QF666 Programming and Computational Finance

Dr. Zhao Yibao
Senior Lecturer
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How to ...

```
import matplotlib.pyplot as plt
import pandas as pd
imprt numpy as np
```

✓ Python

✓ MATLAB

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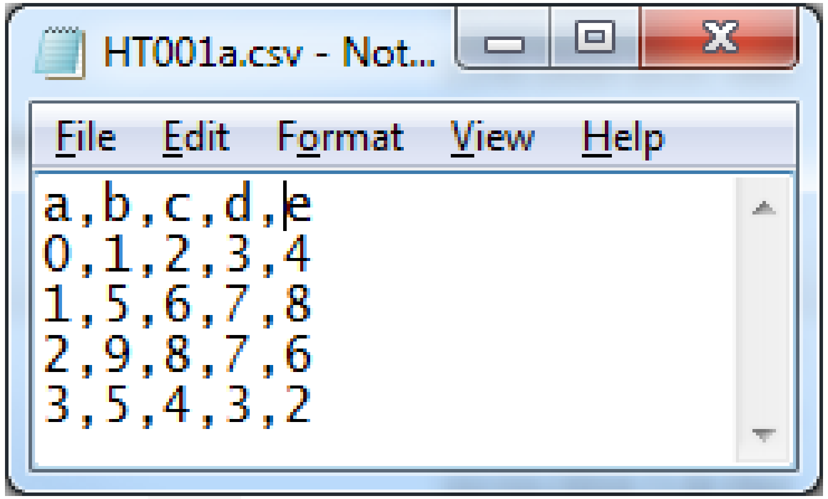
HT001: **Use one command** to import data from a CSV file, **HT001a.csv**, using the **first row as column labels**, and the **first column as row labels**. Name the data imported as **data**.



```
a,b,c,d,e
0,1,2,3,4
1,5,6,7,8
2,9,8,7,6
3,5,4,3,2
```

✓ Python: **pandas.read_csv**

```
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
```

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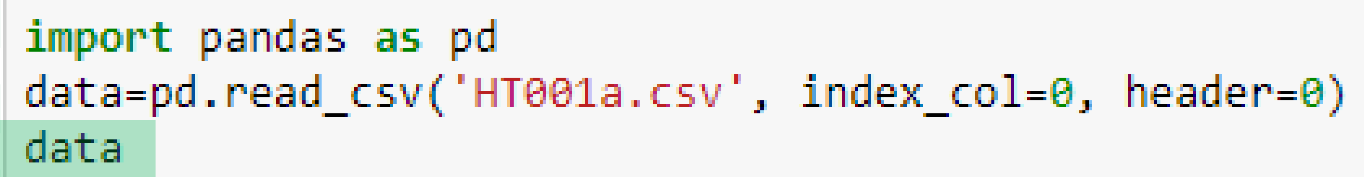
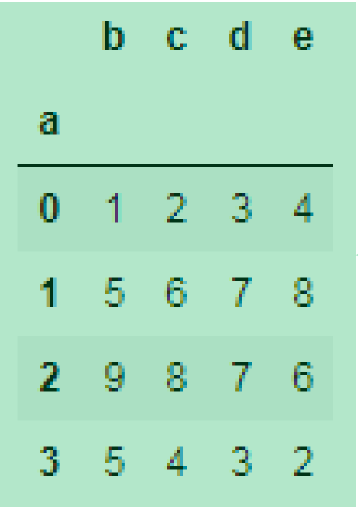
? MATLAB: **readtable**

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
```

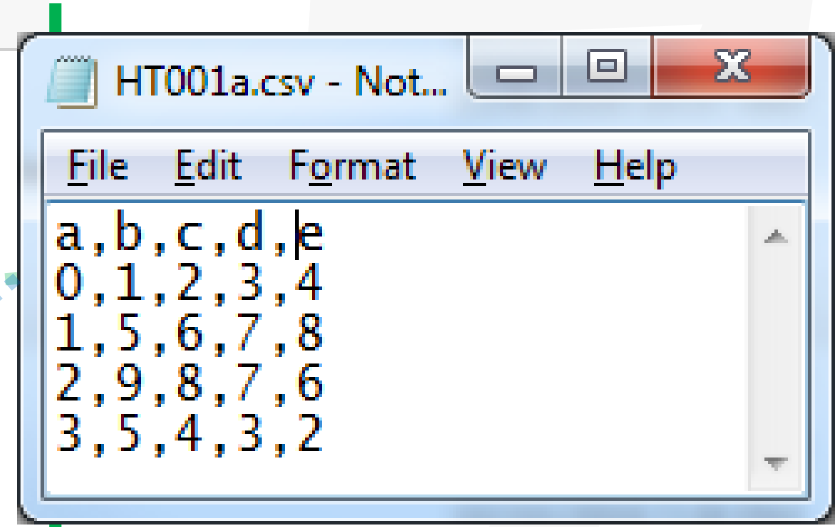


```
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
data
```

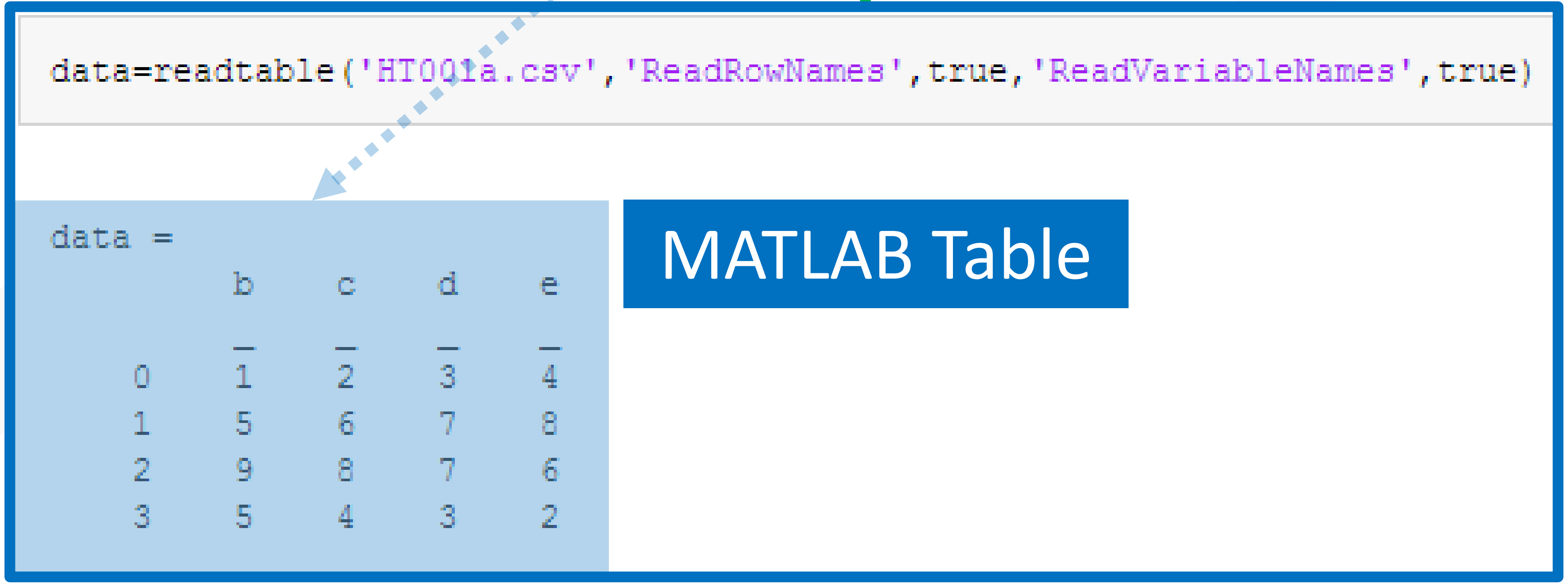


```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

Pandas DataFrame



```
a,b,c,d,e
0,1,2,3,4
1,5,6,7,8
2,9,8,7,6
3,5,4,3,2
```



```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
```

```
data =
              b      c      d      e
              _      _      _      _
      0       1      2      3      4
      1       5      6      7      8
      2       9      8      7      6
      3       5      4      3      2
```

