In [3]:
```python
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")
```

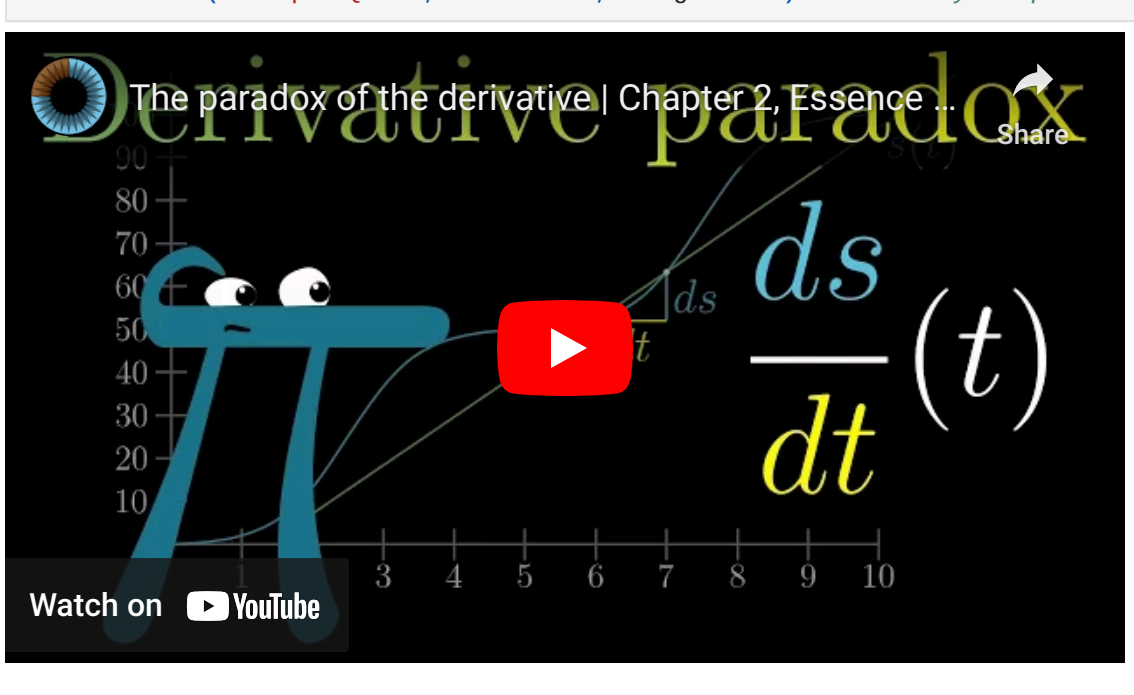
Enter your name below and run the cell:

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

In [6]:
```python
# ganymede.name('YOUR NAME HERE')
# def check(p):
    # ganymede.update(p,True)
# check(0)
```

