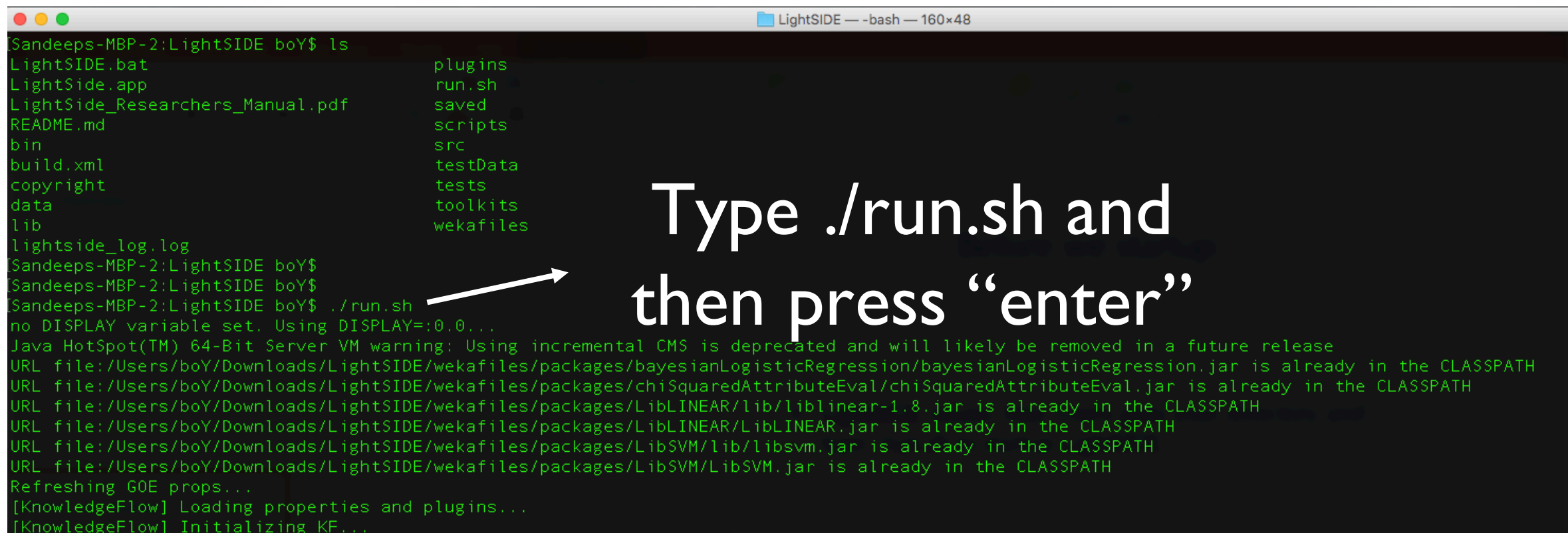


Linear Classifiers

Sandeep Avula
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Before we startup

- LightSIDE issues: Mac Users goto your directory and type `./run.sh` to startup LightSIDE.



The image shows a terminal window titled "LightSIDE — -bash — 160x48". The user is in the directory "Sandeeps-MBP-2:LightSIDE" and has run the command `ls`. The output lists files and directories: `LightSIDE.bat`, `LightSide.app`, `LightSide_Researchers_Manual.pdf`, `README.md`, `bin`, `build.xml`, `copyright`, `data`, `lib`, `lightside_log.log`, `plugins`, `run.sh`, `saved`, `scripts`, `src`, `testData`, `tests`, `toolkits`, and `wekafiles`. The user then runs `./run.sh`, which triggers a series of messages: "no DISPLAY variable set. Using DISPLAY=:0.0...", a Java warning about incremental CMS, several "URL file:..." messages indicating that various JAR files are already in the CLASSPATH, and finally "[KnowledgeFlow] Loading properties and plugins..." and "[KnowledgeFlow] Initializing KF...". A white arrow points from the text "Type ./run.sh and then press 'enter'" to the `./run.sh` command in the terminal.

```
Sandeeps-MBP-2:LightSIDE boY$ ls
LightSIDE.bat
LightSide.app
LightSide_Researchers_Manual.pdf
README.md
bin
build.xml
copyright
data
lib
lightside_log.log
Sandeeps-MBP-2:LightSIDE boY$
Sandeeps-MBP-2:LightSIDE boY$
Sandeeps-MBP-2:LightSIDE boY$ ./run.sh
no DISPLAY variable set. Using DISPLAY=:0.0...
Java HotSpot(TM) 64-Bit Server VM warning: Using incremental CMS is deprecated and will likely be removed in a future release
URL file:/Users/boY/Downloads/LightSIDE/wekafiles/packages/bayesianLogisticRegression/bayesianLogisticRegression.jar is already in the CLASSPATH
URL file:/Users/boY/Downloads/LightSIDE/wekafiles/packages/chiSquaredAttributeEval/chiSquaredAttributeEval.jar is already in the CLASSPATH
URL file:/Users/boY/Downloads/LightSIDE/wekafiles/packages/LibLINEAR/lib/liblinear-1.8.jar is already in the CLASSPATH
URL file:/Users/boY/Downloads/LightSIDE/wekafiles/packages/LibLINEAR/LibLINEAR.jar is already in the CLASSPATH
URL file:/Users/boY/Downloads/LightSIDE/wekafiles/packages/LibSVM/lib/libsvm.jar is already in the CLASSPATH
URL file:/Users/boY/Downloads/LightSIDE/wekafiles/packages/LibSVM/LibSVM.jar is already in the CLASSPATH
Refreshing G0E props...
[KnowledgeFlow] Loading properties and plugins...
[KnowledgeFlow] Initializing KF...
```

- HW2 out today. Deadline will be adjusted.

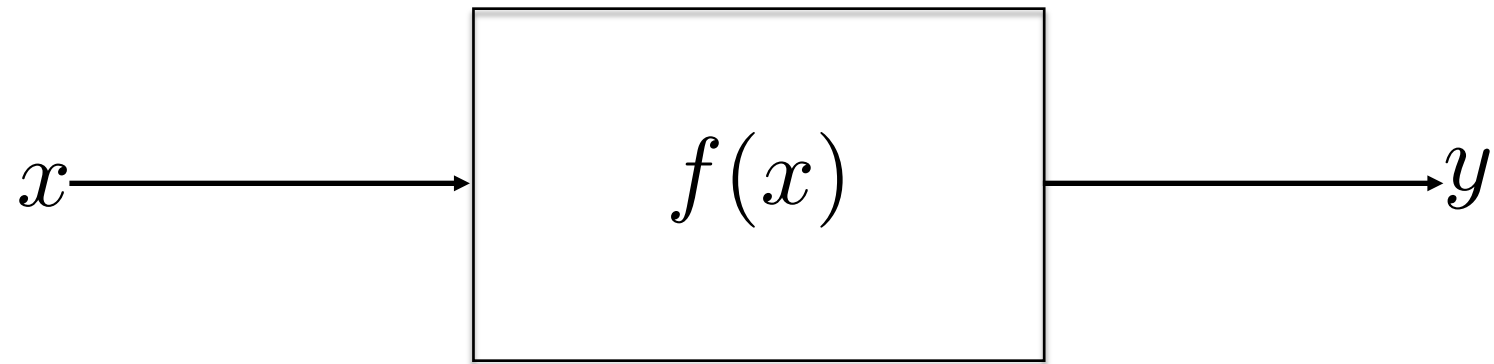
Overview

- Philosophical questions
- Derivatives: What are they good for?
- Linear regression
- Multiple linear regression
- Logistic regression

