# Lecture 1: Introduction

Math 98, Fall 2023

# Introduction

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- Per Section 102.23: Course Materials of the UC Berkeley Student Code of Conduct - don't post any of these materials to CourseHero (or any similar sites)

Lab Computer Login: !cmfmath98
Password: c@1b3arsmathlab

# Lectures, Grading and Deliverables

1. 5 Lectures
   - Every Tu/Th, starting Thurs (08/24)
2. 4 Homeworks
   - Due Tu/Th at 11:59pm, 7 days after corresponding lecture
   - Graded largely on effort and completion
   - Assignment Submission: on bCourses
     - ★ Solutions appear 1 hour after deadline
   - Can be somewhat flexible with deadlines (within reason)
     - ★ But in your best interest to complete course quickly
3. 1 Project
   - Graded for accuracy
   - Expectation is that you get this *completely* correct as warmup for 128a PAs
4. Receiving a P in this class should not be hard
   - Each HW worth 15 points, Project worth 40
   - Must receive minimum of 70% average on the HW assignments and 70% on the project
   - Start early, work hard, and seek help on the assignments

# Who should take this course

1. If you have no/minimal programming experience:
   - This is the target audience of this course
   - We will build things up from scratch
   - I also expect many of you to also feel a bit nervous about programming (and that's OK!)
2. If you have extensive programming experience in another language:
   - This course likely won't be a good use of your time
   - Easy to pick up MATLAB syntax yourself. Work through an online tutorial (see suggestions on my webpage)
3. For everyone else in between.....
   - Take a look at some of the homeworks and see if you could mostly code them up in another language

To everyone: You may find it more efficient to learn yourself once you've gotten started. Everyone is highly encouraged to read/study ahead.

# Why you should take this course

Why take this course? (vs. some other course)

1. Condensed focus that covers the necessary material for Math 128a
2. Assignments that are well aligned with Math 128a
   - Especially the final project
3. Availability of customized help (from me!) in office hours
   - Even if you can figure out the problem, it is extremely useful to get feedback on your thought process and areas for improvement. So make sure to ask for it!

There is no real need to formally enroll for 1 unit (unless you want it). I will be happy to grant access to the course material to auditors and speak with them in office hours.

# Course Plan

Plan: Spend 50-60 minutes lecturing (depends on the day) and do lots of exercises

- Have MATLAB open to experiment and try things out
- Will stop for many in class exercises, and I will go around and offer help

# Course Expectations

This is a fairly intense course. In 3 weeks you will go from no programming experience to being able to complete a 128A Programming Assignment.

What you should do:

- Try to set aside a block of $\sim$2-3 hours at least every other day to practice programming (including the lectures)
  - Like taking a foreign language class. Immersion
- Interrupt me as frequently as needed for clarification and questions
- Talk to neighbors (at a respectful volume) and ask for help
- **Important:** Actually try to figure things out and stay to work on the exercises
- **More Important:** Practice. The best way to learn how to code is to **write lots of code.**