MATLAB Table

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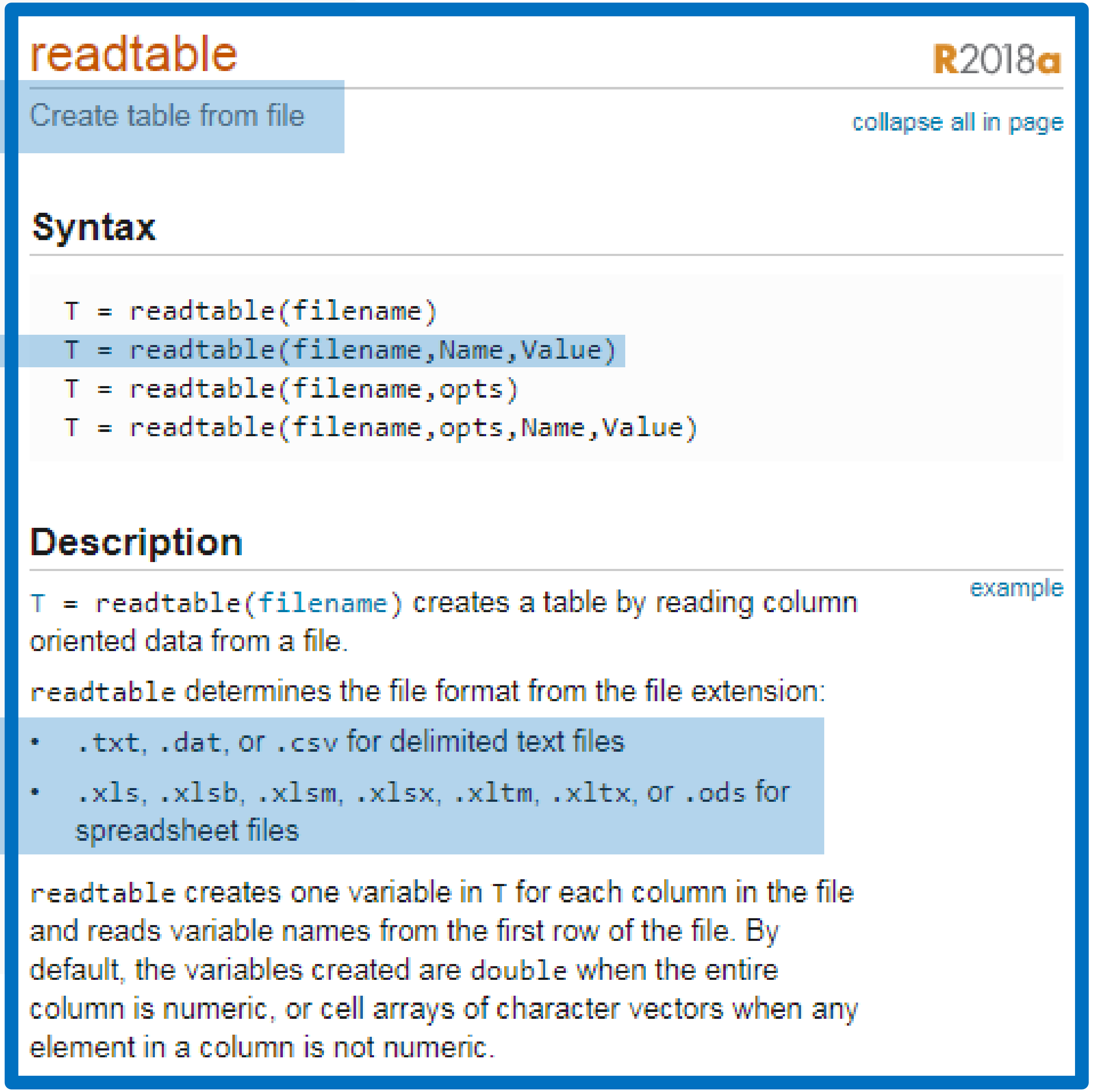
https://www.mathworks.com/help/matlab/ref/readtable.html



readtable

R2018a

Create table from file

collapse all in page

Syntax

```
T = readtable(filename)
T = readtable(filename,Name,Value)
T = readtable(filename,opts)
T = readtable(filename,opts,Name,Value)
```

Description

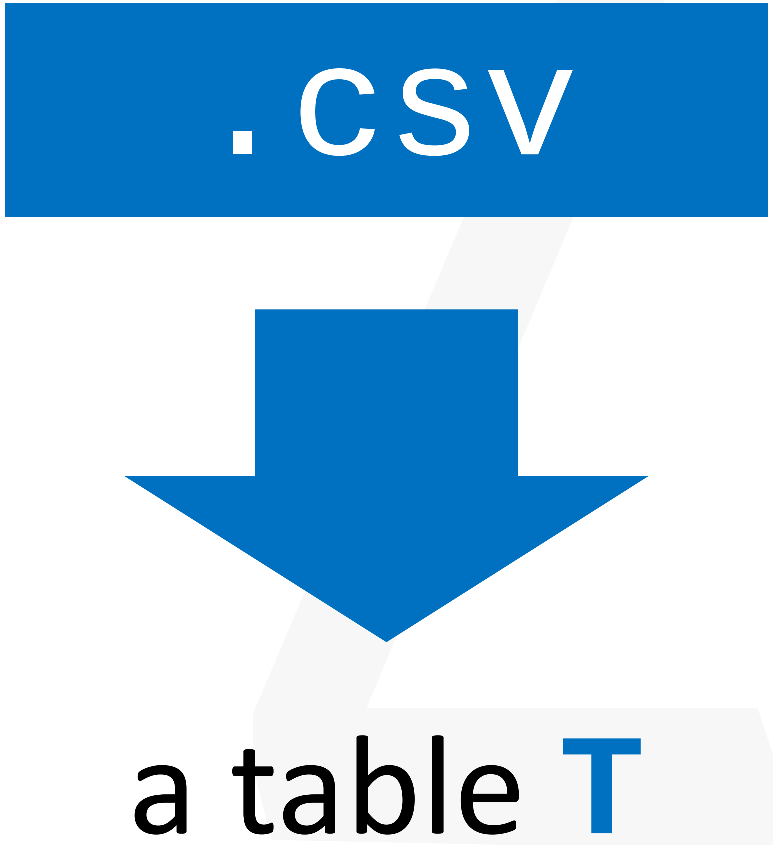
example

T = readtable(filename) creates a table by reading column oriented data from a file.

readtable determines the file format from the file extension:

- .txt, .dat, or .csv for delimited text files
- .xls, .xlsb, .xlsm, .xlsx, .xltm, .xltx, or .ods for spreadsheet files

readtable creates one variable in T for each column in the file and reads variable names from the first row of the file. By default, the variables created are double when the entire column is numeric, or cell arrays of character vectors when any element in a column is not numeric.



.csv

a table T

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What if the file is newfolder\newfile.csv?

```
✓ data=pd.read_csv('newfolder\\newfile.csv')
✓ data=pd.read_csv(r'newfolder\newfile.csv')
```

(Mac)
```
data=pd.read_csv('newfolder/newfile.csv')
```

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```
✓ data=readtable('newfolder\newfile.csv')
```

(Mac)
```
data=readtable('newfolder/newfile.csv')
```

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Name-Value Pair Arguments

- □ 'ReadVariableNames' – **Read first row as variable names**
- □ 'ReadRowNames' – **Read first column as row names**
- □ 'DatetimeType' – Type for imported date and time date
- □ 'Delimiter' – Field delimiter character
- □ 'HeaderLines' – Lines to skip
- □ 'Format' – Column format
- □ 'EmptyValue' – Returned value for empty numeric fields
- □ 'DurationType' – Output data type of duration data

Spreadsheet Files Only

- □ 'Sheet' – Worksheet to read
- □ 'Range' – Portion of worksheet to read

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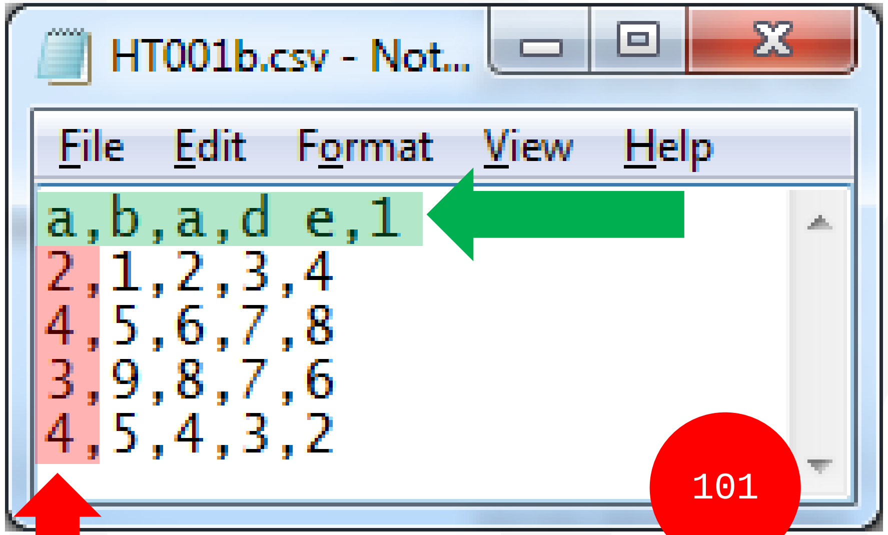
What if the labels are as follows?