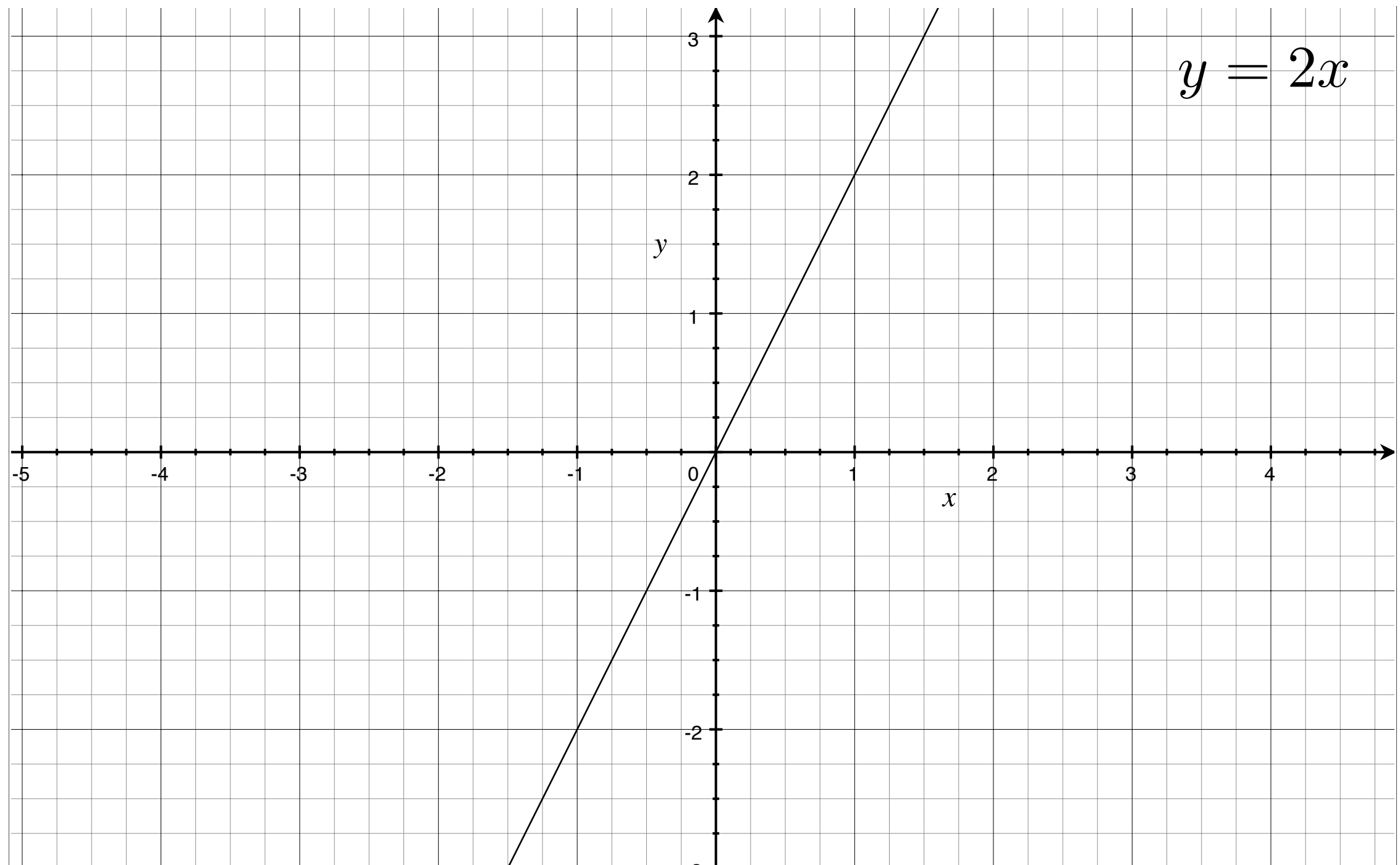
Philosophical Questions

- What would you do if ...
- What does this have to do with linear classifiers?