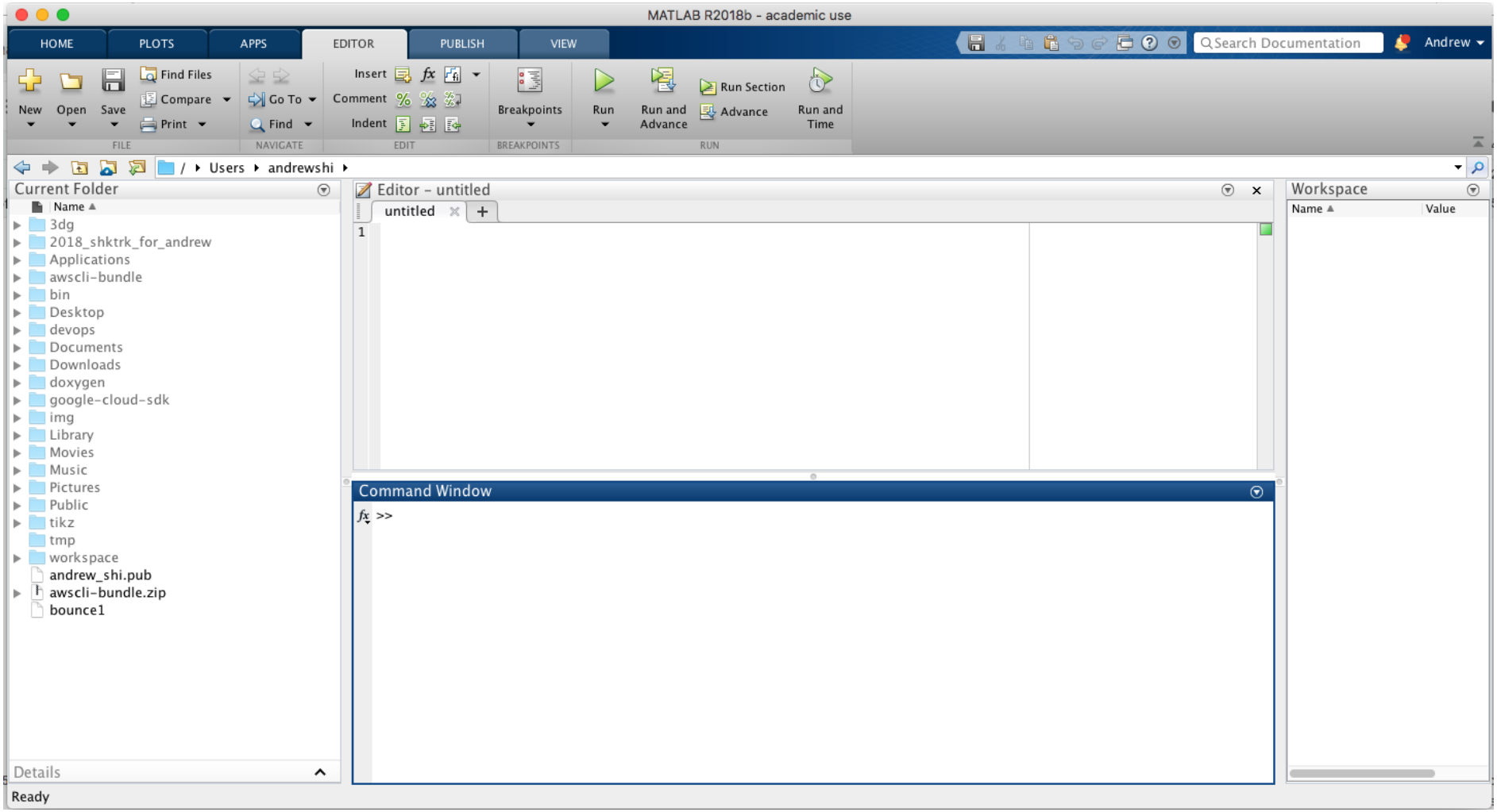
# Agenda

- Go over items on the course webpage
- MATLAB Introduction
- Variables and Formatting
- Vectors and Matrices
- Relations
- Scripts
- Exercises

# Downloading MATLAB

- MATLAB is available for free for UC Berkeley students via a campus license
- Make sure to download ASAP in case issues arise