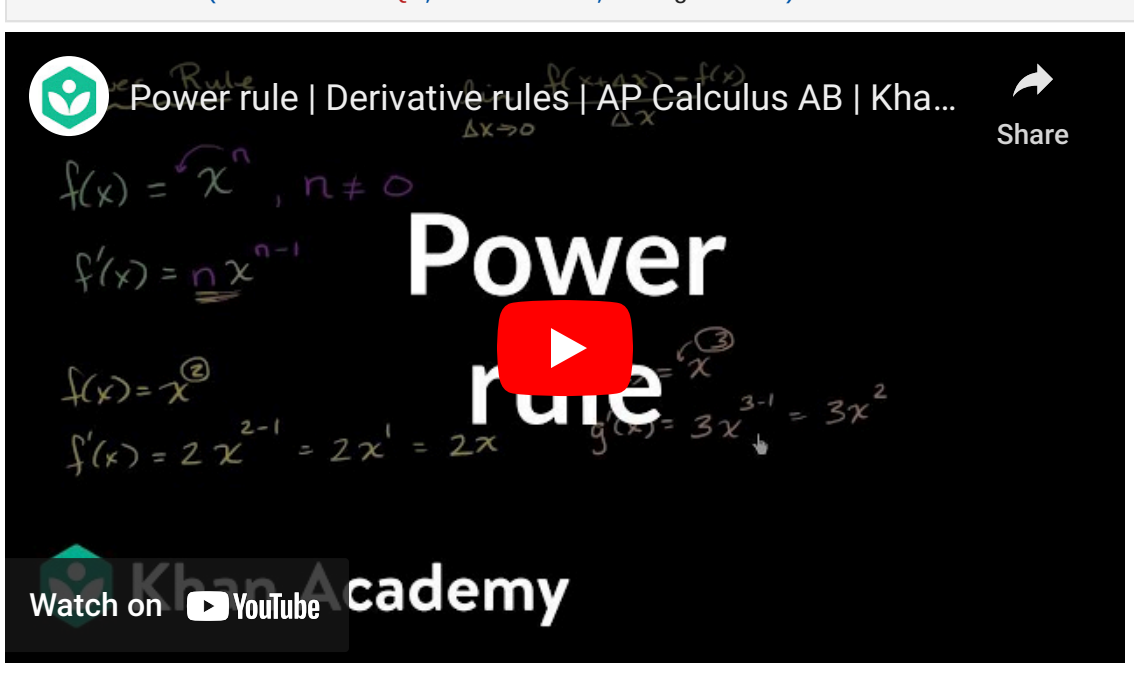
In [7]:
```python
YouTubeVideo('9vKqVkMQHKk', width=560, height=315) # Video by http://www.3blue1brown.com/
```

Out[7]:



In [8]:
```python
YouTubeVideo('bRZmfc1YFsQ', width=560, height=315) #Note: All Khan Academy content is available for free at khanacademy.org
```

Out[8]:



Power Rule

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

Read more

Other derivative rules

In [9]:
```python
# Creating algebraic symbols
x = sym.symbols('x')
x
```

Out[9]: x

In [10]:
```python
x = sym.symbols('x')
expr = x ** 2
expr
```

Out[10]: x^2

In [11]:
```python
sym.Derivative(expr) # does not actually compute the derivative
```