```
a,b,a,d e,1
2,1,2,3,4
4,5,6,7,8
3,9,8,7,6
4,5,4,3,2
```

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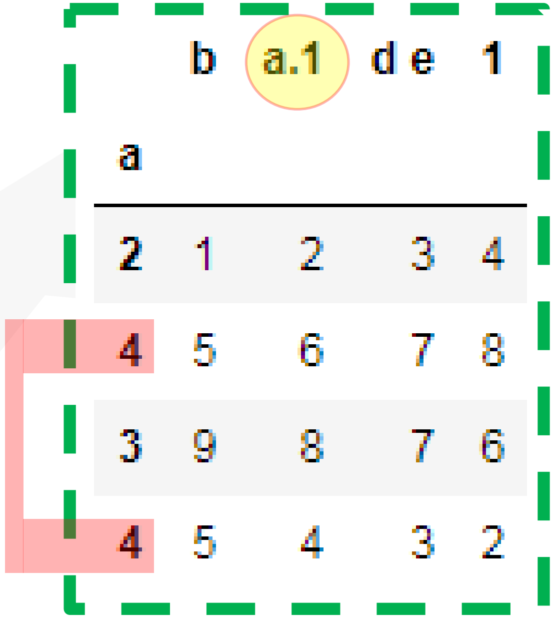


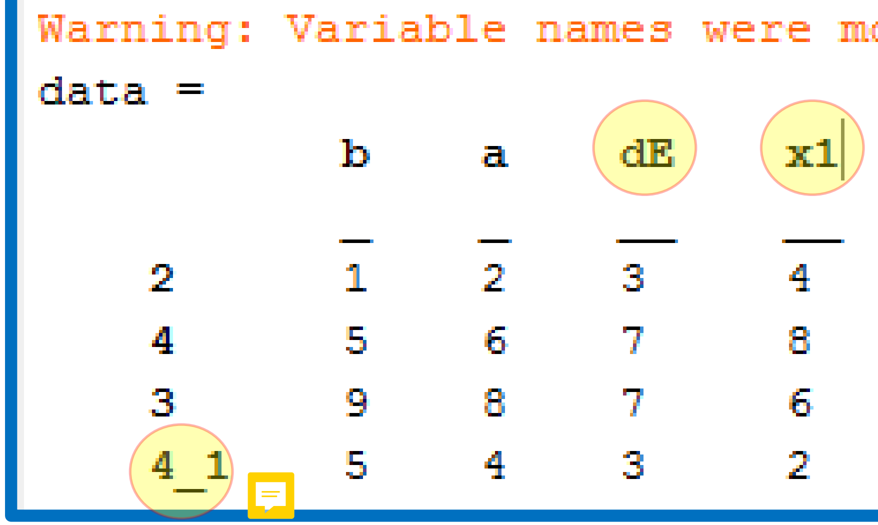
```
     b  a.1  d e  1
a
2    1    2    3  4
4    5    6    7  8
3    9    8    7  6
4    5    4    3  2
```

`mangle_dupe_cols=True`

mangle_dupe_cols : *boolean, default True*

Duplicate columns will be specified as 'X', 'X.1', ...'X.N', rather than 'X'...'X'. Passing in False will cause data to be overwritten if there are duplicate names in the columns.

Remember DataFrame is a dict-like container of Series??



```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =

               b    a    dE    x1
               _    _    __    __

      2        1    2    3     4
      4        5    6    7     8
      3        9    8    7     6
      4_1      5    4    3     2
```

```
d e -> dE
1 -> x1   (column label)
4 -> 4_1 (row label)
```

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no duplicate names

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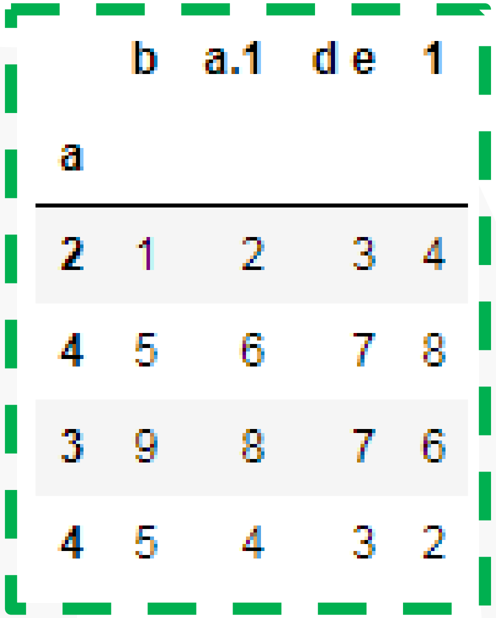
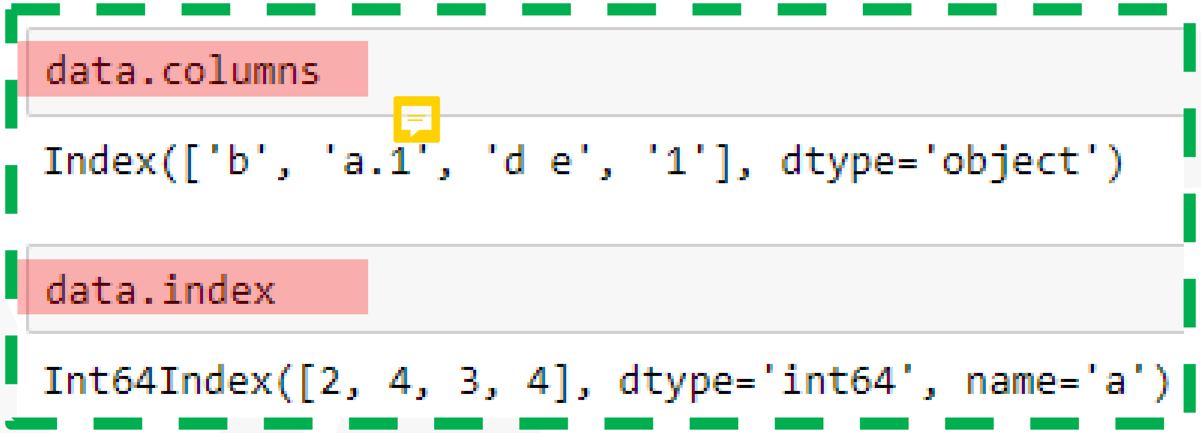
(continued)



```
   b  a.1  d e  1
a
2  1  2    3    4
4  5  6    7    8
3  9  8    7    6
4  5  4    3    2
```



```
data.columns

Index(['b', 'a.1', 'd e', '1'], dtype='object')

data.index

Int64Index([2, 4, 3, 4], dtype='int64', name='a')
```

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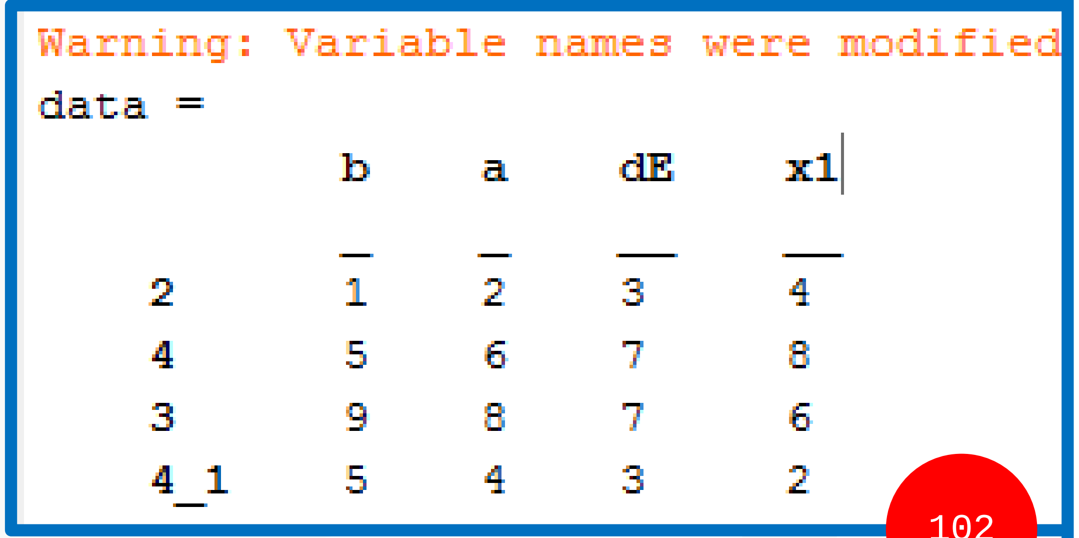

```
Warning: Variable names were modified
data =
              b      a      dE      x1
              _      _      __      __
   2          1      2      3       4
   4          5      6      7       8
   3          9      8      7       6
   4_1        5      4      3       2
```

```
LAB identifiers.
```

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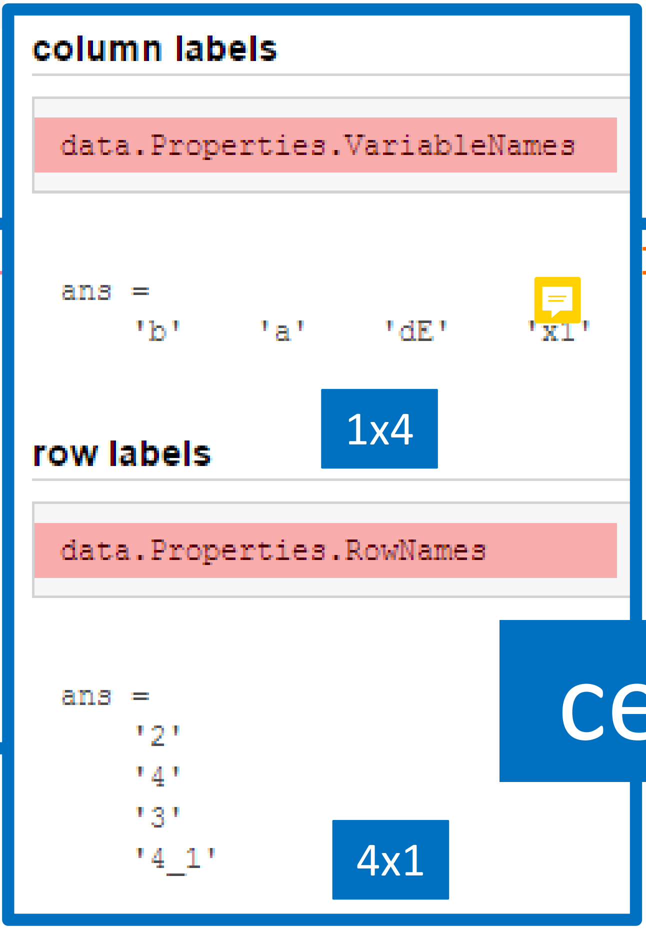


column labels