# MATLAB Intro: Opening up MATLAB



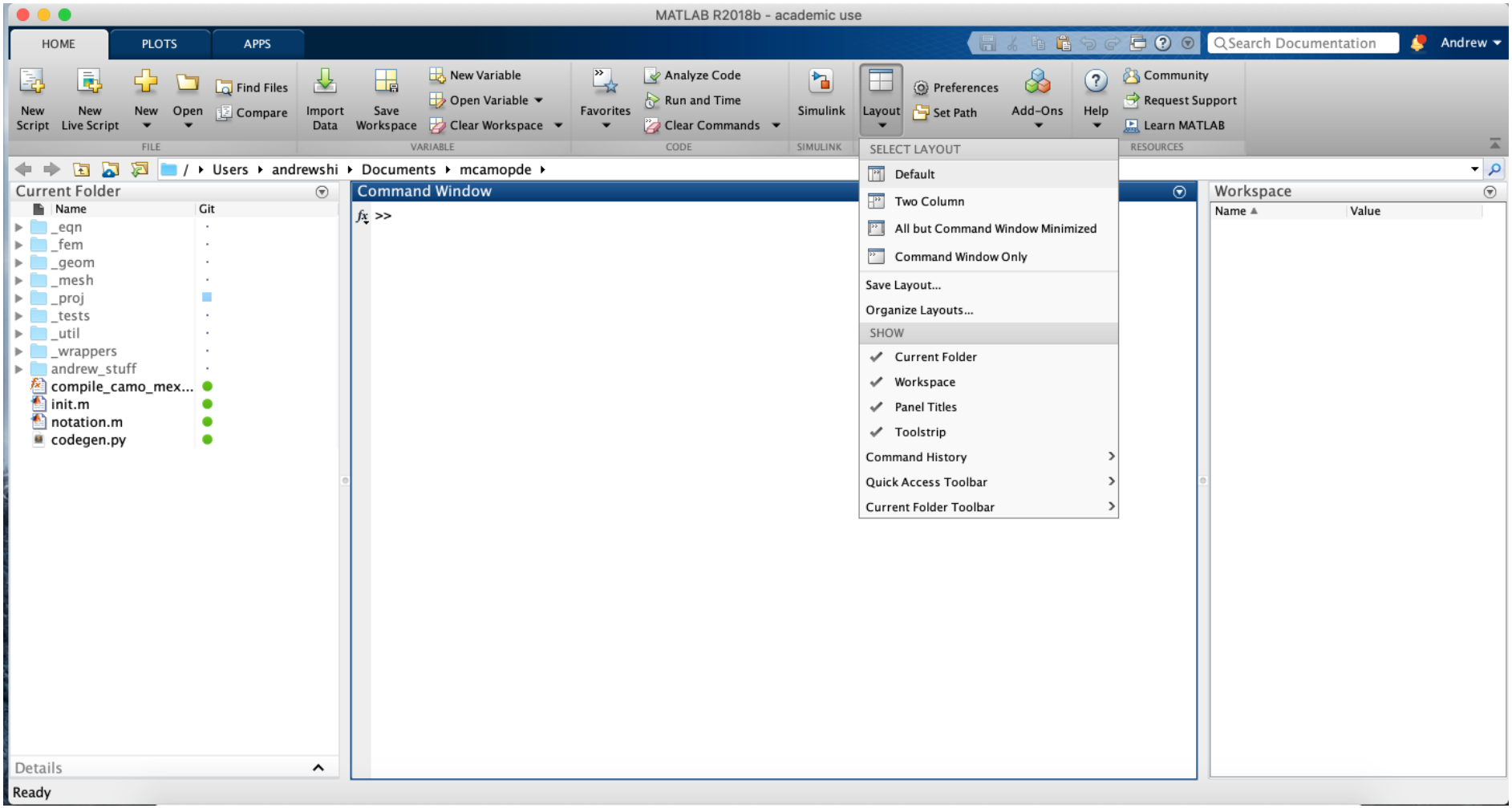
# MATLAB Intro: Getting started with MATLAB

Matlab has five features:

1. **Current Folder** shows the files that MATLAB is accessing. By default MATLAB cannot execute files contained in other folders.
2. **Command Window** Here we can define variables, perform calculations, and much more.
3. **Workspace** is a MAT-file containing the variables you have defined in your session.
4. **Editor** allows us to save collections of commands as M-files.
5. **Command History** can be accessed using the up arrow.

It's OK if this doesn't make much sense yet.....we will revisit this.

# MATLAB Intro: Reset Layout




If something happens to this, you can reset the layout to the default configuration.

