In [44]:

```
from __future__ import print_function
%matplotlib inline
# import ganymede
# ganymede.configure('uav.beaver.works')
import matplotlib.pyplot as plt
import numpy as np
import sympy as sym
from IPython.display import YouTubeVideo, HTML
sym.init_printing(use_latex = "mathjax")
```

Enter your name below and run the cell:

Individual cells can be run with `Ctrl` + `Enter`

In [ ]:

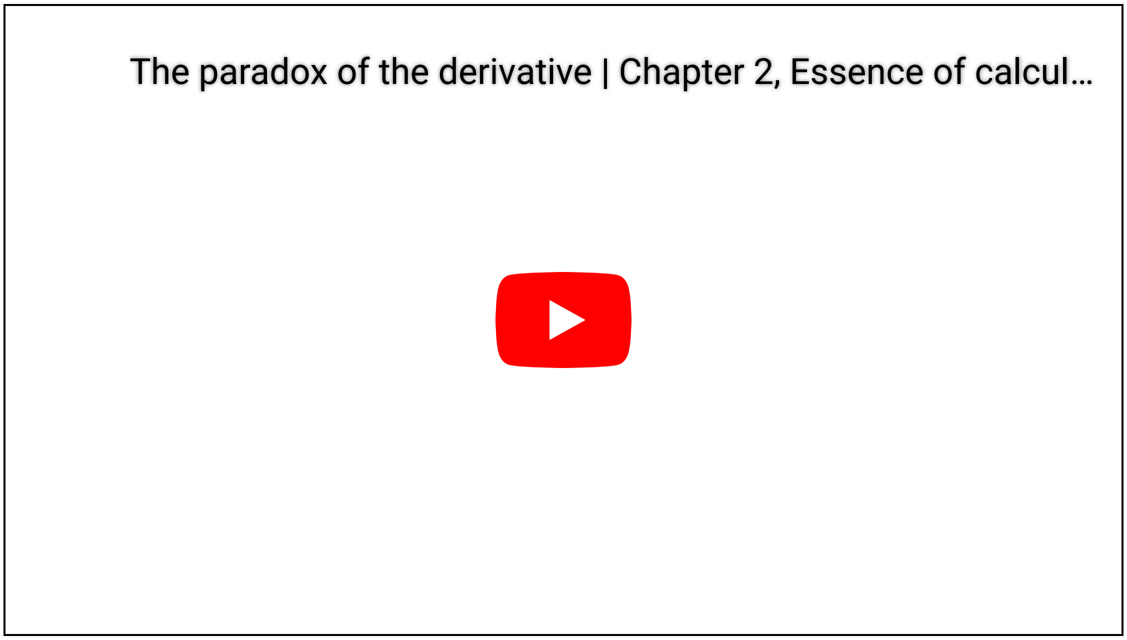
```

```

In [45]:

```
YouTubeVideo('9vKqVkMQHKk', width=560, height=315) # Video by http://www.3blue
```