```
data.Properties.VariableNames

ans =
    'b'    'a'    'dE'    'x1'
```

1x4

row labels

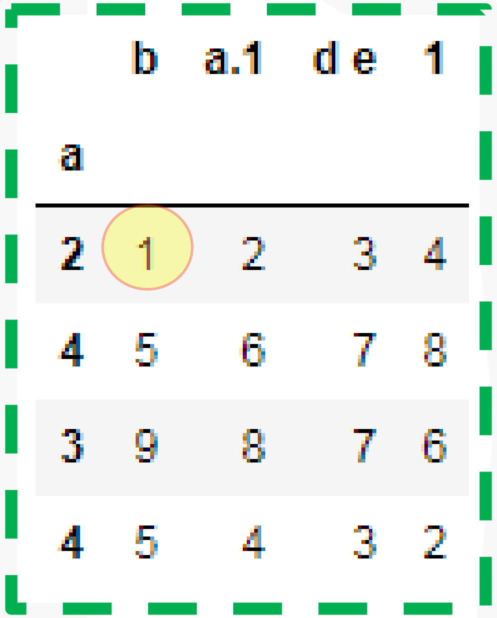
```
data.Properties.RowNames

ans =
    '2'
    '4'
    '3'
    '4_1'
```

4x1

cell array

HT002: Use an appropriate **position-based indexing/slicing** method to select data in **`data`**.



```
    b  a.1  d e  1
a
2   1    2    3  4
4   5    6    7  8
3   9    8    7  6
4   5    4    3  2
```

✓ `data.iloc[0,0]`

× `data[0][0]`

× `data[0,0]`

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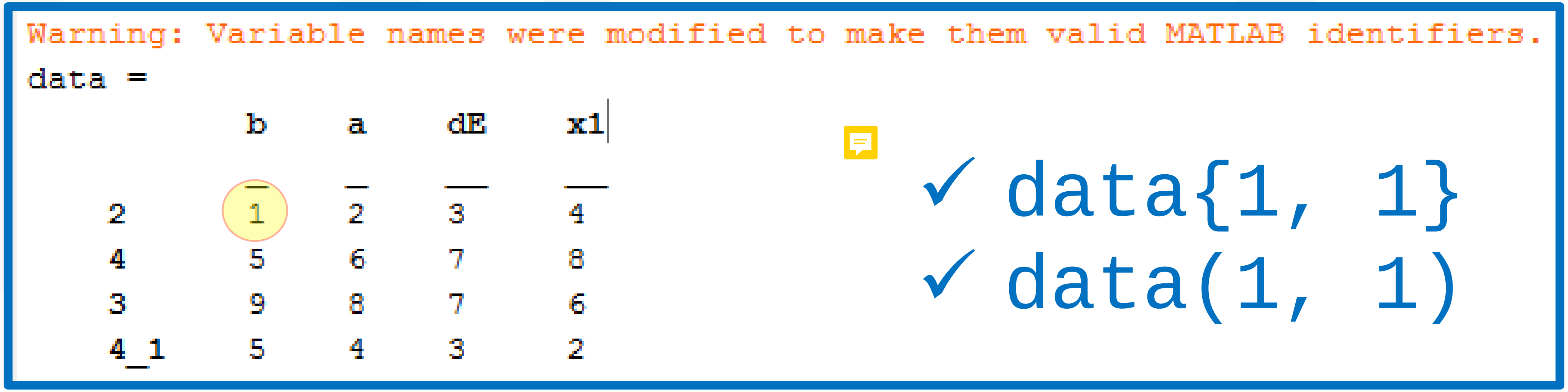
DataFrame ⇨ Number



```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =
                b     a     dE     x1
                _     _     __     __
    2           1     2     3      4
    4           5     6     7      8
    3           9     8     7      6
    4_1         5     4     3      2
```

✓ `data{1, 1}`

✓ `data(1, 1)`

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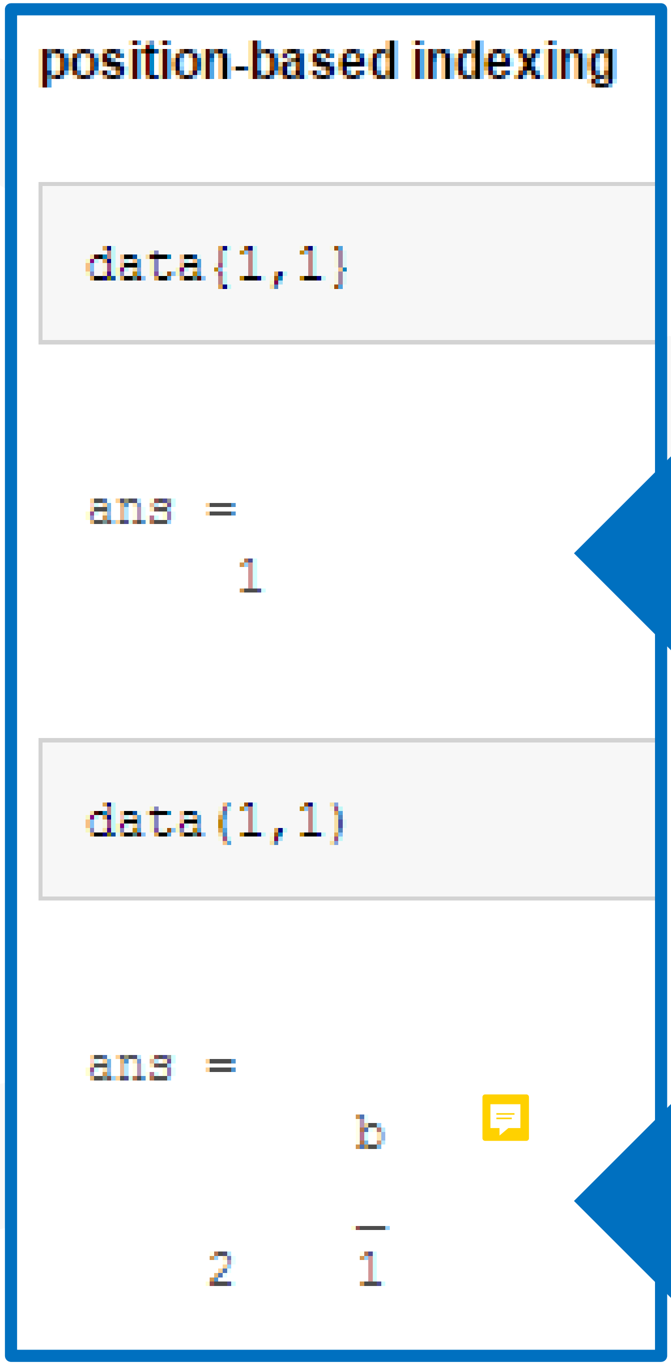

position-based indexing