# MATLAB Intro: Command Window

To begin with, think of MATLAB as a giant calculator.
**Operations:** $+, -, *, /, \hat{\cdot}, \exp(\cdot), \sqrt{\cdot}, \log(\cdot)$

```
>> 2 - 3*(1+2)/2
ans =
    -2.5000
>> 3^4
ans =
    81
>> log(4)
ans =
    1.3863
>> sqrt(9.01)
ans =
    3.0017
```

# MATLAB Intro: Help

Wait, what kind of logarithm is that?

```
>> help log
 log    Natural logarithm.
    log(X) is the natural logarithm of the elements of X.
    Complex results are produced if X is not positive.

    See also log1p, log2, log10, exp, logm, reallog.

    Reference page for log
    Other functions named log
```

help is going to be your best friend when using MATLAB.

# MATLAB Intro: MATLAB Documentation

- The online documentation is also excellent with many examples.
- Google search "matlab log"
  - https://www.mathworks.com/help/matlab/ref/log.html
- Knowing where to find the answer is much more important than knowing the answer.

# MATLAB Intro: Built-in MATLAB Functions

- Many built in functions in MATLAB to do math.

| | | | |
|---|---|---|---|
| `cos(x)` | Cosine | `abs(x)` | Absolute value |
| `sin(x)` | Sine | `sign(x)` | Signum function |
| `tan(x)` | Tangent | `max(x)` | Maximum value |
| `acos(x)` | Arc cosine | `min(x)` | Minimum value |
| `asin(x)` | Arc sine | `ceil(x)` | Round towards $+\infty$ |
| `atan(x)` | Arc tangent | `floor(x)` | Round towards $-\infty$ |
| `exp(x)` | Exponential | `round(x)` | Round to nearest integer |
| `sqrt(x)` | Square root | `rem(x)` | Remainder after division |
| `log(x)` | Natural logarithm | `angle(x)` | Phase angle |
| `log10(x)` | Common logarithm | `conj(x)` | Complex conjugate |

# Variables: ans

The workspace shows variables that have been defined in the current session. In particular, ans is by default the value of the last arithmetic computation we made. We can check the value of a variable by entering its name in the command window.

```
>> 1 + 3
ans =
     4
>> ans
ans =
     4
>> 3 * 8
ans =
     24
>> ans
ans =
     24
```

# Variables: Defining Your Own

We can define our own variables, too! Variable names must start with a letter and can contain letters, digits, and underscores. MATLAB is case sensitive but all built-in MATLAB functions use lowercase letters, so if you use at least one capital letter in your variable names you can be sure to avoid any name conflicts.

```
>> x1 = 5.337
>> my_variable = ‘‘howdy"
>> frodoBaggins33 = sqrt(2)*pi
>> x2 = x1 + 1
```

# Variables: Built-in Variables I

There are many built in variables too.

```
>> pi
ans =
    3.1416
>> eps
ans =
    2.2204e-16
```

You can override these if you want....

```
>> pi = 4
>> pi
pi =
    4
```

.....but this is usually a bad idea. Try to avoid ambiguity.

# Variables: Built-in Variables II

There are two more special built in variables: `Inf` and `NaN` (not a number)

```
>> 1/0
ans =
    Inf
>> -1/0
ans =
    -Inf
>> 0/0
ans =
    NaN
>> Inf/Inf
ans =
    NaN
```

What is `Inf/0`? What about `exp(exp(7))`? Compare to `exp(exp(6))`.

# Variables: Using Informative Names

Give your variables informative names. Good.

```
>> radius = 4
>> area = pi*radius^2
area =
    50.2655
```

Bad.

```
>> foo = 4
>> blah = pi*foo^2
blah =
    50.2655
```

# Variables: Suppresing Output

Use a semicolon to suppress the output of a command. Using `disp` will suppress the `ans =` text, but will also not save the output to `ans`. Multiple commands can be placed on a line separated by semicolons.

```
>> x = 5; y = 6; disp(x+y)
11
```

Use SHIFT-ENTER to start a new line. Use ellipses (...) and SHIFT-ENTER to continue a line.

```
>> sqrt(5 + 7 + ...
13)
ans =
    5
```

# Variables: Clearing

Use `clear` to clear all variables from the workspace. Use `clear VAR1 VAR2` to clear specific variables `VAR1` and `VAR2`.

```
>> x = 5; clear x;
>> x
Undefined function or variable 'x'.
```

Use `clc` to clear the command line.