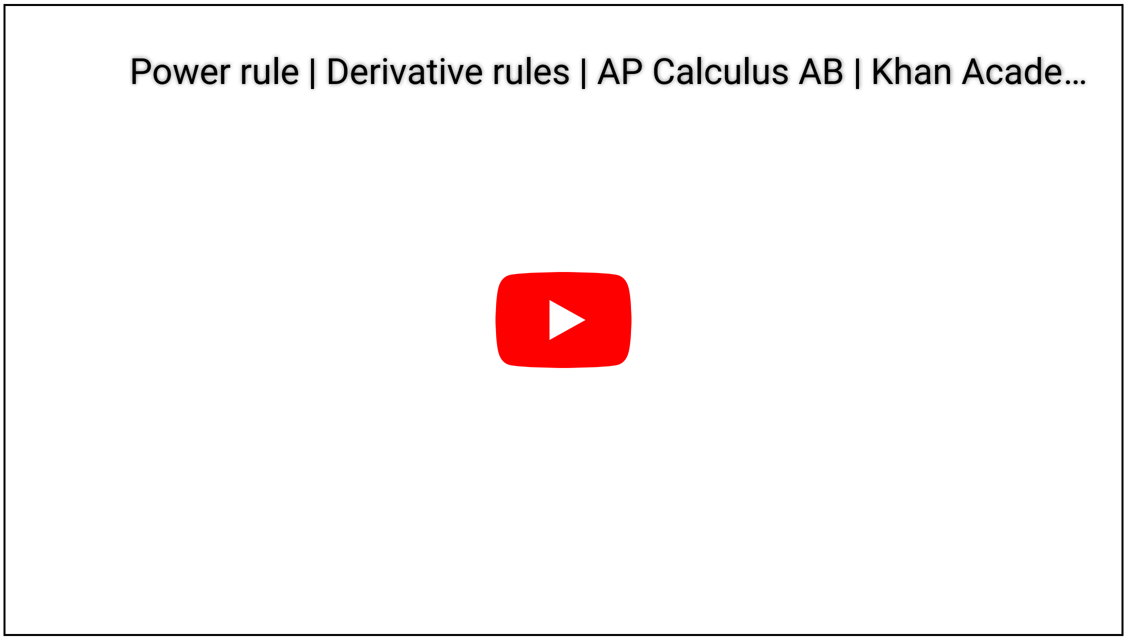
Out[45]:


The paradox of the derivative | Chapter 2, Essence of calcul...

In [46]:

```
YouTubeVideo('bRZmfc1YFsQ', width=560, height=315) #Note: All Khan Academy con
```

Out[46]:



Power rule | Derivative rules | AP Calculus AB | Khan Acade…

Power Rule

The derivative of x^n is nx^{n-1}

Read more

Other derivative rules

In [47]:
```
# Creating algebraic symbols
x = sym.symbols('x')
x
```

Out[47]: x

In [48]:
```
x = sym.symbols('x')
expr = x ** 2
expr
```

Out[48]: x^2

In [49]:
```
sym.Derivative(expr) # does not actually compute the derivative
```

Out[49]: $\frac{d}{dx}x^2$

In [50]:
```
sym.Derivative(expr).doit()
```

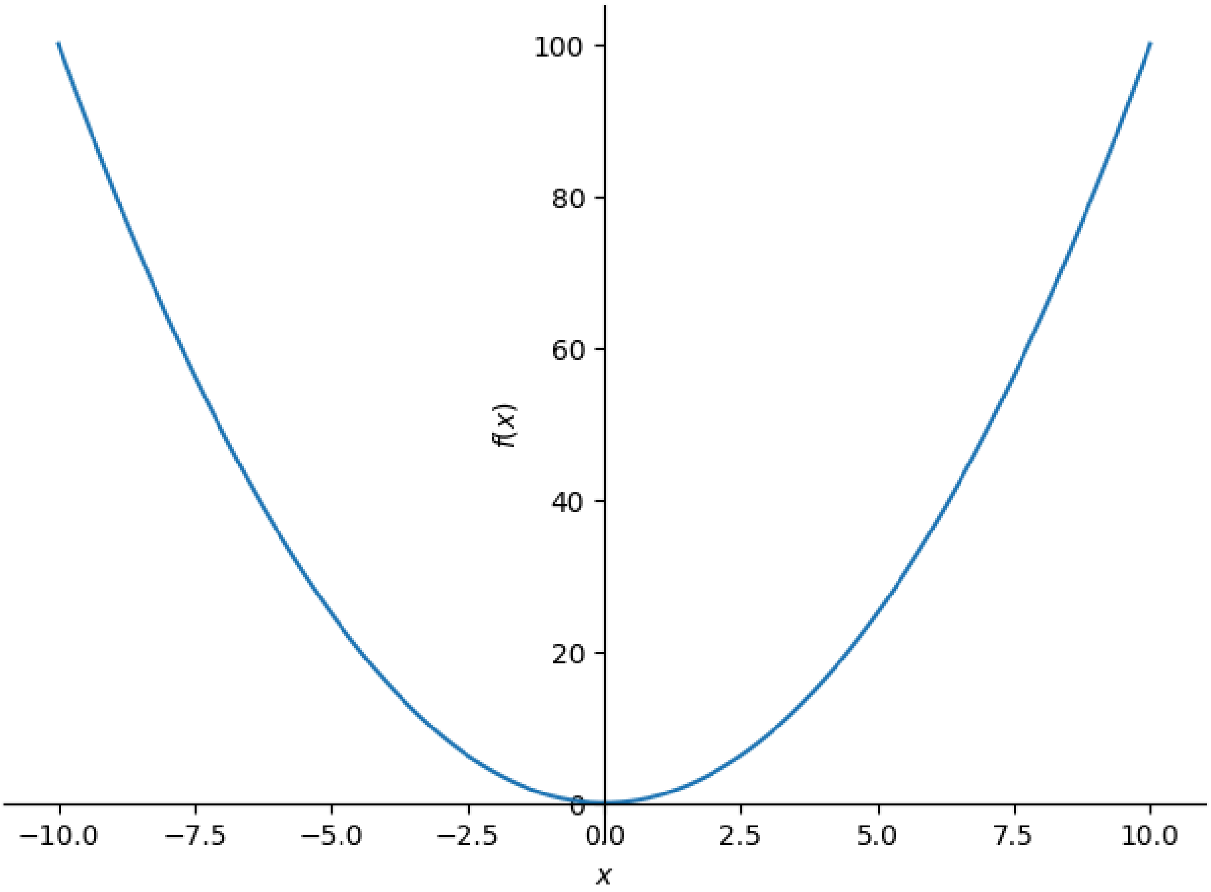
Out[50]: $2x$

In [51]:
```
sym.diff(expr) #equivalent to doit()
```

Out[51]: $2x$

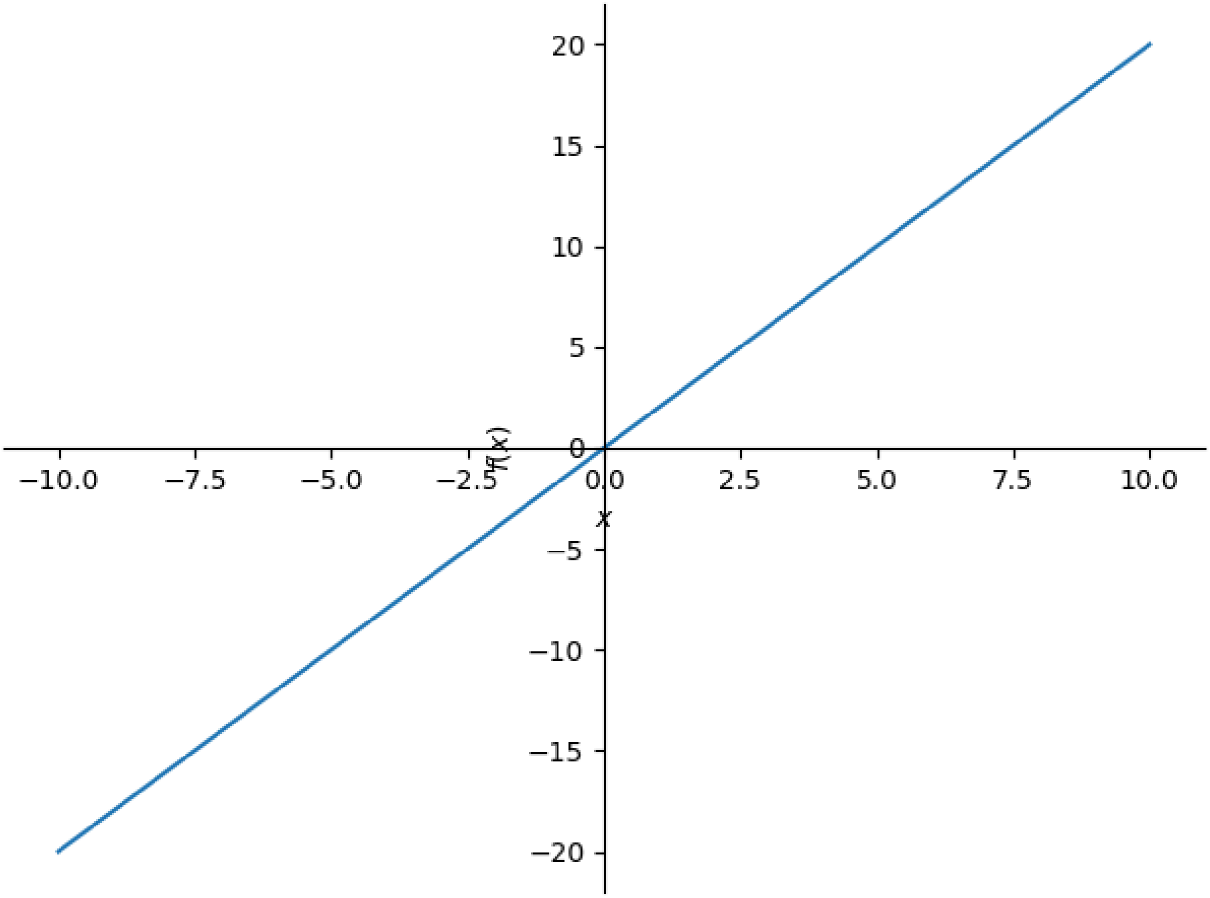
In [52]:

```