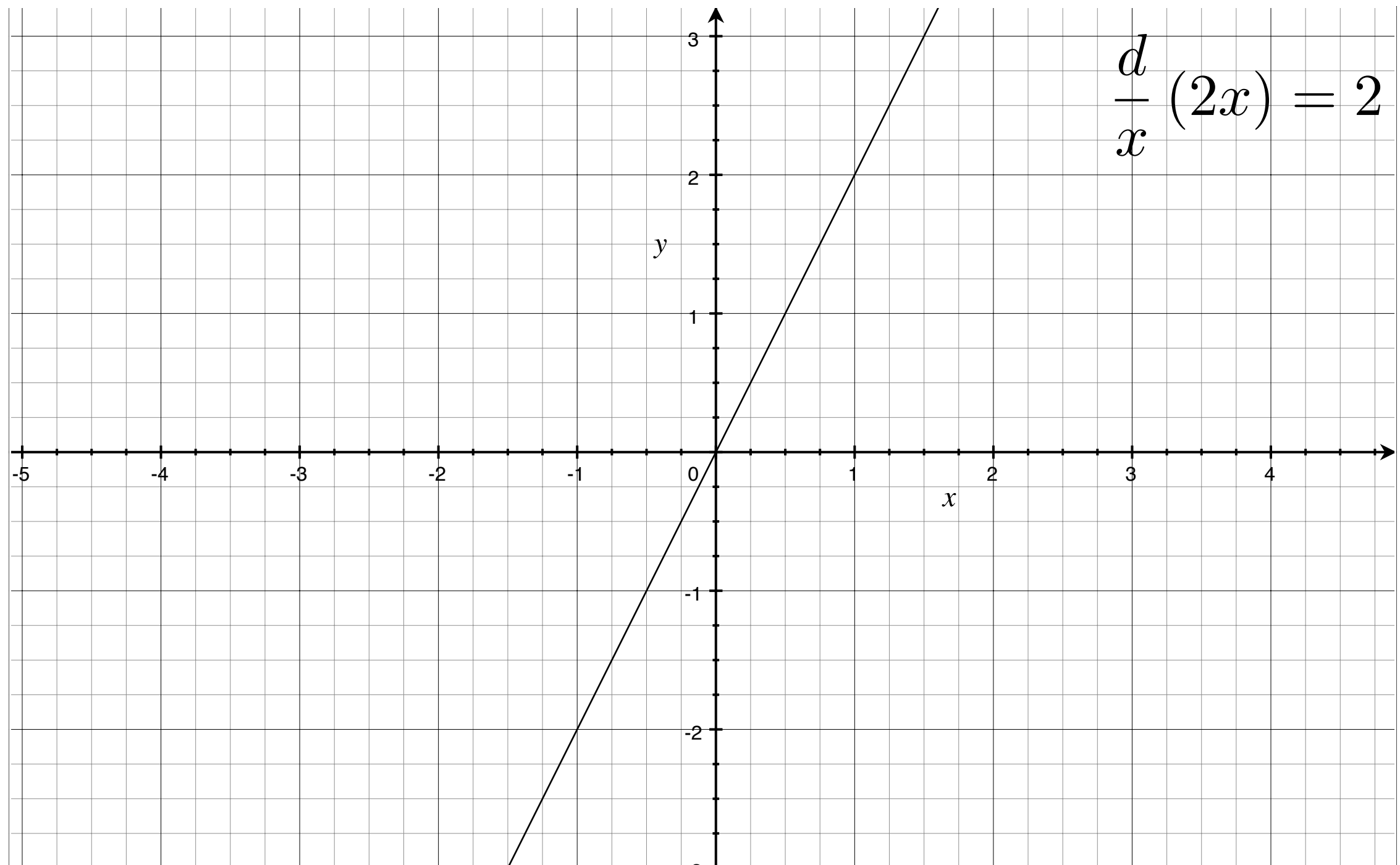
Functions



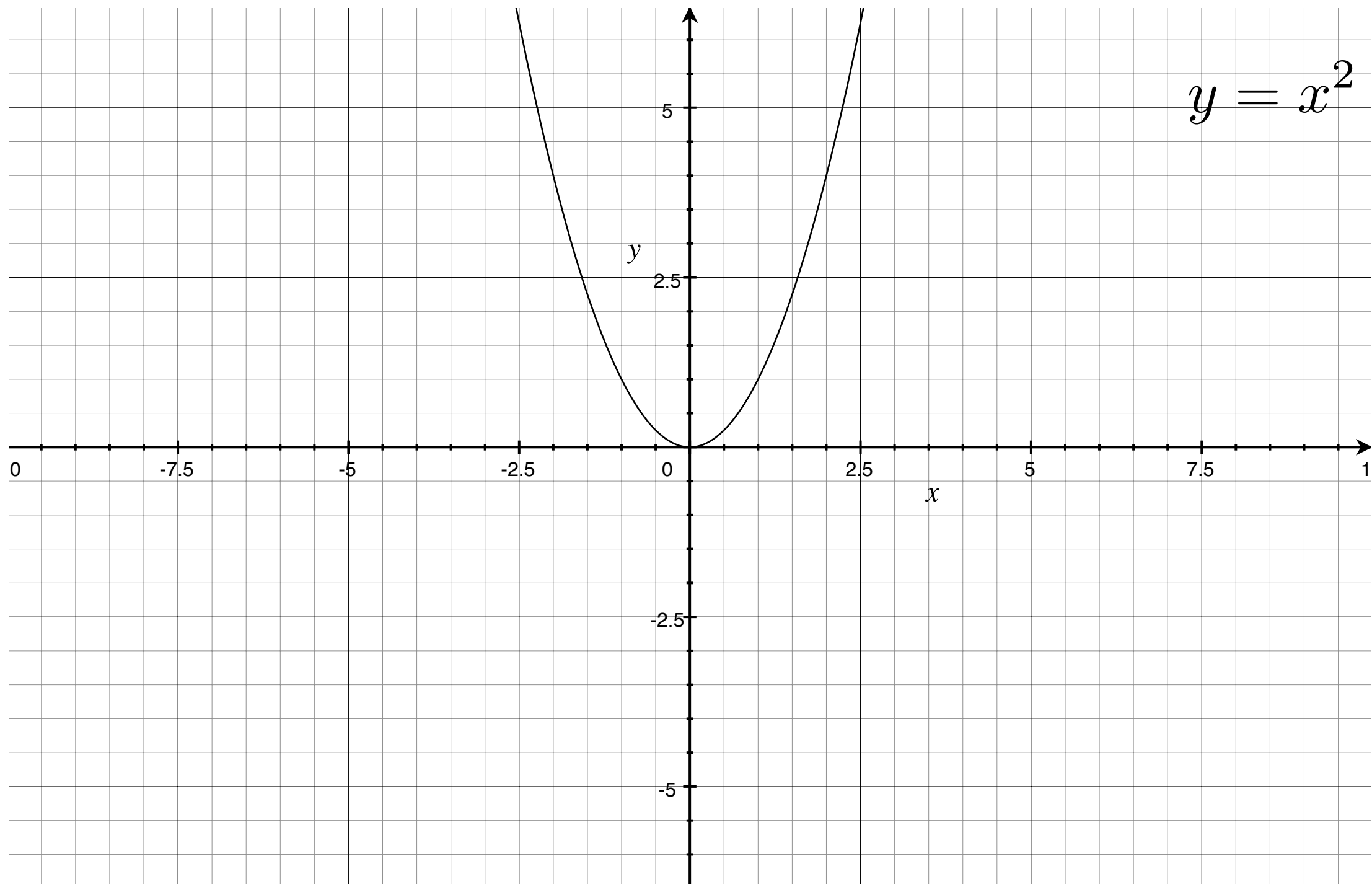
Derivatives



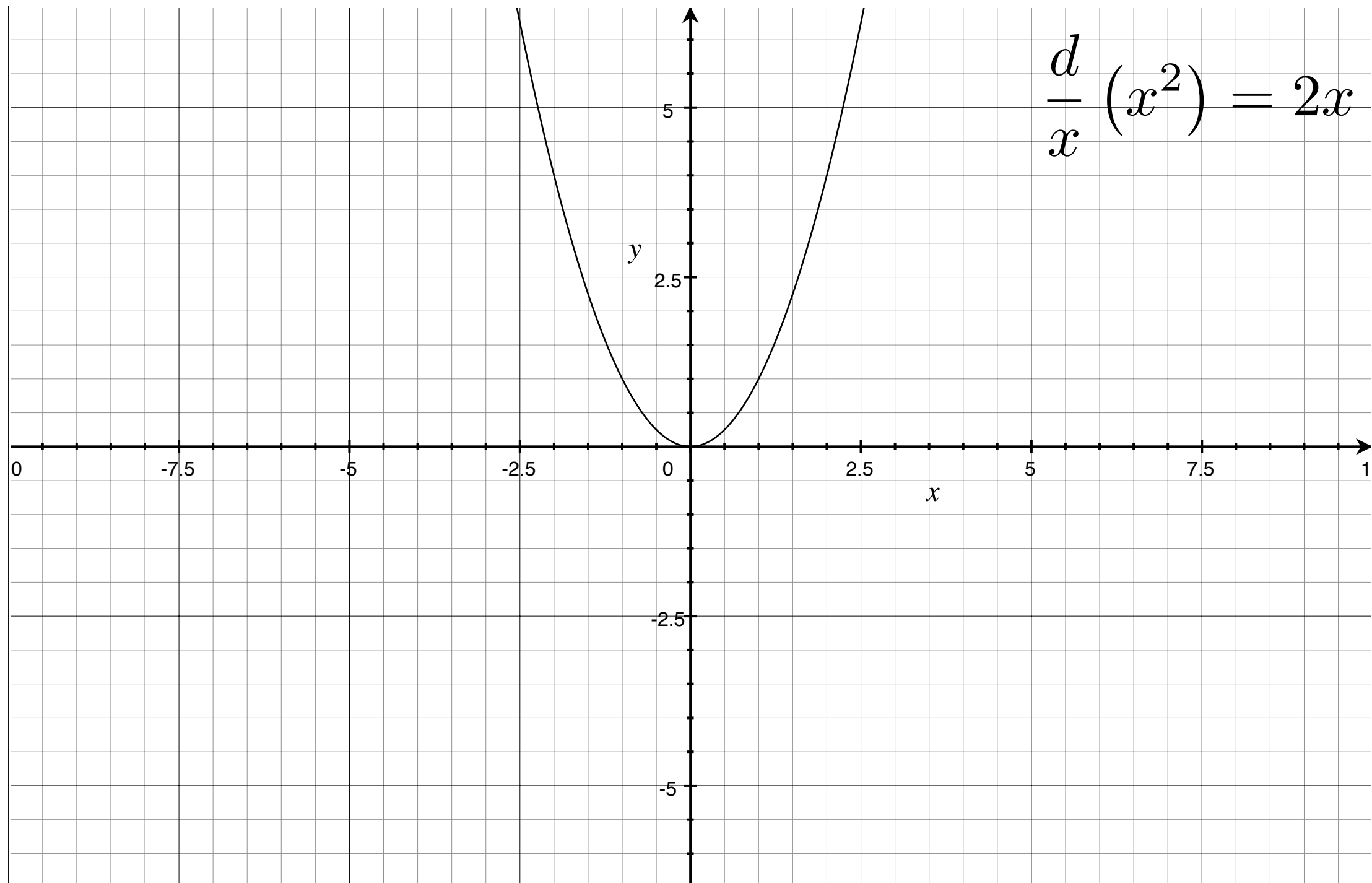