# Formatting: `long` and `short`

Doesn't `pi` have more digits than this?

```
>> pi
ans =
    3.1416
```

This is just a formatting/visual thing. Try format long to show 15 digits.

```
>> format long
pi
ans =
    3.141592653589793
```

Then try format short.

```
>> format short
pi
ans =
    3.1416
```

# Formatting: `compact` and `loose`

Go into MATLAB and do stuff in the command window. Do you notice all those blank lines in between the command window output?
Experiment with `format compact` and `format loose`.

# Vectors: Introduction

In addition to strings and scalars, we can define variables that represent vectors.

```
>> v = [1, 5, -2];
>> y = [2; 3; 4; 10];
>> z = [-1 10 4];
>> max(v)
ans =
    5
>> length(y)
ans =
    4
```

# Vectors: Arithmetic

We can do arithmetic with vectors and scalars, or with pairs of vectors. When working with pairs of vectors the symbols $*, /, \hat{}$ are reserved for matrix operations while element-wise operations use $.*, ./, .\hat{}$ instead.

```
>> v + 2
ans =
    3   7   0
>> v.^2
ans =
    1   25   4
```

# Vectors: Creating Them

If the elements of the vector follow a pattern then we may have some quick commands that define them. Try:

```
>> ones(1,5)
>> zeros(1,5)
>> rand(1,5)
>> 1:3:18
>> 16:-3:-5
>> linspace(0, 10, 7)
>> logspace(-1, 0, 5)
>> cos(pi*(0:1/6:2))
```

# Vectors: Accessing Elements

Use the notation `v(i)` to look up the i-th element of the vector $v$. We can also change individual elements of `v` this way.

```
>> v = [1,3,5,8,10]; v(3)
    5
>> v(3:5)
    5   8   10
>> v(5:-1:1)            % same as fliplr(v)
    10   8   5   3   1
>> w = [1,4,2]; v(w)   % can you solve this one?
    1   8   3
>> v = [v, 6]
    1   3   5   8   10   6
>> v(3) = 2; v(9) = 7        % pad with zeros
    1   3   2   8   10   6   0   0   7
```

# Vectors: Vector Operations

```
>> w = [1; 3; 5; 7]; w = w';
    1   3   5   7
>> w(2:end)
    3   5   7
>> w(end+1) = 500
    1   3   5   7   500
>> x = [1, 2; 3; 4]
Dimensions of arrays being concatenated are not consistent.
```

# MATLAB = Matrix Laboratory

Matrices: like vectors, but with more dimensions?

```
>> ones(2, 3)
     1     1     1
     1     1     1
>> ones(2)
     1     1
     1     1
```

Try also:

- `zeros(m,n)`
- `rand(m,n)`
- `randn(m,n)`

What happens if you enter only `m` and leave out `n`? Read the documentation to confirm.

# Matrices: Special Ways to Create Them

Other commands to create special types of matrices:

```
>> eye(2)
    1    0
    0    1
>> v = [3,5]; diag(v)
    3    0
    0    5
>> diag(v,-1) + 2*eye(3)
    2    0    0
    3    2    0
    0    5    2
```

# Matrices: Build Your Own

To type a a matrix into MATLAB you must:

- Begin with a square bracket, `[`
- Separate Elements in a row with spaces or commas
- Use a semicolon `;` to seperate rows
- End with another square bracket, `]`

```
>> A = [1, 4, 6; 3, 6, 8; 0, 2, 6]
A =
     1     4     6
     3     6     8
     0     2     6
>> B = [1:5; 1, 3:4, 5, 6]
B =
     1     2     3     4     5
     1     3     4     5     6
```

# Matrices: Accessing Entries

Accessing entries of a matrix

```
>> A(2, 3) %row, column
ans =
     8
>> A(6)
ans =
     2
```

What does the second result suggest to you about how the entries in a matrix are indexed?