Out[11]: $\frac{d}{dx} x^2$

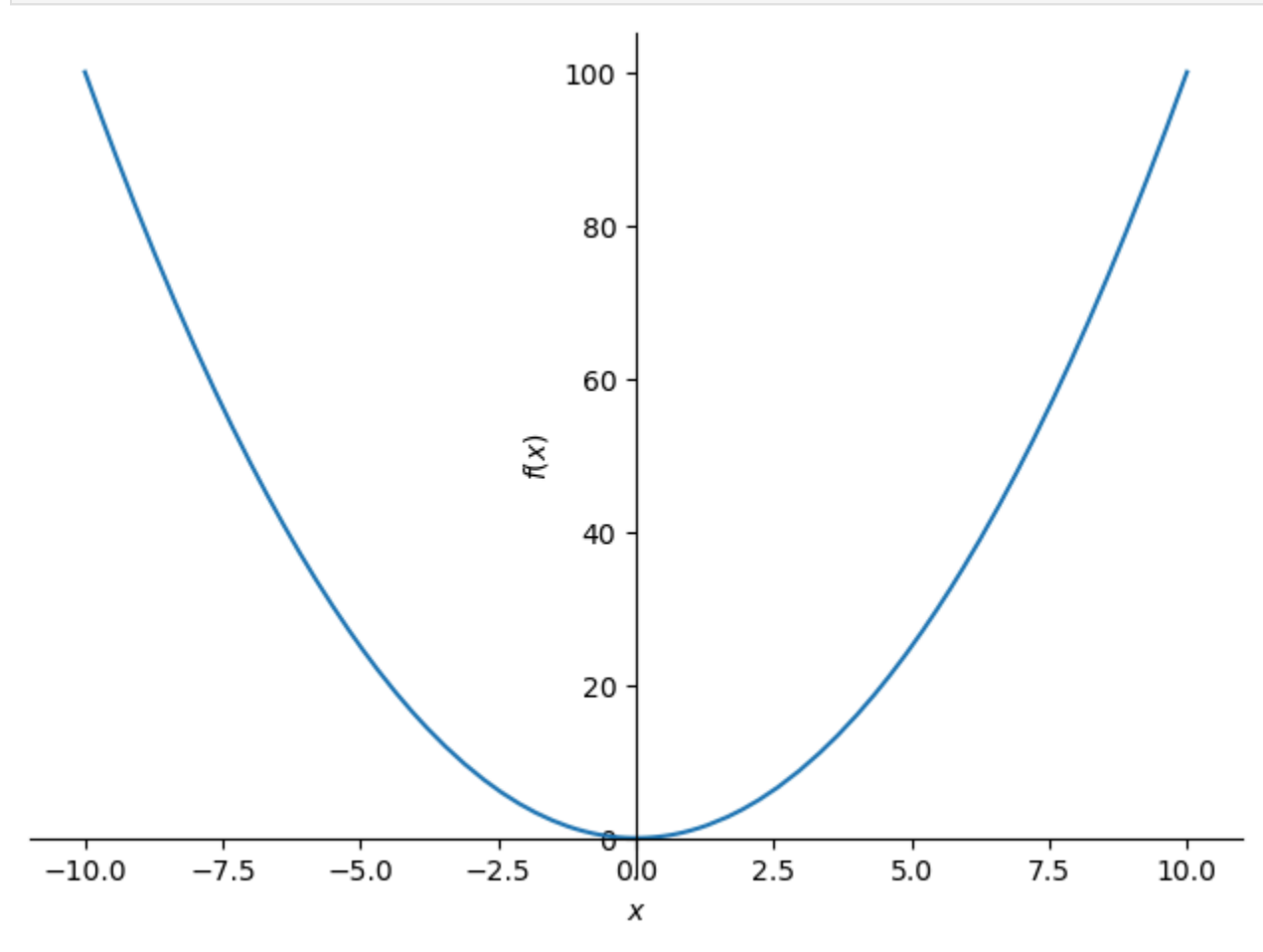
In [12]:
```python
sym.Derivative(expr).doit()
```