```
data{1,1}
```

```
ans =
     1
```

```
data(1,1)
```

```
ans =
          b
          _
  2       1
```

1x1 **double**

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1x1 **table**

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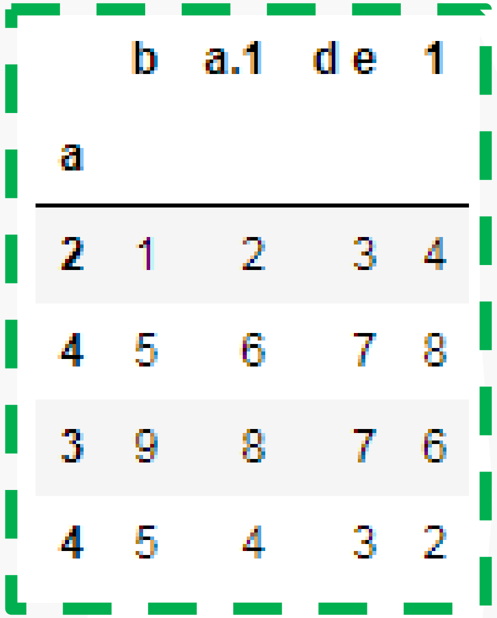
(continued)

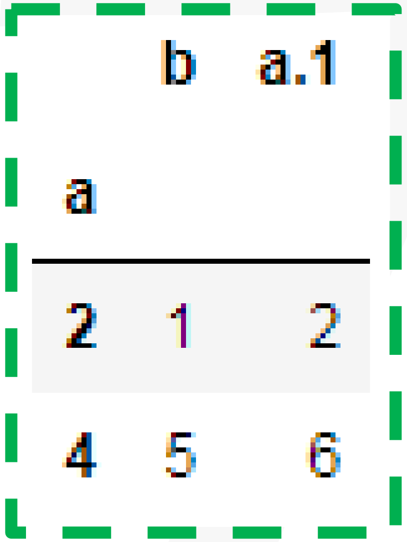
position-based slicing (1)



	b	a.1	d e	1
a				
2	1	2	3	4
4	5	6	7	8
3	9	8	7	6
4	5	4	3	2

data.iloc[0:2,0:2]

DataFrame⇨DataFrame



	b	a.1
a		
2	1	2
4	5	6

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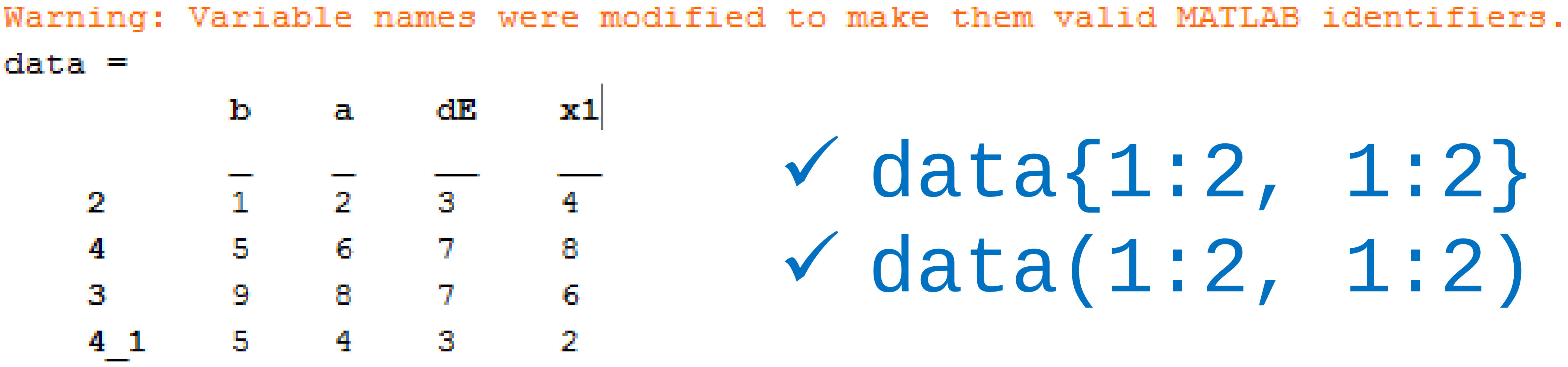

```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =
                b     a     dE     x1
                _     _     __     __
      2         1     2     3      4
      4         5     6     7      8
      3         9     8     7      6
      4_1       5     4     3      2
```

✓ data{1:2, 1:2}

✓ data(1:2, 1:2)

https://www.mathworks.com/help/matlab/matlab_prog/access-data-in-a-table.html

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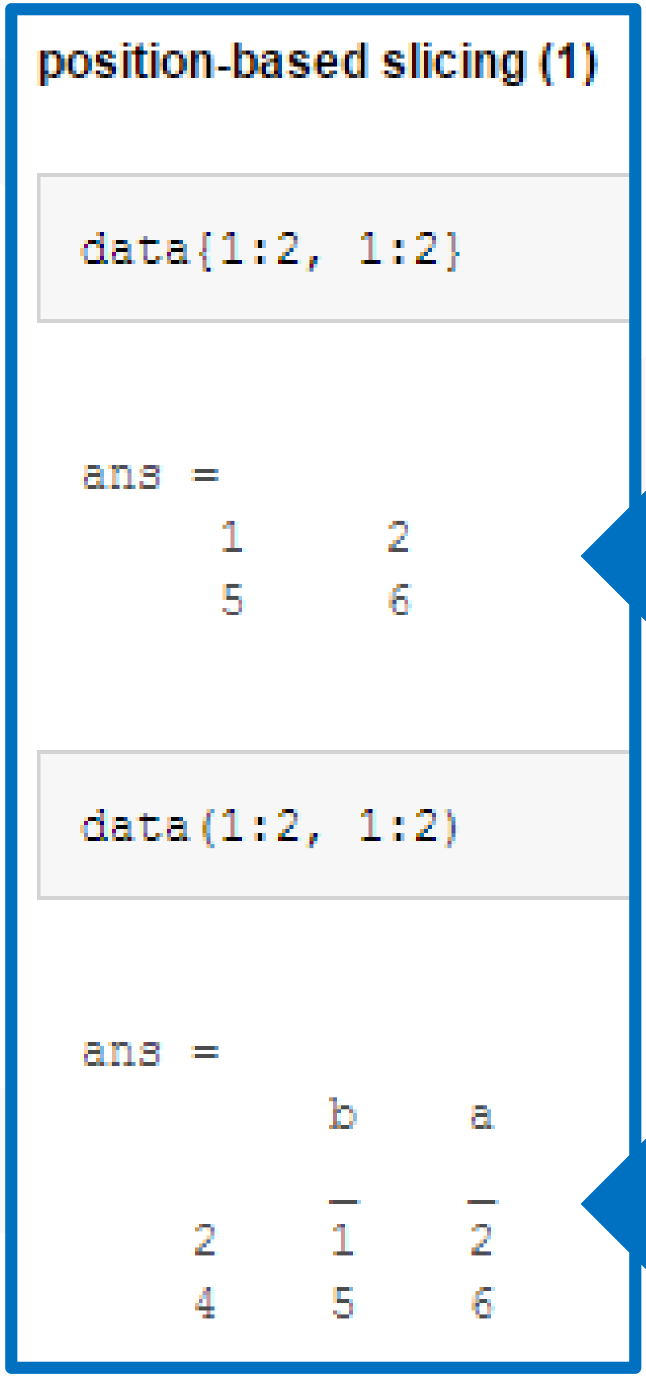

position-based slicing (1)

```
data{1:2, 1:2}
```

```
ans =

     1     2
     5     6
```

```
data(1:2, 1:2)
```

```
ans =

           b    a
           _    _

     2     1    2
     4     5    6
```

2x2 **double**

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2x2 **table**

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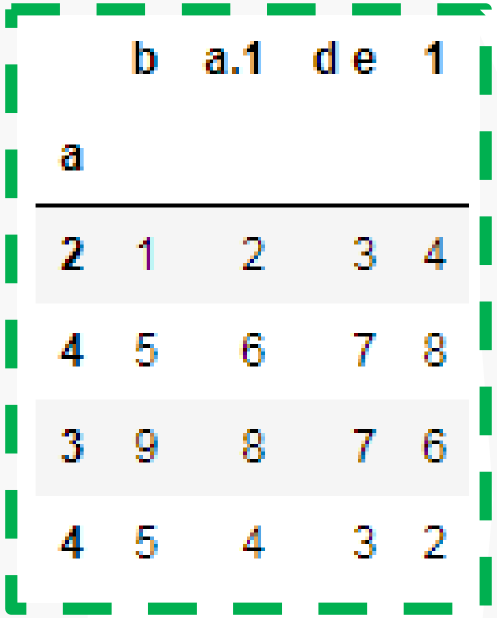
(continued)

position-based slicing (2)

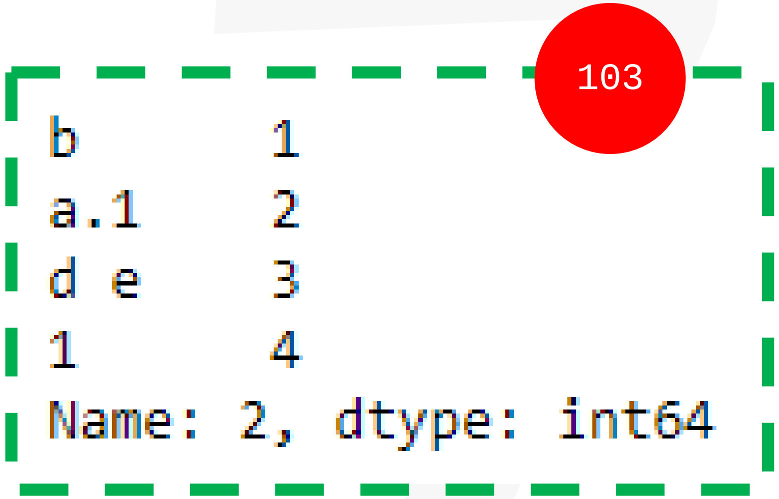


