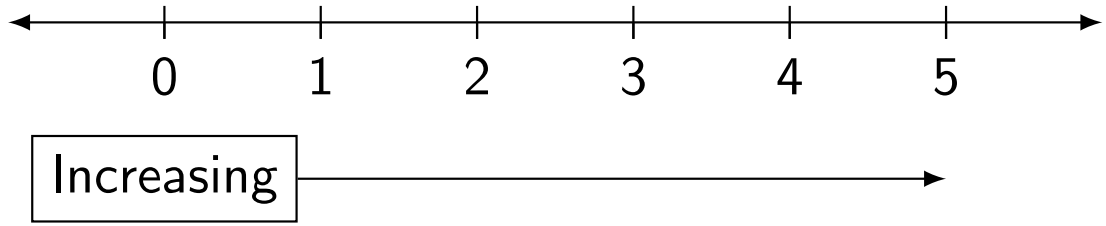


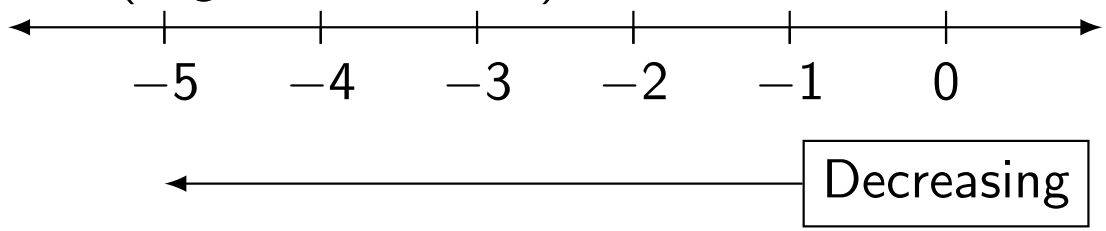
- Example: move left 3, starting at 100?
  - Subtract 3

The number line

- Movement on the number line:
  - Right (positive numbers):



  - Left (negative numbers):



- Example: move left 3, starting at 100?
  - Subtract 3
  - Add negative 3

Properties of negative numbers

- Represent opposites of positive numbers, or movement left on the number line

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- Represent opposites of positive numbers, or movement left on the number line
- Subtraction = adding a negative number
- The product of two negatives is a positive
- Movement left on the number line $\rightarrow$ smaller numbers

Negative fractions

- First, positive fractions: for the same numerator, a larger denominator makes a smaller number, e.g., $1/4 < 1/2$

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- Negatives are opposites: think of zero as a mirror

Negative fractions

- First, positive fractions: for the same numerator, a larger denominator makes a smaller number, e.g., $1/4 < 1/2$
- Negatives are opposites: think of zero as a mirror
- So for the same numerator (a negative number), a larger denominator makes a less negative number, e.g., $-1/2 < -1/4$

Example: two negatives make a positive

- Expression: -1×-1

Example: two negatives make a positive

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- Answer: 1!
- Why?

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- Why?
  - -1 is a negative number

Example: two negatives make a positive

- Expression: -1×-1
- Answer: 1!
- Why?
  - -1 is a negative number
  - Negative numbers mean opposites; the opposite of -1 is 1

Example: ordering negative numbers

- Expression: $-3 \_\_\_ -2$

Example: ordering negative numbers

- Expression: $-3 \_\_\_ -2$
- Answer: $-3 < -2$

Example: ordering negative numbers

- Expression: $-3 \_\_\_ -2$
- Answer: $-3 < -2$
- Why?

Example: ordering negative numbers

- Expression: $-3 \_\_\_ -2$
- Answer: $-3 < -2$
- Why?
  - Negative numbers are left motion on number line! -3 is further left than -2

Exercise: negative numbers

- Try to work out the following examples by yourself or in pairs:
  1. $-5.2 - (-11.3)$
  2. $-5 - 6$
  3. $(-1) \times (-5) + (-3)$
  4. $-\frac{3}{7} - \left(-\frac{1}{4}\right)$

Related concepts: absolute value

- Magnitudes: how "large" is a number, with no direction
  - Examples: speed (how fast an object is moving), length