sym.plot(expr);
```



In [53]:

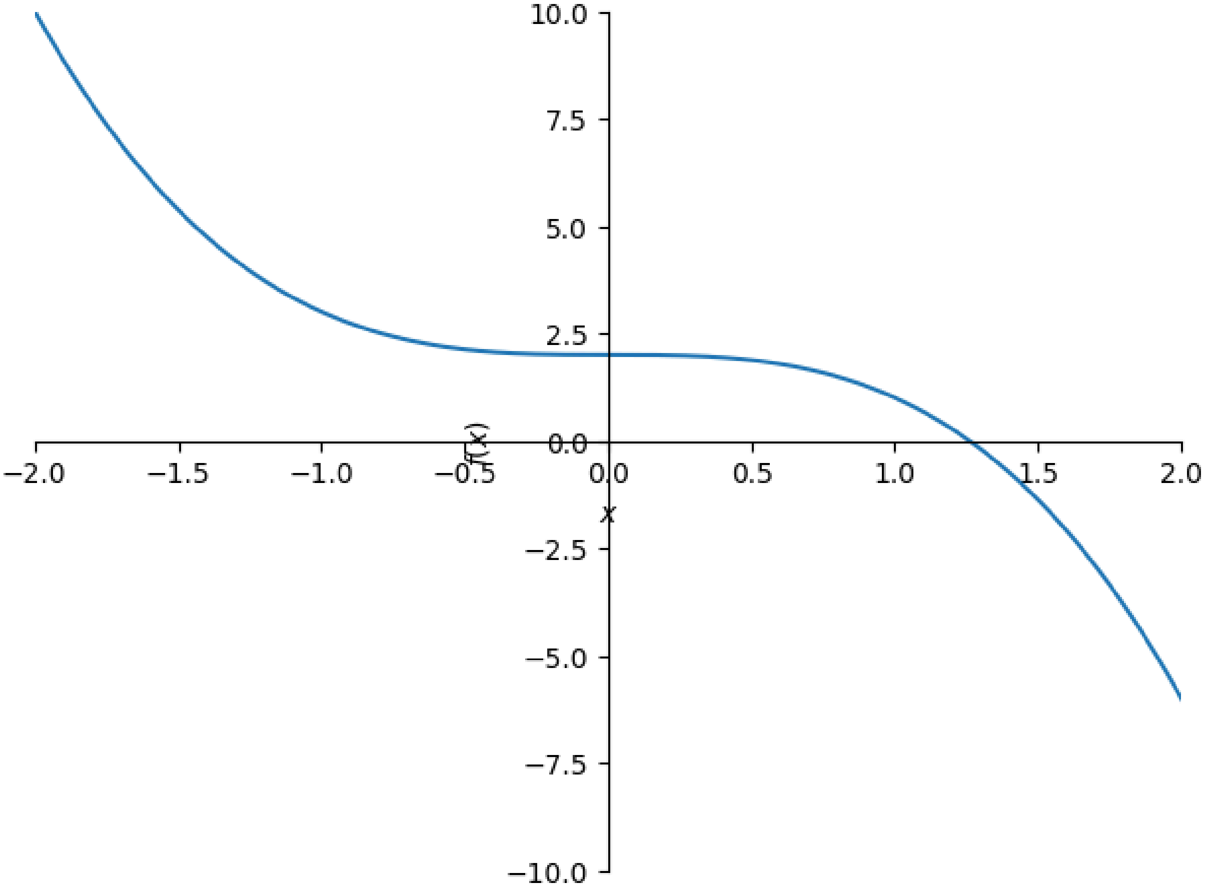
```
sym.plot(sym.diff(expr))
```



```
Out[53]: <sympy.plotting.backends.matplotlibbackend.matplotlib.MatplotlibBackend at 0x1
152374c0>
```

```
In [54]: x = sym.symbols('x')
expr = -x ** 3 + 2

sym.plot(expr, xlim=(-2, 2), ylim=(-10, 10));
```