Derivatives



Derivatives



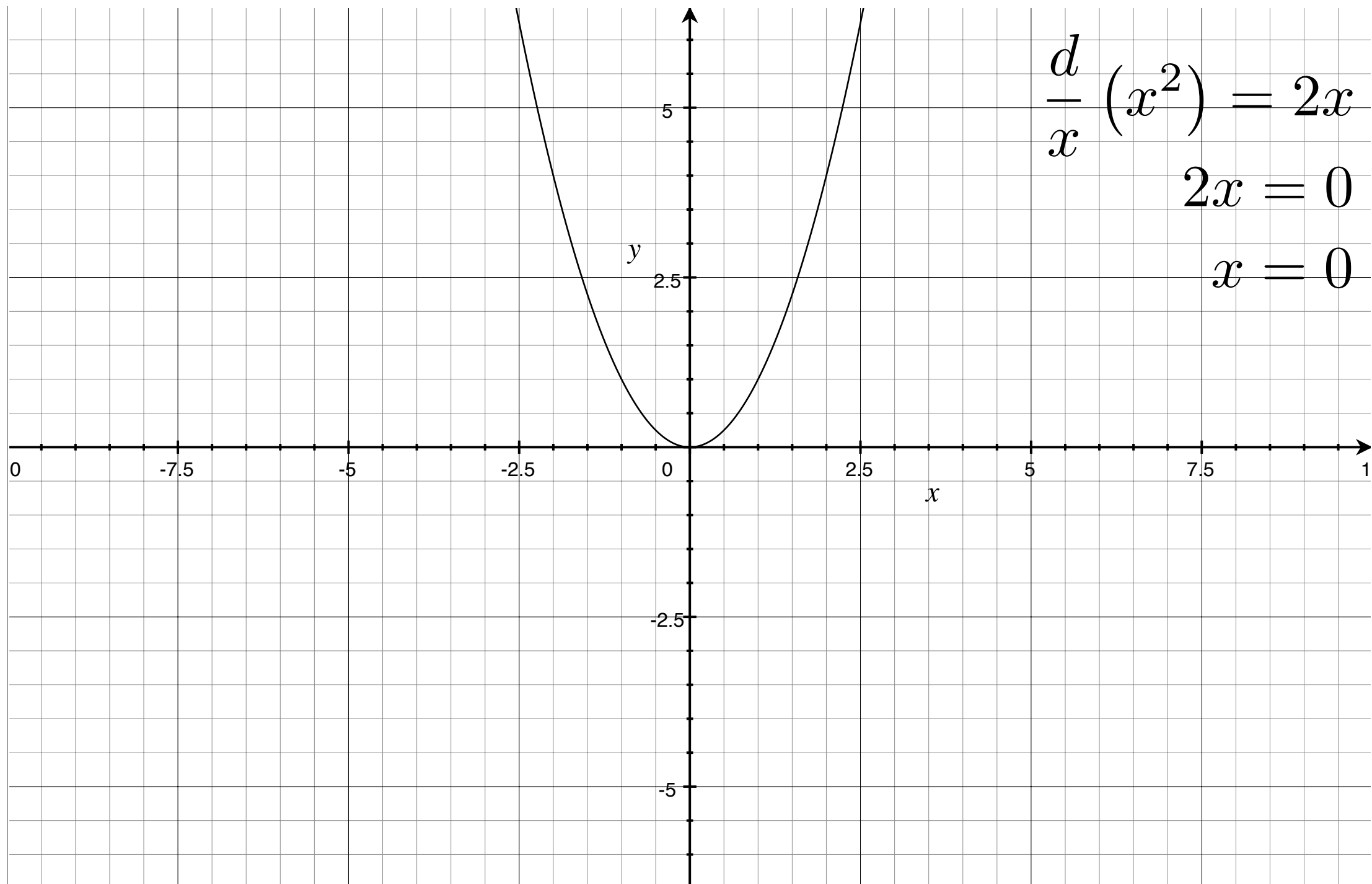
Derivatives



Derivatives: What are they good for?