# Matrices: Accessing Columns, Rows, and Submatrices

Accessing rows and columns of a matrix

```
>> A(:, 2)
ans =
     4
     6
     2
>> A(3, :)
ans =
     0   2   6
```

Accessing submatrices

```
>> A(2:3, 2:3)
ans =
     6    8
     2    6
```

# Matrices: Matrix Operations

As with vectors, we have lots of ways to access and manipulate the entries of matrices. Try out the following commands:

```
>> A = reshape(1:12,3,4)
>> size(A)  % also size(A,1) and size(A,2)
>> A'
>> fliplr(A) % also flipud(A)
>> A(:,[1, 3])
>> p = randperm(3); q = randperm(4); A(p,q)
>> reshape(A,2,6)
>> A(3, 3) = 1
>> A(:, 2) = A(:, 1)
```

Type `help [your command here]` to learn more!

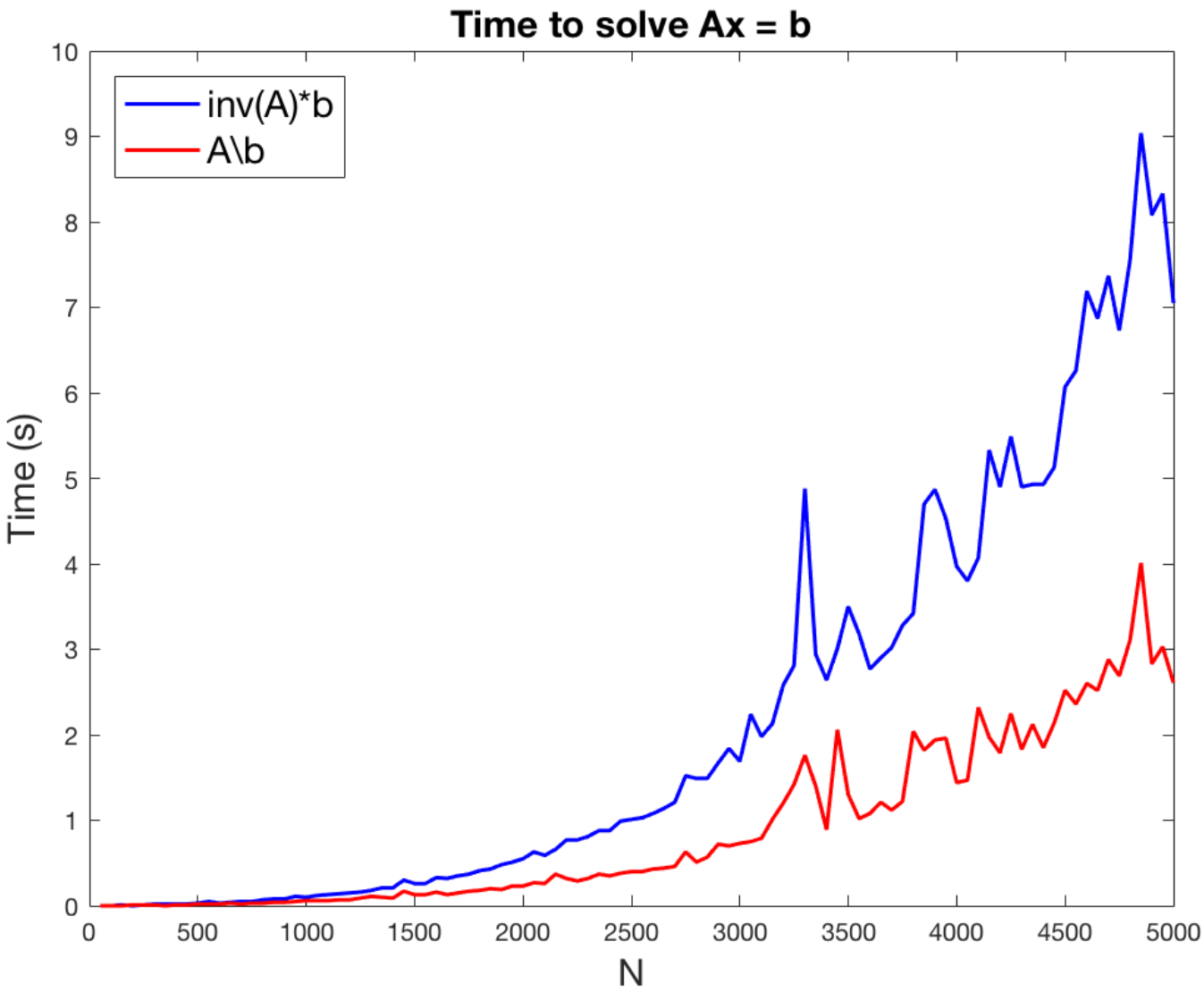
# Matrices: Solving $Ax = b$

Two ways to solve $Ax = b$:

```
>> x = inv(A)*b
>> x = A\b
```

Which one should we use?

# Matrices: Solving $Ax = b$: Graph



# Why Don't These Work?

It is also equally (if not more) informative to study things that don't work, since much of your time will be dealing with bugs and errors.

```
>> A = [1, 3, 5; 1, 2];
>> A = [1, 3, 5]; B = [1, 3]; A + B
>> A = eye(3); A(0)
>> A = [1, 3, 5]; A^2
```

# Relations

The following statements will take value 0 (if false) or 1 (if true)

- $a < b$: $a$ less than $b$
- $a > b$: $a$ greater than $b$
- $a <= b$: $a$ less than or equal to $b$
- $a >= b$: $a$ greater than or equal to $b$
- $a == b$: $a$ equal to $b$ (note the doubled equals sign!)
- $a \sim= b$: $a$ not equal to $b$

# Relations: Vectors and Matrices

You can also utilize a relation on a vector, as well as to index a vector at certain indices:

```
>> a = [1,5,3];
>> a <= 3
ans =
     1   0   1
>> b = a(a <= 3)
b =
     1   3
```

The last command selects all elements in the vector a that are less than or equal to 3.