Out[12]: $2x$

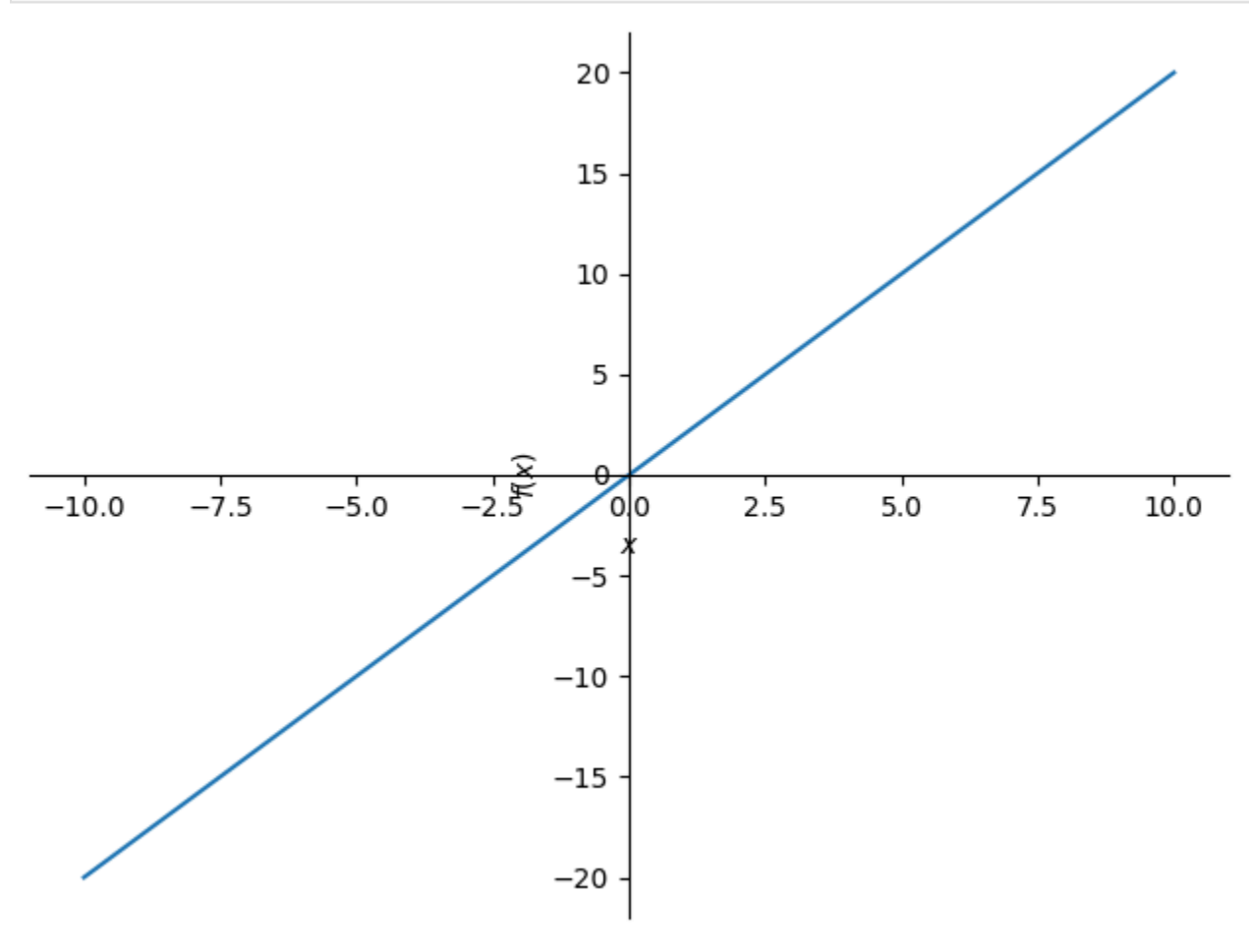
In [13]:
```python
sym.diff(expr) #equivalent to doit()
```