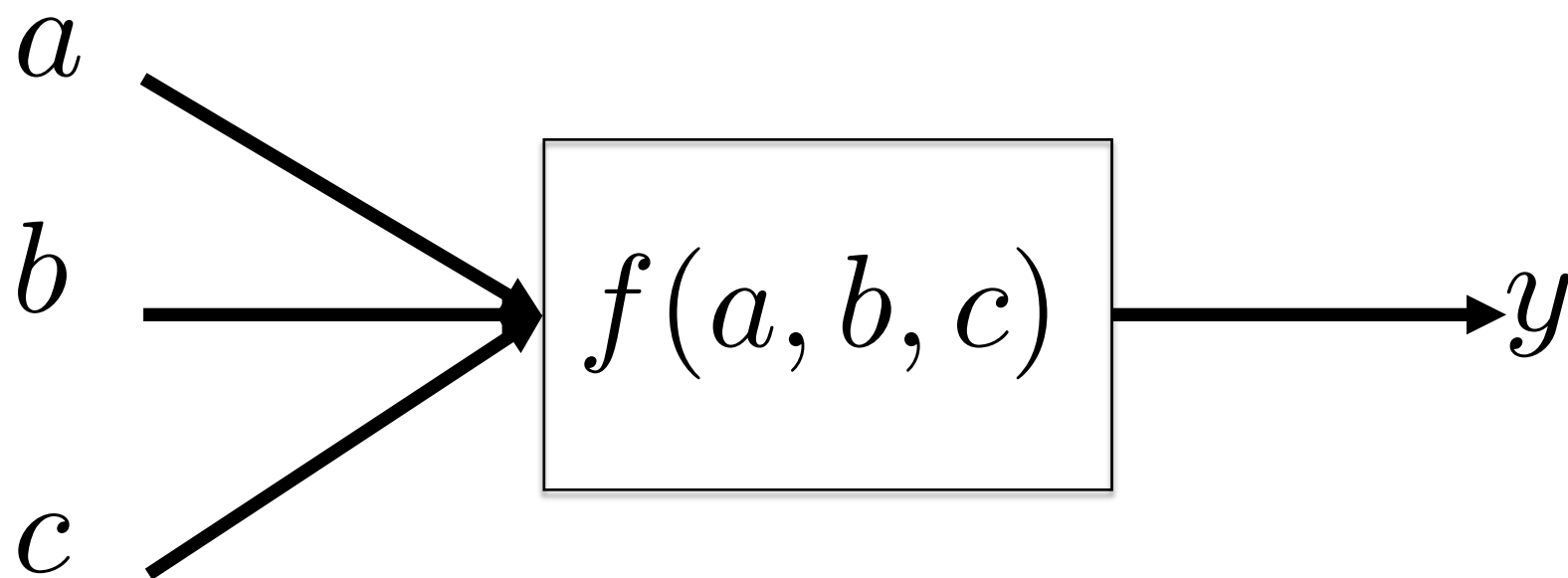
- The derivative of $f(x)$ outputs the slope of $f(x)$ for a particular value of x
- A point of which the slope is zero is a point at which $f(x)$ is at its highest or lowest value.
- What does this have to do with machine learning?