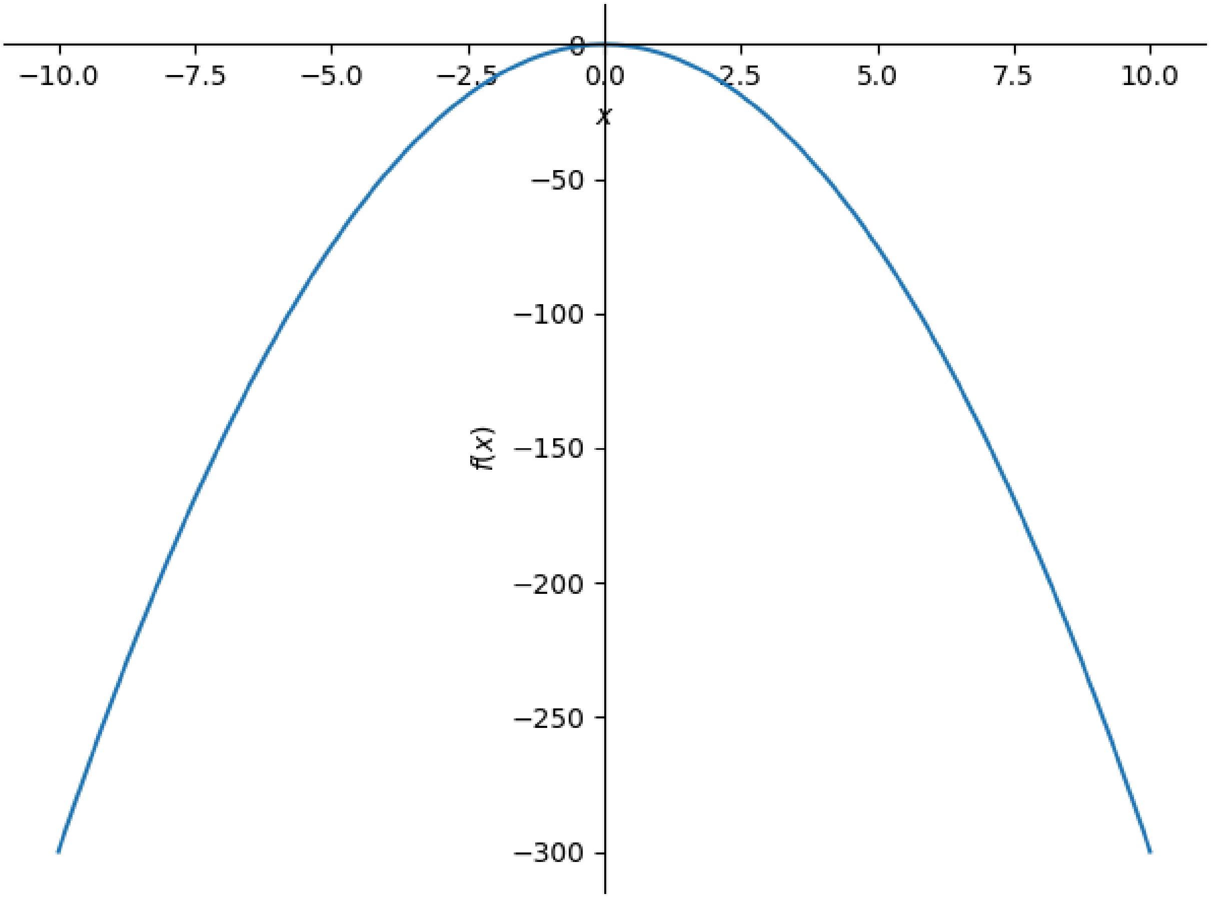
In [55]:
```
sym.Derivative(expr)
```

Out[55]: $\frac{d}{dx}\left(2 - x^{3}\right)$

In [56]:
```
sym.Derivative(expr).doit()
```

Out[56]: $-3x^{2}$

In [57]:
```
sym.plot(sym.diff(expr));
```

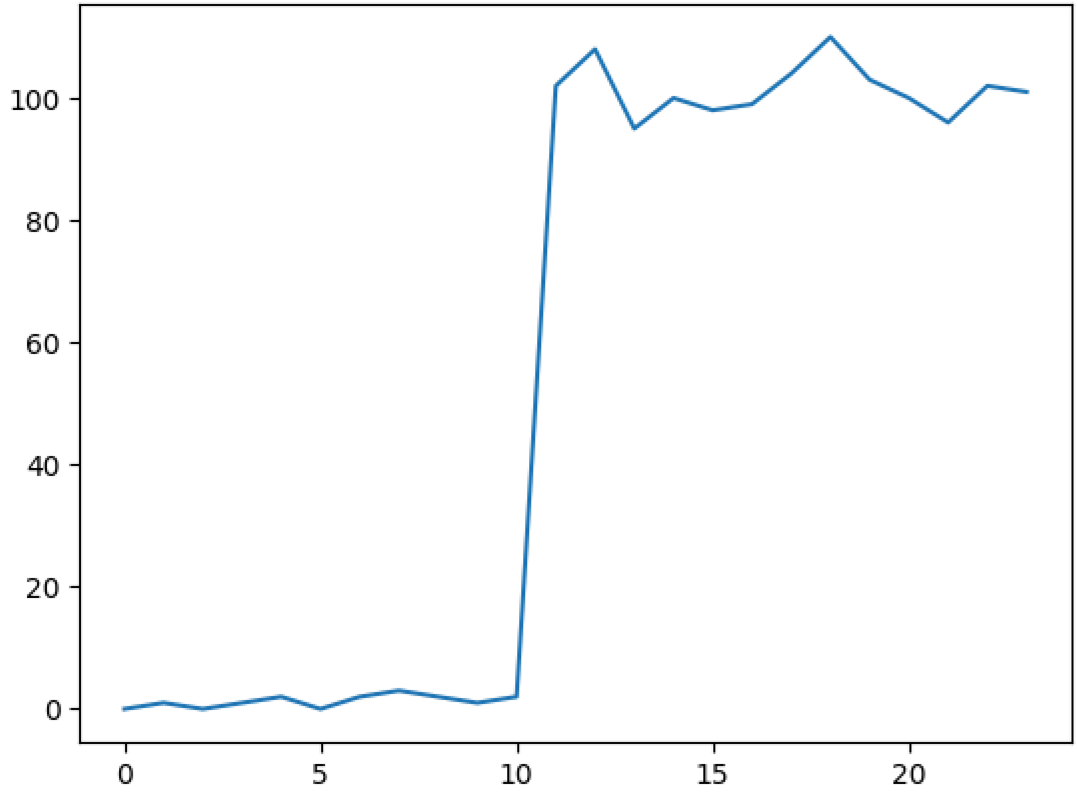


Now, let's generate a fake one-dimensional signal:

In [58]:

```
ys = np.array([0, 1, 0, 1, 2, 0, 2, 3, 2, 1, 2, 102, 108,  95, 100,  98,  99, 

fig,ax = plt.subplots()
ax.plot([i for i in range(len(ys))], ys);
```



Next, let's look at small chunks of our fake signal:

```
In [59]: chunks = np.split(ys, len(ys)//2)
         print(chunks)
```

```
[array([0, 1]), array([0, 1]), array([2, 0]), array([2, 3]), array([2, 1]), ar
ray([  2, 102]), array([108,  95]), array([100,  98]), array([ 99, 104]), arra
y([110, 103]), array([100,  96]), array([102, 101])]
```

Question: Which one of these chunks would you say is the most "interesting"?

Question If we always divide up the signal as we did above, will we always find something "interesting"?

Convolutions

Derivatives and convolutions are one technique to help us tackle the above problem.

First, you'll need to generate windows into the signal. Write a function that can generate windows with a user-supplied windowsize, and print them out.

An example signal with 3 window sizes is shown below. Your output does not need to replicate the formatting shown, but they should produce the same windows. E.g., given an input signal of `[10,20,30]` and a `windowsize=2`, your function should return `[[10,20], [20,30]]`.

A windowsize of 1:

```
signal:
        0   1   0   2   1   0   1 101 100  98 102 101
 0:     0
 1: ____    1
 2: ________    0
 3: ____________    2
 4: ________________    1
 5: ____________________    0
 6: ________________________    1
 7: ____________________________  101
 8: ________________________________  100
 9: ____________________________________   98
10: ________________________________________  102
11: ____________________________________________  101

     ::::::::::::::::::::::::::::::::::::::::::::::::::

i:    0 |  i + windowsize:     1  |  window:  [   0]
i:    1 |  i + windowsize:     2  |  window:  [   1]
i:    2 |  i + windowsize:     3  |  window:  [   0]
i:    3 |  i + windowsize:     4  |  window:  [   2]
i:    4 |  i + windowsize:     5  |  window:  [   1]
i:    5 |  i + windowsize:     6  |  window:  [   0]
i:    6 |  i + windowsize:     7  |  window:  [   1]
i:    7 |  i + windowsize:     8  |  window:  [ 101]
i:    8 |  i + windowsize:     9  |  window:  [ 100]
i:    9 |  i + windowsize:    10  |  window:  [  98]
i:   10 |  i + windowsize:    11  |  window:  [ 102]
i:   11 |  i + windowsize:    12  |  window:  [ 101]
```

A windowsize of 2:

```
signal:
        0   1   0   2   1   0   1 101 100  98 102 101
 0:     0   1
 1: ____    1   0
 2: ________    0   2
 3: ____________    2   1
 4: ________________    1   0
 5: ____________________    0   1
 6: ________________________    1 101
 7: ____________________________  101 100
 8: ________________________________  100  98
 9: ____________________________________   98 102
10: ________________________________________  102 101

     ::::::::::::::::::::::::::::::::::::::::::::::::::

i:    0 |  i + windowsize:     2  |  window:  [   0,   1]
i:    1 |  i + windowsize:     3  |  window:  [   1,   0]
i:    2 |  i + windowsize:     4  |  window:  [   0,   2]
i:    3 |  i + windowsize:     5  |  window:  [   2,   1]
i:    4 |  i + windowsize:     6  |  window:  [   1,   0]
```

```
i:    5 |  i + windowsize:     7  |  window:  [   0,   1]
i:    6 |  i + windowsize:     8  |  window:  [   1, 101]
i:    7 |  i + windowsize:     9  |  window:  [ 101, 100]
i:    8 |  i + windowsize:    10  |  window:  [ 100,  98]
i:    9 |  i + windowsize:    11  |  window:  [  98, 102]
i:   10 |  i + windowsize:    12  |  window:  [ 102, 101]
```