Out[13]: $2x$

In [15]:
```python
sym.plot(expr);
```

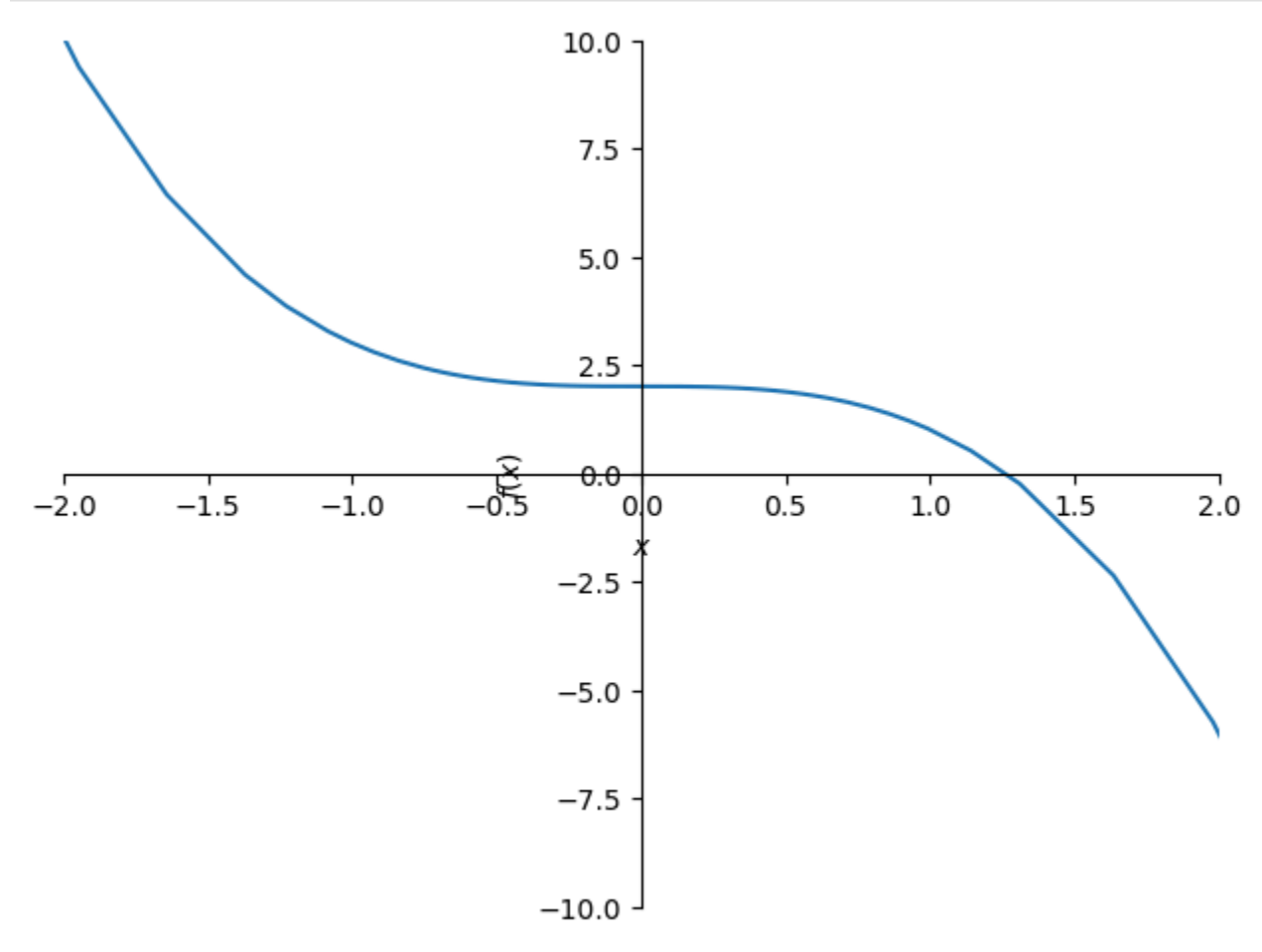


In [16]:
```python
sym.plot(sym.diff(expr));
```



In [17]:
```python
x = sym.symbols('x')
expr = -x ** 3 + 2

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



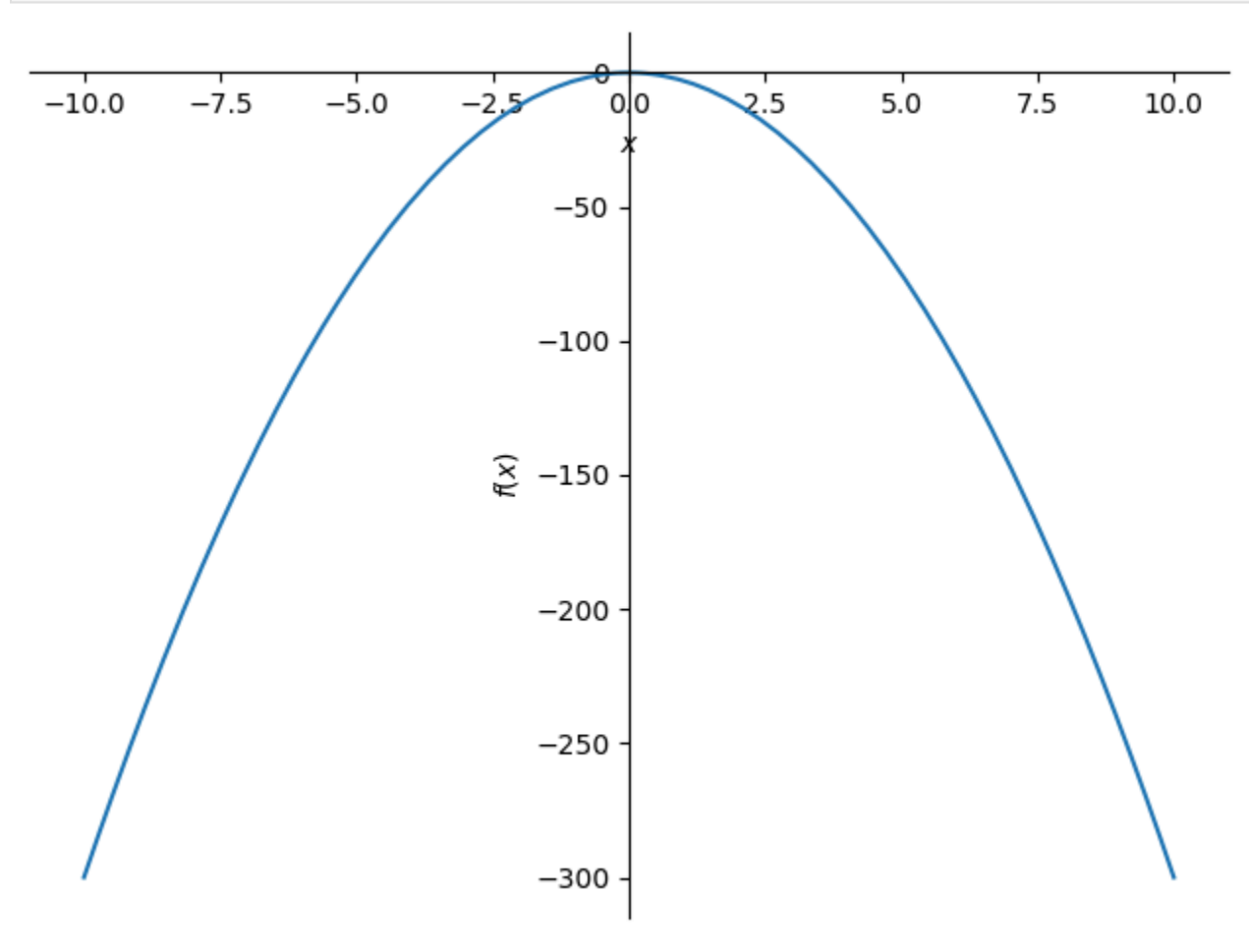
In [18]:
```python
sym.Derivative(expr)
```