# Scripts

Okay, it's finally time to make a proper script! In the command line, enter

```
>> edit Hello.m
```

Or New → Script (Top Left)

- An m-file is a file containing a script for MATLAB—a sequence of instructions for the computer.
- The name of the file must have the format `filename.m`.
  - Filenames are case sensitive (like everything in MATLAB).
  - `filename.m` and `Filename.m` are different!
- For MATLAB to execute the file, it must be saved in the Current Directory.

Two ways to run a script:

- Open up the script and hit "Run".
- Type the name of the script into the Command Window.

# input

Sometimes we want to be able to request input from the user.

```
>> input('Please input a starting value: ')
Please input a starting value:
```

Let's give it the number 3.

```
>> input('Please input a starting value: ')
Please input a starting value: 3
ans =
      3
```

We should probably assign the input to a value.

```
>> myval = input('Please input a starting value: ')
Please input a starting value: 3
myval =
      3
```

# Commenting with %

Except within a string, everything following `%` is a comment. Comments do not get executed when the program runs, but can make the code easier to read by providing information about its organization and usage.

Comments in the beginning lines of a program will be revealed when using the command `help`.

`help` (as well as `doc`) is also invaluable when learning how to use various MATLAB functions.

# Exercise: `conversion.m`

A temperature can be converted from Fahrenheit to Celsius using the formula $c = (5/9)(f - 32)$, where $c$ is Celsius and $f$ is Fahrenheit. Write a script that prompts the user for a temperature in Fahrenheit, converts it to Celsius, and prints it.