A windowsize of 3

```
signal:
        0   1   0   2   1   0   1 101 100  98 102 101
 0:     0   1   0
 1: ____    1   0   2
 2: ________    0   2   1
 3: ____________    2   1   0
 4: ________________    1   0   1
 5: ____________________    0   1 101
 6: ________________________    1 101 100
 7: ____________________________  101 100  98
 8: ________________________________  100  98 102
 9: ____________________________________   98 102 101

     ::::::::::::::::::::::::::::::::::::::::::::::::::

i:    0 |  i + windowsize:     3  |  window:  [   0,   1,   0]
i:    1 |  i + windowsize:     4  |  window:  [   1,   0,   2]
i:    2 |  i + windowsize:     5  |  window:  [   0,   2,   1]
i:    3 |  i + windowsize:     6  |  window:  [   2,   1,   0]
i:    4 |  i + windowsize:     7  |  window:  [   1,   0,   1]
i:    5 |  i + windowsize:     8  |  window:  [   0,   1, 101]
i:    6 |  i + windowsize:     9  |  window:  [   1, 101, 100]
i:    7 |  i + windowsize:    10  |  window:  [ 101, 100,  98]
i:    8 |  i + windowsize:    11  |  window:  [ 100,  98, 102]
i:    9 |  i + windowsize:    12  |  window:  [  98, 102, 101]
```

The below resources may be helpful::

List Comprehensions

https://www.pythonlikeyoumeanit.com/Module2_EssentialsOfPython/Generators_and_Compreh
&-Tuple-Comprehensions

Numpy indexing with slices

http://www.pythonlikeyoumeanit.com/Module3_IntroducingNumpy/AccessingDataAlongMultiple
Indexing

Formatting numbers in python

https://pyformat.info/#number

input: `'{:4d}'.format(42)`

output: `_` `_` `4` `2`

input: `'{:06.2f}'.format(3.141592653589793)`

output: `003.14`

String concatenation

```
>>> print('a' + 'b' + 'c')
abc
>>> print(''.join(['a', 'b', 'c']))
abc
>>> print(''.join(['a', 'b', 'c']))
a,b,c
```

In [60]:

```
def make_windows(sequence, windowsize):
    l=len(sequence)
    windows=np.zeros(shape=(l-windowsize+1,windowsize))
    for i in range(l-windowsize+1):
        windows[i]=sequence[i:i+windowsize]
    print(windows)
    return windows
```

In [61]:

```
series = [0, 1, 0, 2, 1, 0, 1, 101, 100, 98, 102, 101]


make_windows(sequence=series, windowsize=1)
make_windows(sequence=series, windowsize=2)
make_windows(sequence=series, windowsize=3)
```

```
[[  0.]
 [  1.]
 [  0.]
 [  2.]
 [  1.]
 [  0.]
 [  1.]
 [101.]
 [100.]
 [ 98.]
 [102.]
 [101.]]
[[  0.   1.]
 [  1.   0.]
 [  0.   2.]
 [  2.   1.]
 [  1.   0.]
 [  0.   1.]
 [  1. 101.]
 [101. 100.]
 [100.  98.]
 [ 98. 102.]
 [102. 101.]]
[[  0.   1.   0.]
 [  1.   0.   2.]
 [  0.   2.   1.]
 [  2.   1.   0.]
 [  1.   0.   1.]
 [  0.   1. 101.]
 [  1. 101. 100.]
 [101. 100.  98.]
 [100.  98. 102.]
 [ 98. 102. 101.]]
```

```
Out[61]: array([[  0.,   1.,   0.],
                [  1.,   0.,   2.],
                [  0.,   2.,   1.],
                [  2.,   1.,   0.],
                [  1.,   0.,   1.],
                [  0.,   1., 101.],
                [  1., 101., 100.],
                [101., 100.,  98.],
                [100.,  98., 102.],
                [ 98., 102., 101.]])
```

When you are done:

Generate some example outputs in this notebook.

1. Double-check that you filled in your name at the top of the notebook!
2. Click `File` -> `Export Notebook As` -> `PDF`
3. Email the PDF to `YOURTEAMNAME@beaver.works`