```
     b  a.1  d e  1
a
2    1  2    3    4
4    5  6    7    8
3    9  8    7    6
4    5  4    3    2
```

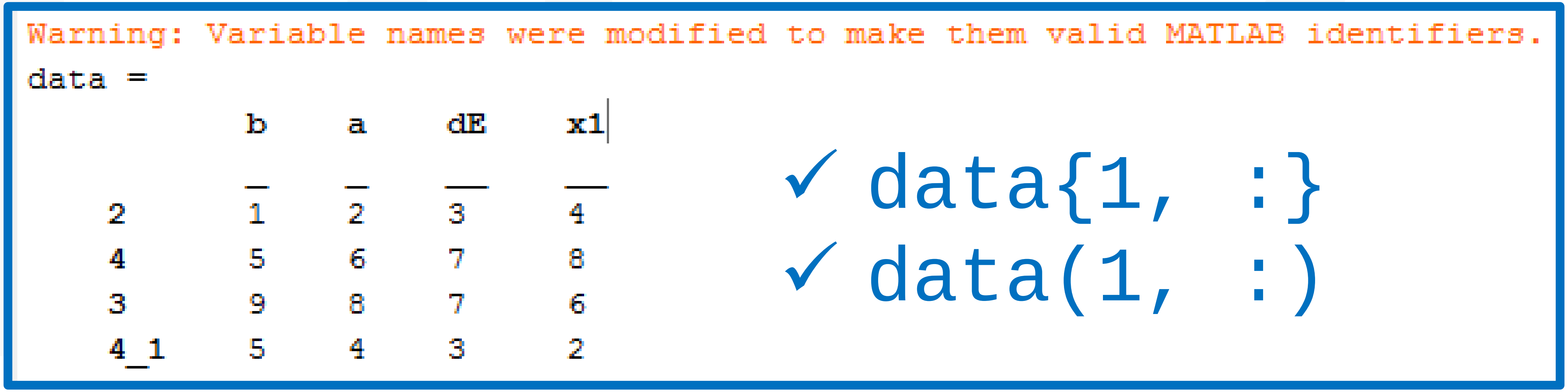
(the 1st row)

data.iloc[0,:]

DataFrame⇨Series



```
b       1
a.1     2
d e     3
1       4
Name: 2, dtype: int64
```



```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =
              b    a    dE    x1
              _    _    __    __
      2       1    2    3     4
      4       5    6    7     8
      3       9    8    7     6
      4_1     5    4    3     2
```

✓ data{1, :}

✓ data(1, :)

https://www.mathworks.com/help/matlab/matlab_prog/access-data-in-a-table.html

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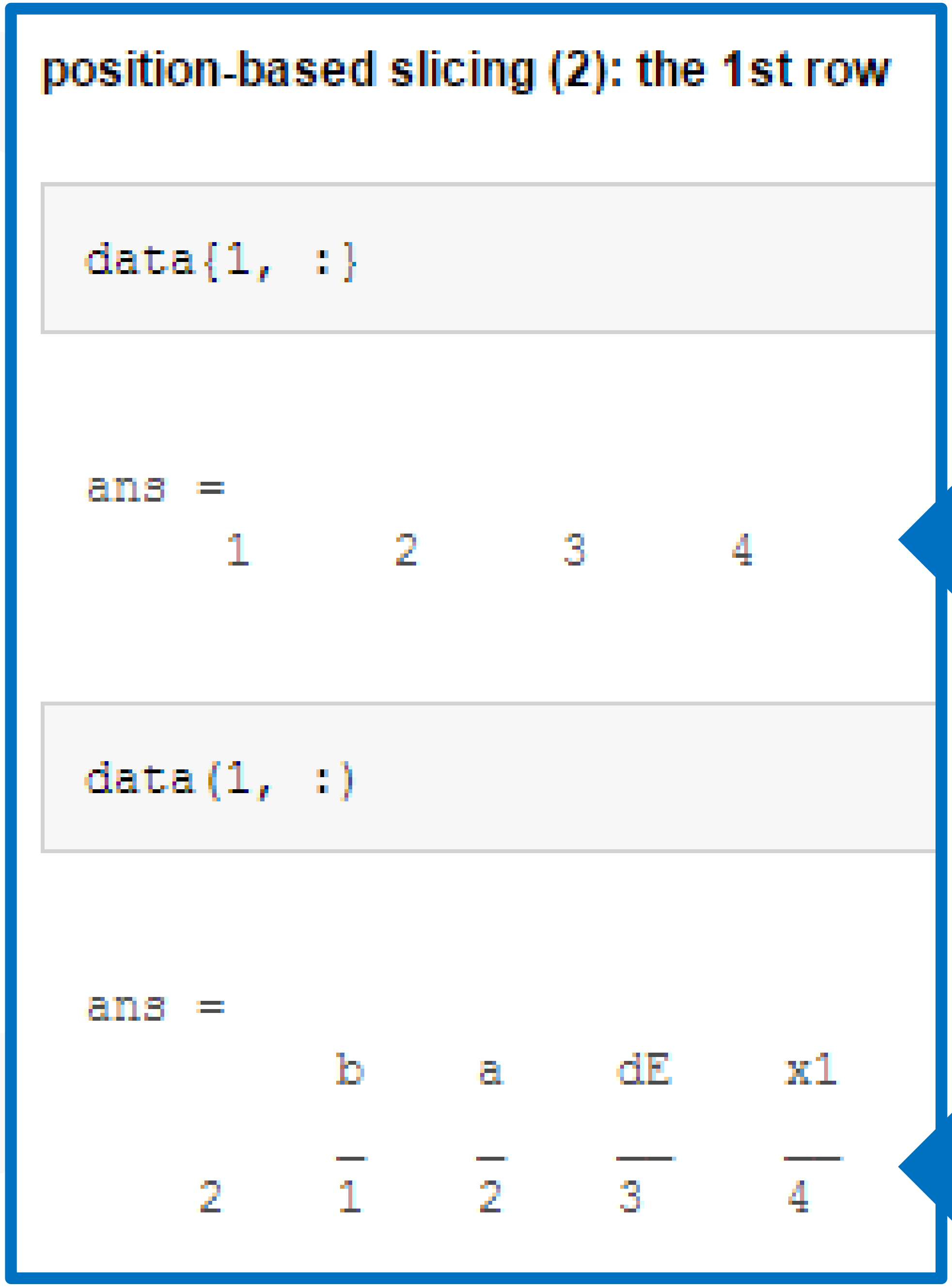

position-based slicing (2): the 1st row

```
data{1, :}
```

```
ans =

     1     2     3     4
```

```
data(1, :)
```

```
ans =

          b    a    dE    x1
          _    _    __    __
     2    1    2    3     4
```

1x4 **double**

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1x4 **table**

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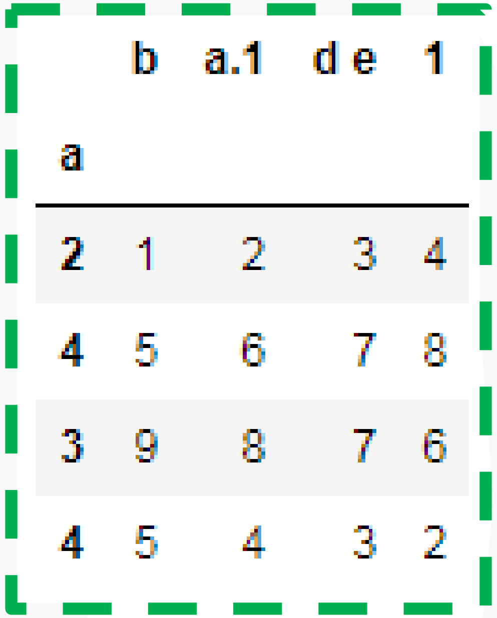
(continued)

position-based slicing (3)

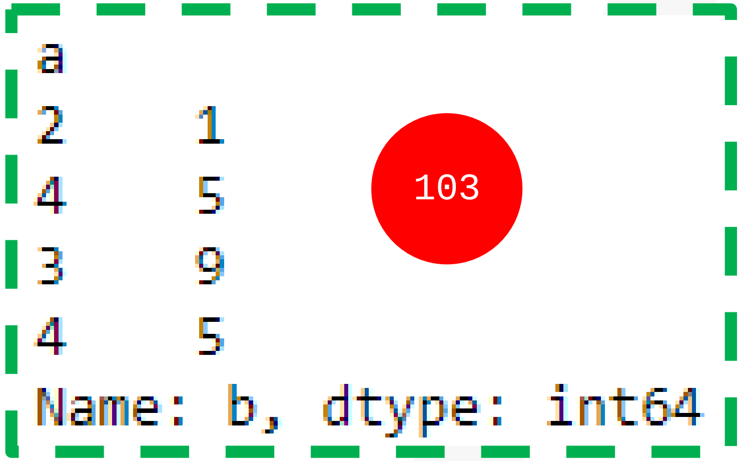


```
     b  a.1  d e  1
a
2    1  2    3    4
4    5  6    7    8
3    9  8    7    6
4    5  4    3    2
```

(the 1st column)

data.iloc[:,0]

DataFrame⇨Series