Derivatives



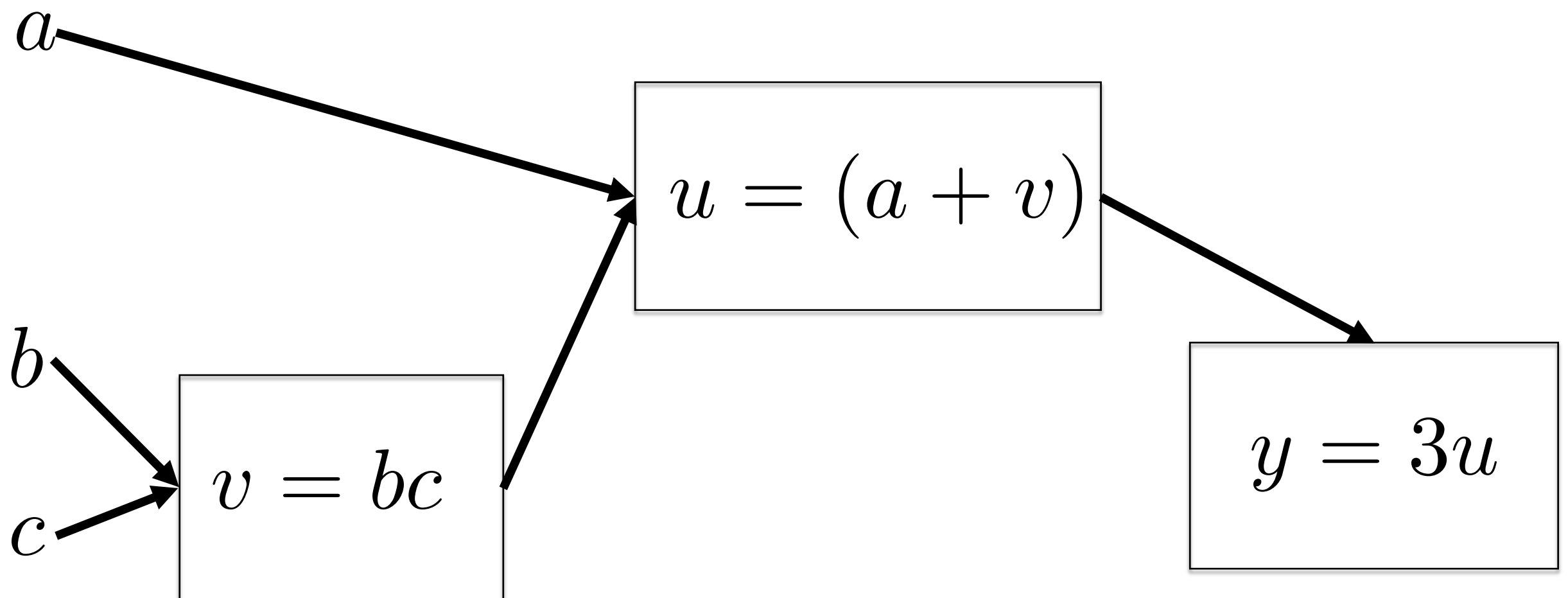
Computation Graphs

$$y = 3(a + bc)$$



Computation Graphs

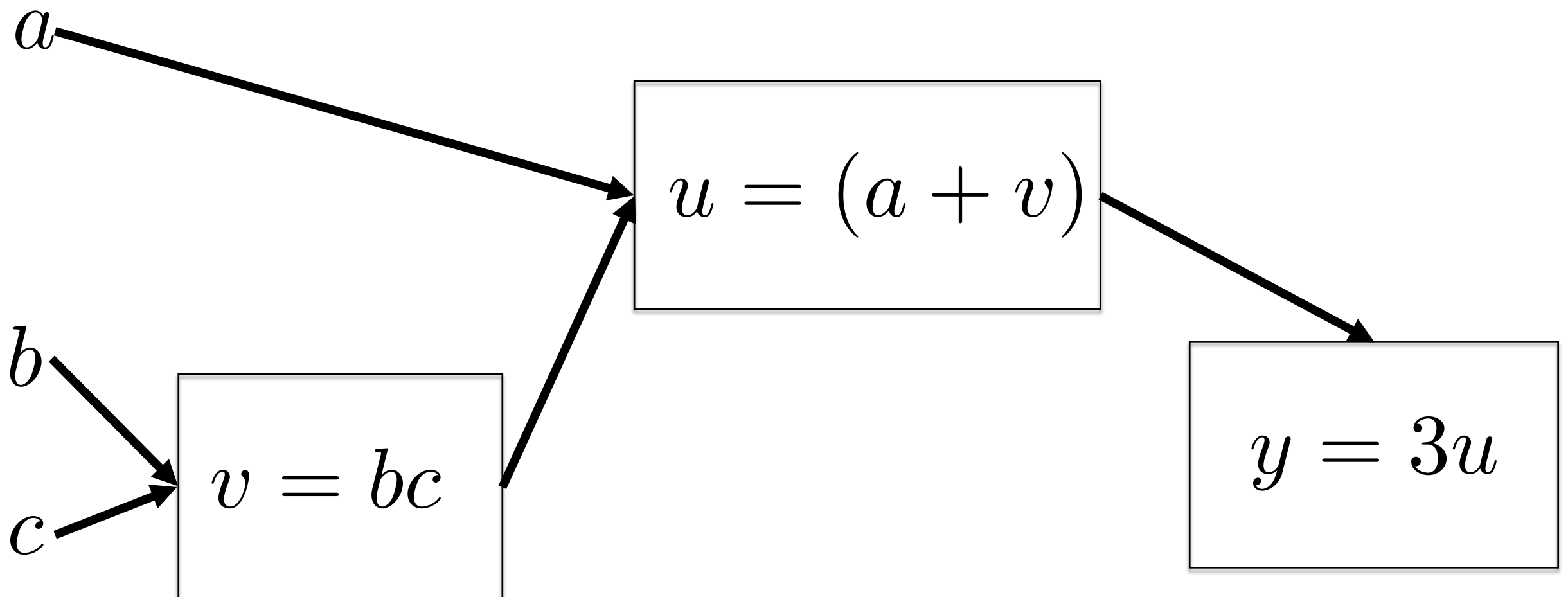
$$y = 3(a + bc)$$



Derivatives: Chain Rule

$$y = 3(a + bc)$$

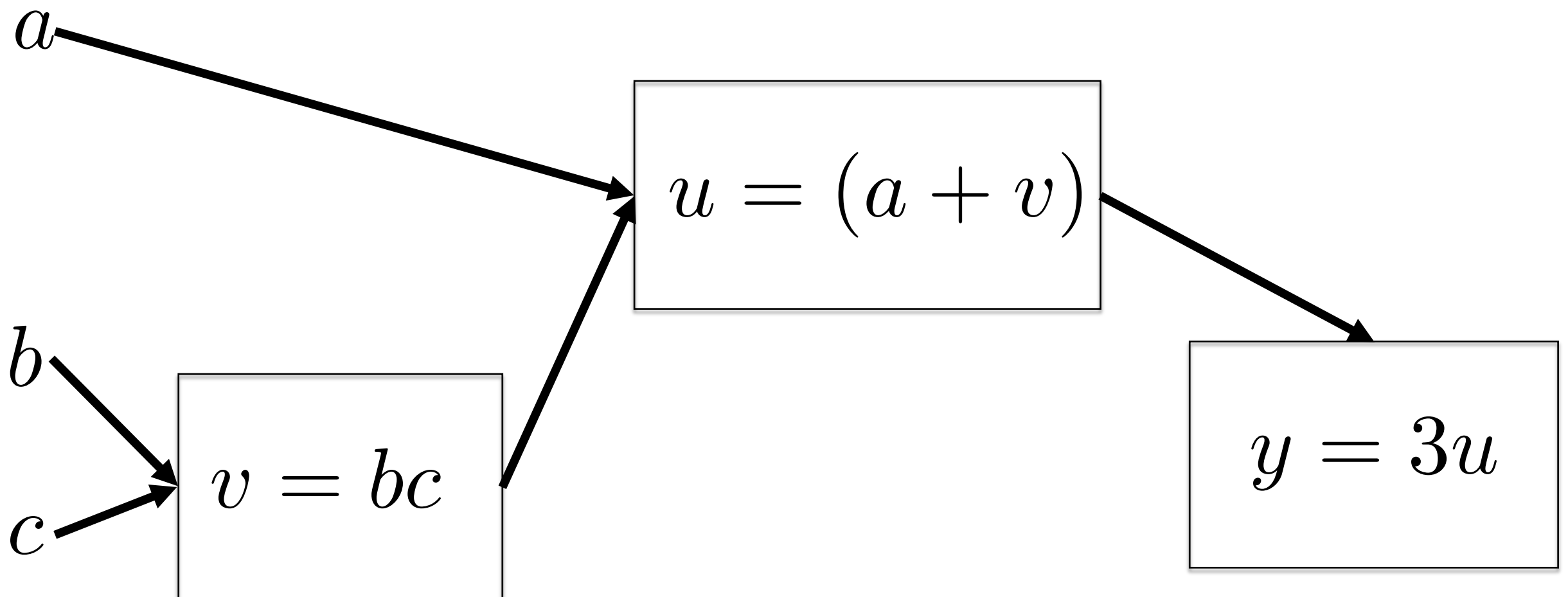
$$\frac{dy}{dc} = \frac{dv}{dc} \times \frac{du}{dv} \times \frac{dy}{du}$$



Derivatives: Chain Rule

$$y = 3(a + bc)$$

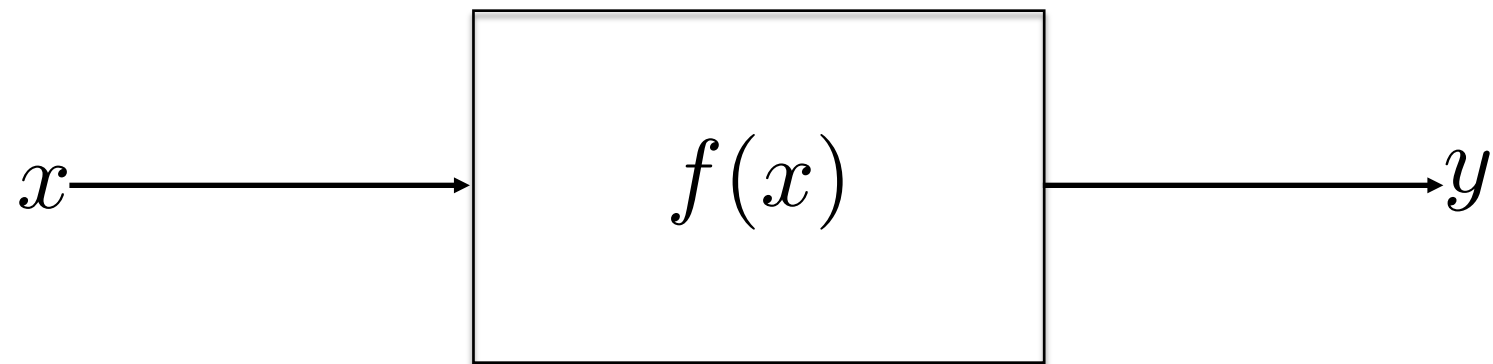
$$\frac{dy}{dc} = b \times 1 \times 3 = 3b$$