Out[18]: $\frac{d}{dx}\left(2 - x^3\right)$

In [19]:
```python
sym.Derivative(expr).doit()
```

Out[19]: $-3x^2$

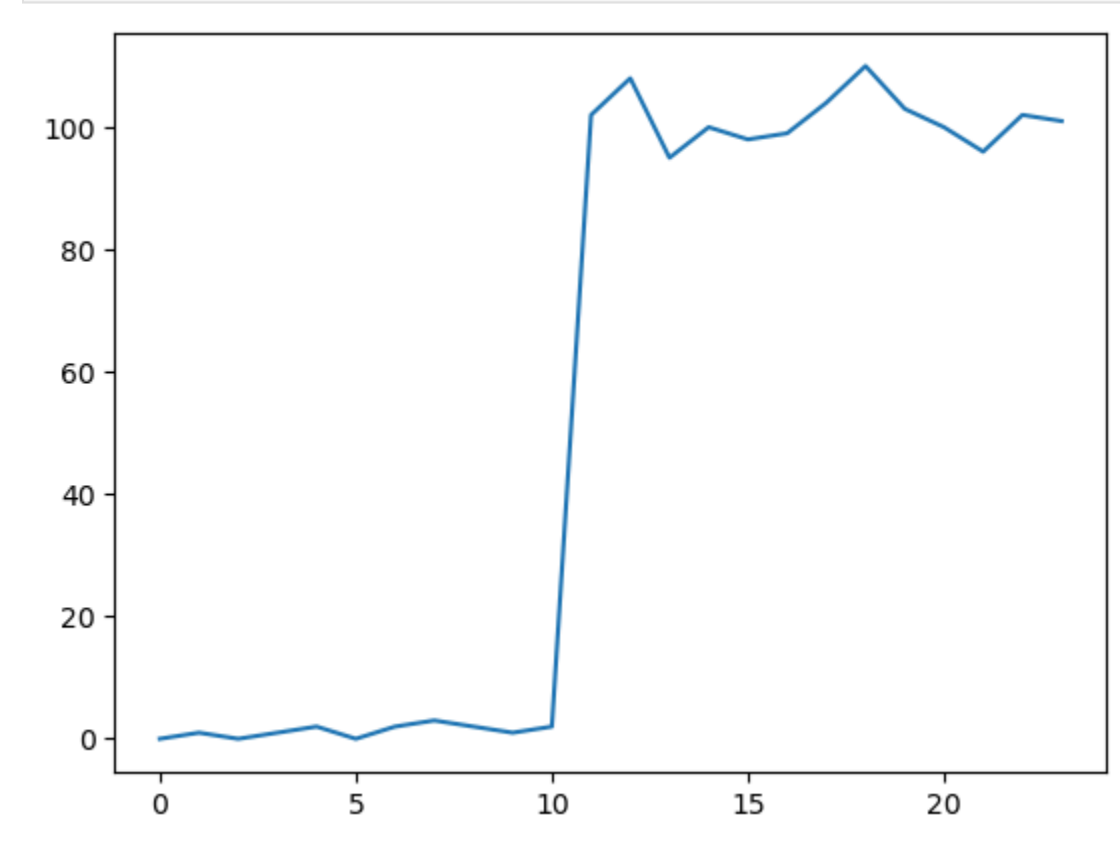
In [20]:
```python
sym.plot(sym.diff(expr));
```



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

In [22]:
```python
ys = np.array([0, 1, 0, 1, 2, 0, 2, 3, 2, 1, 2, 102, 108,  95, 100,  98,  99, 104, 110, 103, 100,  96, 102, 101])