```
a
2      1
4      5
3      9
4      5
Name: b, dtype: int64
```

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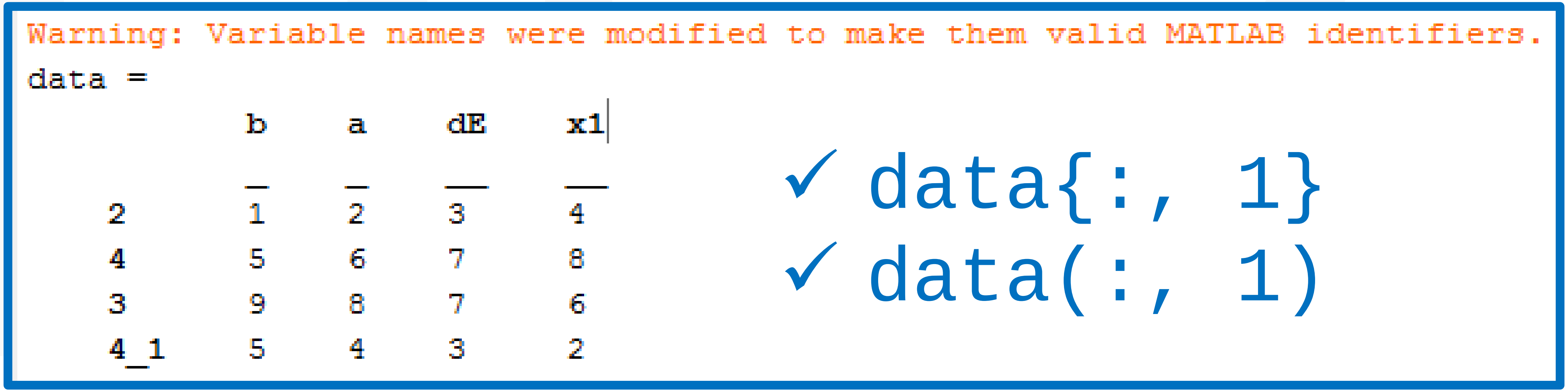

```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =
               b     a     dE     x1
               _     _     __     __
    2          1     2     3      4
    4          5     6     7      8
    3          9     8     7      6
    4_1        5     4     3      2
```

✓ data{:, 1}

✓ data(:, 1)

https://www.mathworks.com/help/matlab/matlab_prog/access-data-in-a-table.html

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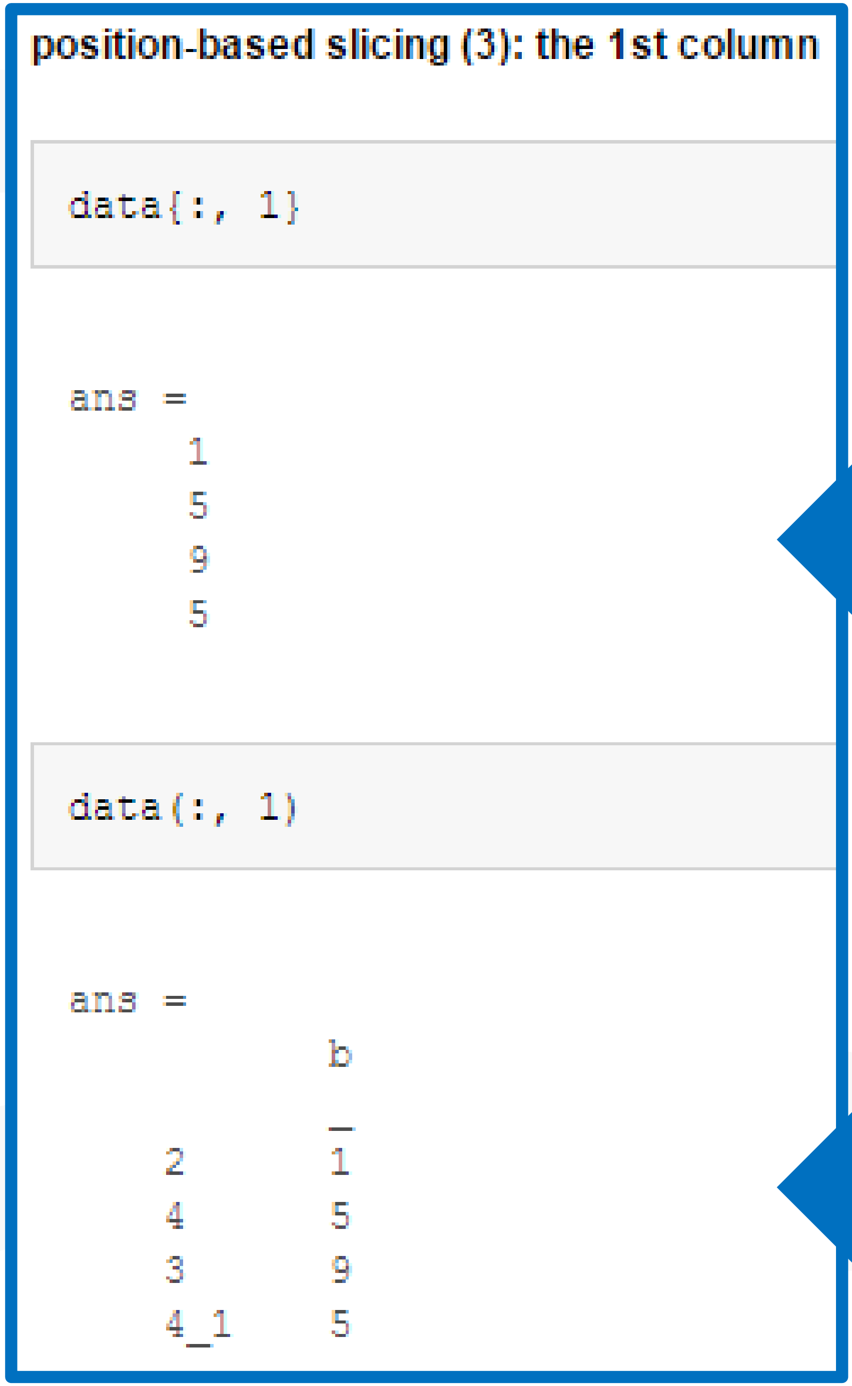

position-based slicing (3): the 1st column

```
data{:, 1}
```

```
ans =
      1
      5
      9
      5
```

```
data(:, 1)
```

```
ans =
              b
              _
    2         1
    4         5
    3         9
    4_1       5
```

4x1 **double**

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4x1 **table**

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Assume the table consists of numbers only.

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data.values ⇔ **data{:, :}**

⇨ Numpy 2D ndarray

⇨ 2D array

data.Variables

R2018a

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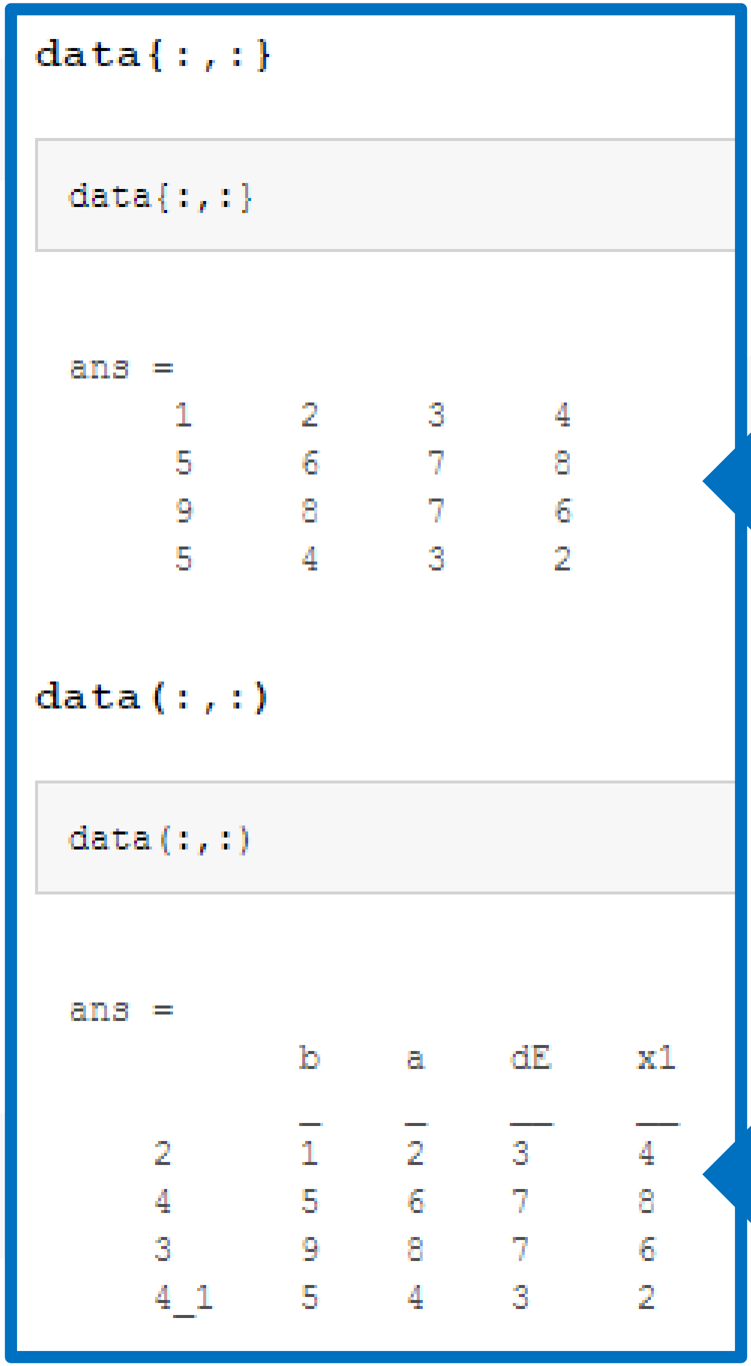

data{:,:}