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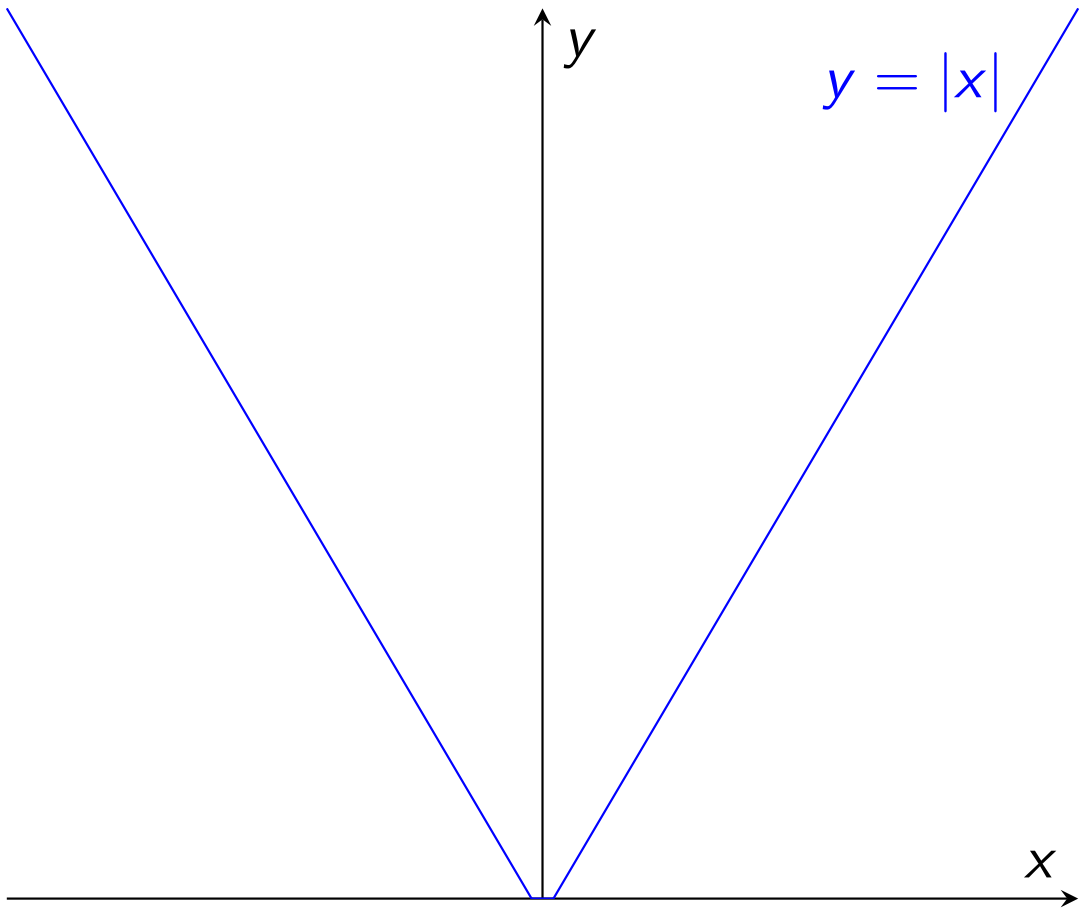
- Magnitudes: how "large" is a number, with no direction
  - Examples: speed (how fast an object is moving), length

- Symbol for absolute value is $|\cdot|$



Example: absolute value of a positive number

- Expression: $|4|$

Example: absolute value of a positive number

- Expression: $|4|$
- Answer is 4! Positive numbers already measure size, with no direction

Example: absolute value of a negative number

- Expression: $|-4|$

Example: absolute value of a negative number

- Expression: $|-4|$
- Answer is 4!
- Why?

Example: absolute value of a negative number

- Expression: $|-4|$
- Answer is 4!
- Why?
  - Negatives are opposites of positives

Example: absolute value of a negative number

- Expression: $|-4|$
- Answer is 4!
- Why?
  - Negatives are opposites of positives
  - Absolute value has no direction

Example: absolute value of a negative number

- Expression: $|-4|$
- Answer is 4!
- Why?
  - Negatives are opposites of positives
  - Absolute value has no direction
  - 4 and -4 are equally far away from zero

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- Negatives are opposites: signs change and inequality flips, yielding $2 < 3$

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  3. Multiply both sides by -1, yielding (with inequality rules) $-1/2 < -1/4$

Exercise: absolute value, negative numbers

- Try to work out the following examples by yourself or in pairs:
  1. $|-5|$ and $|5|$
  2. Is $|-5| < 4$?
  3. Is $-15 > -14$?
  4. Is $-(3+1) \times 5 < -(4+1) \times 3$?

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- The order of operations is a recipe for solving expressions
- A handy memory tool is PEMDAS: Parentheses, Exponents, Multiplication/Division, Addition/Subtraction
- Negative numbers decrease as we move away from zero (left on the number line)
- Absolute value measures the magnitude of a number – how far away from zero is it?