Overview

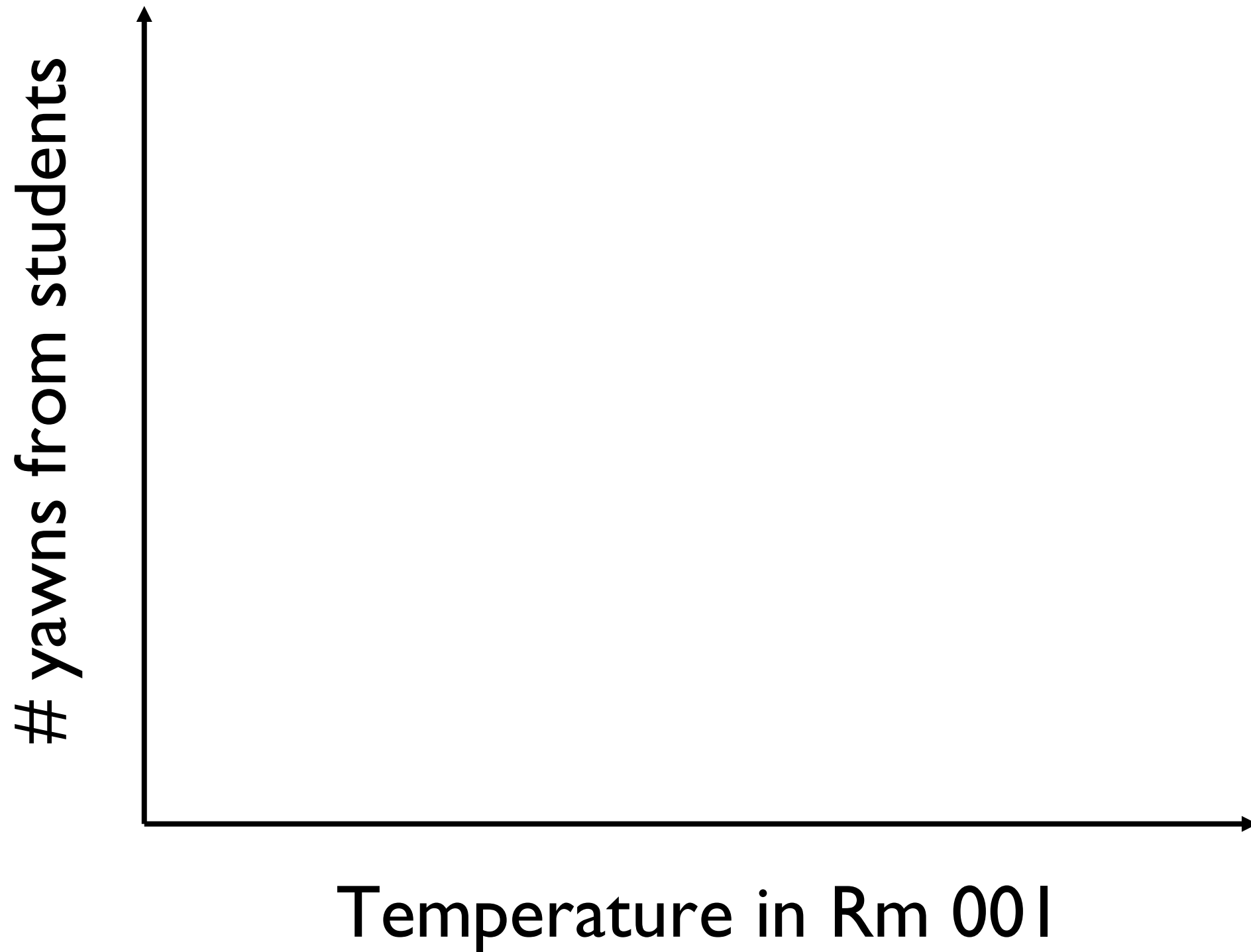
- Philosophical questions
- Derivatives: What are they good for?
- Linear regression
- Multiple linear regression
- Logistic regression