fig,ax = plt.subplots()
ax.plot([i for i in range(len(ys))], ys);
# check(1)
```



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

In [24]:
```python
chunks = np.split(ys, len(ys)//2)
print(chunks)
# check(2)
```

```
[array([0, 1]), array([0, 1]), array([2, 0]), array([2, 3]), array([2, 1]), array([  2, 102]), array([108,  95]), array([100,  98]), array([ 99, 10
4]), array([110, 103]), array([100,  96]), array([102, 101])]
```

Question: Which one of these chunks would you say is the most "interesting"? array([1,102]) is th most interesting

Question If we always divide up the signal as we did above, will we always find something "interesting"? No, the signal can be just a straight line

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_Comprehensions.html#List-&-Tuple-Comprehensions

Numpy indexing with slices

http://www.pythonlikeyoumeanit.com/Module3_IntroducingNumpy/AccessingDataAlongMultipleDimensions.html#Slice-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 [31]:
```python
def make_windows(sequence, windowsize):

    ans = []
    while len(sequence) > windowsize:
        chunk = []
        for i in range(windowsize):
            chunk.append(sequence[i])
        sequence = sequence[1:]
        ans.append(chunk)


    print(ans)
    print("-----------------")
```

In [32]:
```python
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)

# check(3)
```

```
[[0], [1], [0], [2], [1], [0], [1], [101], [100], [98], [102]]
-----------------
[[0, 1], [1, 0], [0, 2], [2, 1], [1, 0], [0, 1], [1, 101], [101, 100], [100, 98], [98, 102]]
-----------------
[[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]]
-----------------
```

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`