Linear Regression

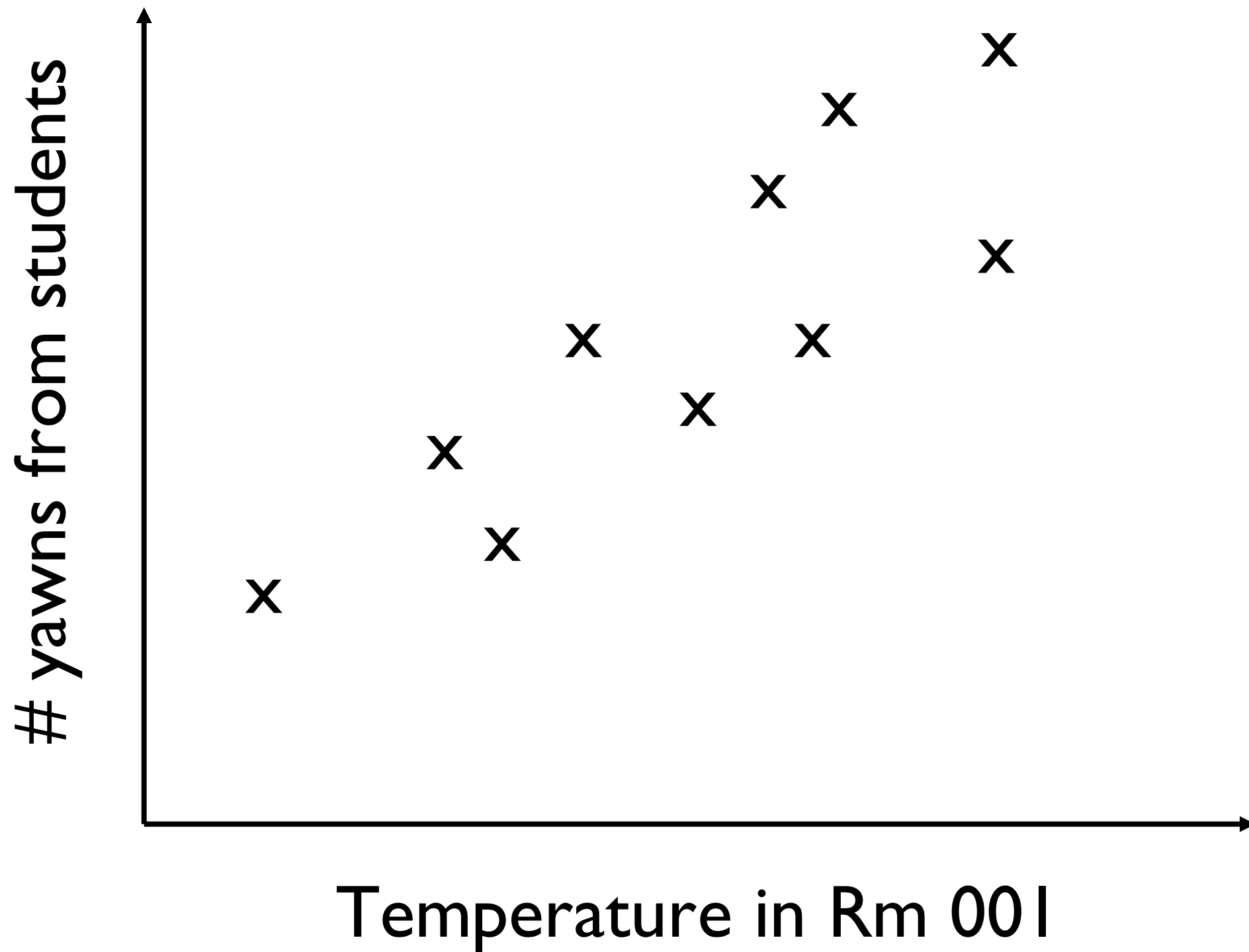


$$y = wx + b$$

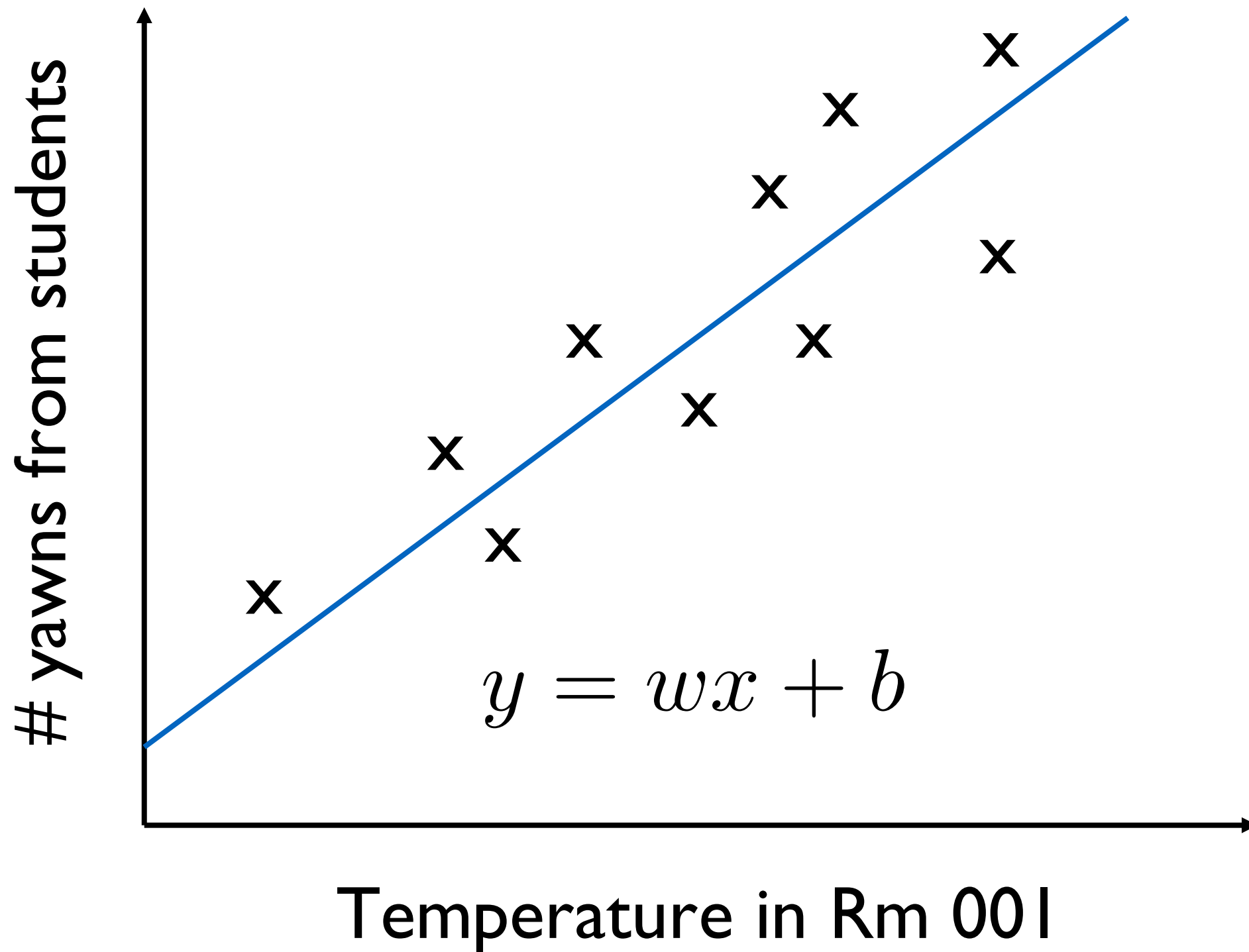
Linear Regression



Linear Regression



Linear Regression



Linear Regression: Training

$$y = wx + b$$

- **Input:** set of m training examples (x, y)
- Find the value of w and b that minimize the error:

$$\sum_{i=1}^m \left(y^{(i)} - \hat{y}^{(i)} \right)^2$$

Linear Regression: Training

$$y = wx + b$$

- Find the value of w and b that minimize the error:

$$\sum_{i=1}^m \left(y^{(i)} - \hat{y}^{(i)} \right)^2$$

$$\sum_{i=1}^m \left(y^{(i)} - wx^{(i)} - b \right)^2$$

Linear Regression: Training

$$y = wx + b$$

- Find the value of w and b that minimize the error:

$$\sum_{i=1}^m \left(y^{(i)} - wx^{(i)} - b \right)^2$$

- Take the derivative with respect to w , set it equal to 0, and solve for w .
- Take the derivative with respect to b , set it equal to 0, and solve for b .

Linear Regression: Training

- Find the value of w and b that minimize the error:

$$w = \frac{\frac{1}{m} \sum_{i=1}^m (x^{(i)} - \bar{x}) (y^{(i)} - \bar{y})}{\sum_{i=1}^m (x^{(i)} - \bar{x})^2}$$

$$b = \bar{y} - w\bar{x}$$

Linear Regression: Training

- Find the value of w and b that minimize the error:

$$w = \frac{\frac{1}{m} \sum_{i=1}^m (x^{(i)} - \bar{x}) (y^{(i)} - \bar{y})}{\sum_{i=1}^m (x^{(i)} - \bar{x})^2}$$

Always
positive!

$$b = \bar{y} - w\bar{x}$$

It depends!