```
data{:,:}
```

```
ans =

     1     2     3     4
     5     6     7     8
     9     8     7     6
     5     4     3     2
```

data(:,:)

```
data(:,:)
```

```
ans =

             b    a    dE    x1
             _    _    __    __

    2        1    2    3     4
    4        5    6    7     8
    3        9    8    7     6
    4_1      5    4    3     2
```

4x4 **double**

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4x4 **table**

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Slide
185/307

(continued)

position-based fancy indexing

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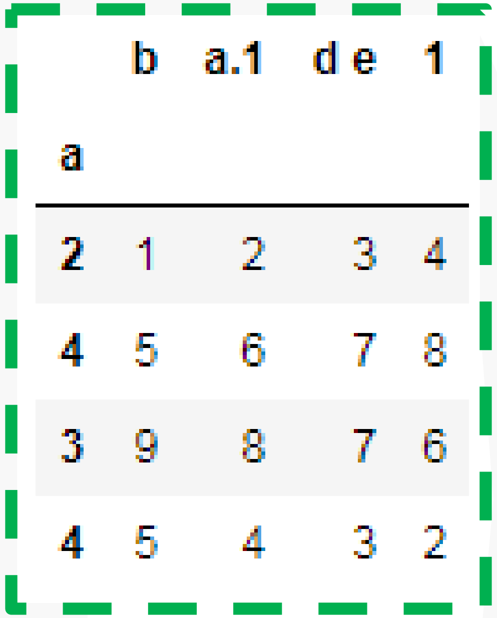
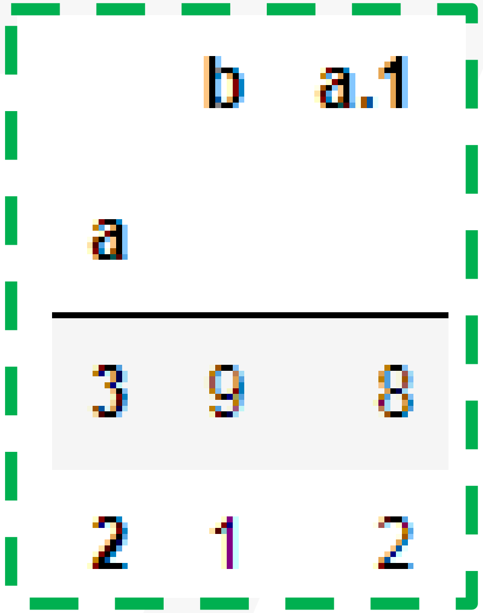


a	b	a.1	d e	1
2	1	2	3	4
4	5	6	7	8
3	9	8	7	6
4	5	4	3	2

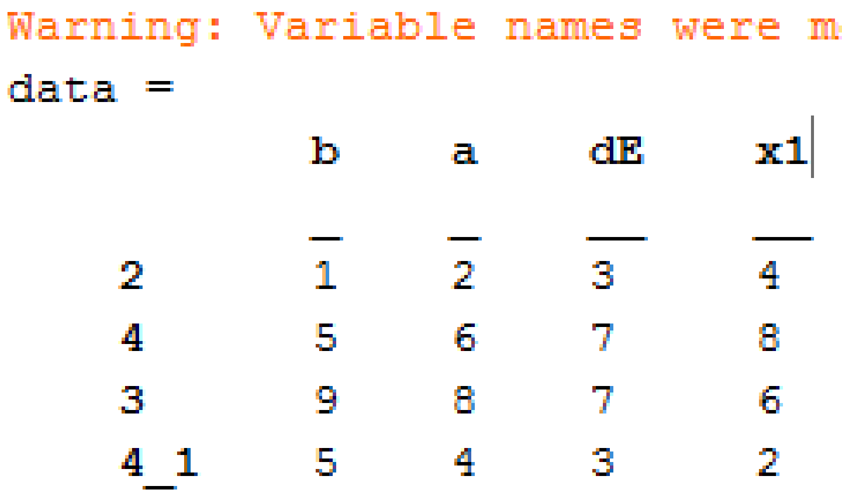
data.iloc[[2,0],[0,1]]

DataFrame⇨DataFrame



a	b	a.1
3	9	8
2	1	2

(Dr. Z: Fancy indexing is similar to slicing.)



```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =

                b     a     dE     x1
               _     _     __     __
       2       1     2     3      4
       4       5     6     7      8
       3       9     8     7      6
       4_1     5     4     3      2
```

✓ data{[3 1], [1 2]}

✓ data([3 1], [1 2])

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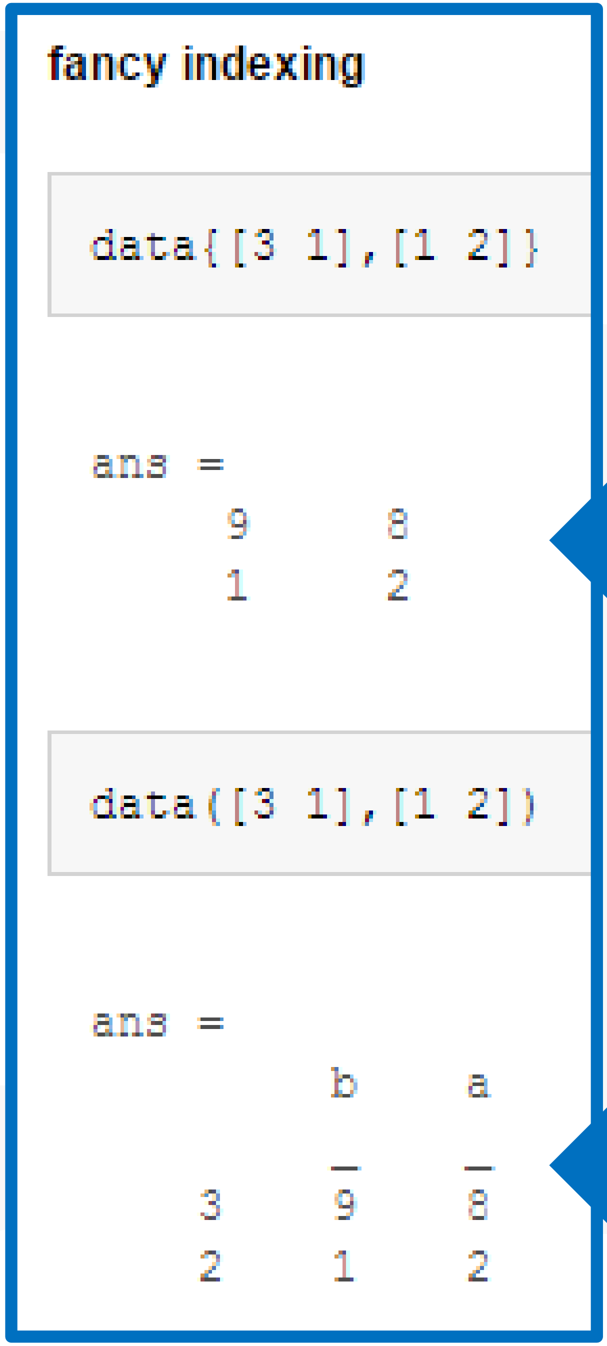

fancy indexing

```
data{[3 1],[1 2]}
```

```
ans =
         9         8
         1         2
```

```
data([3 1],[1 2])
```

```
ans =
              b         a
              _         _
       3      9         8
       2      1         2
```

2x2 **double**

2x2 **table**

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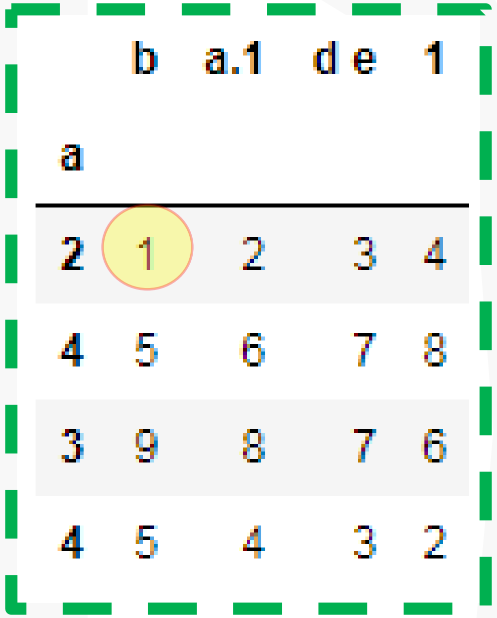
HT003: Use an appropriate **label-based indexing/slicing** method to select data in **`data`**.



```
   b  a.1  d e  1
a
2  1   2    3   4
4  5   6    7   8
3  9   8    7   6
4  5   4    3   2
```

✓ `data.loc[2,'b']`
✓ `data['b'][2]`
× `data[2,'b']`

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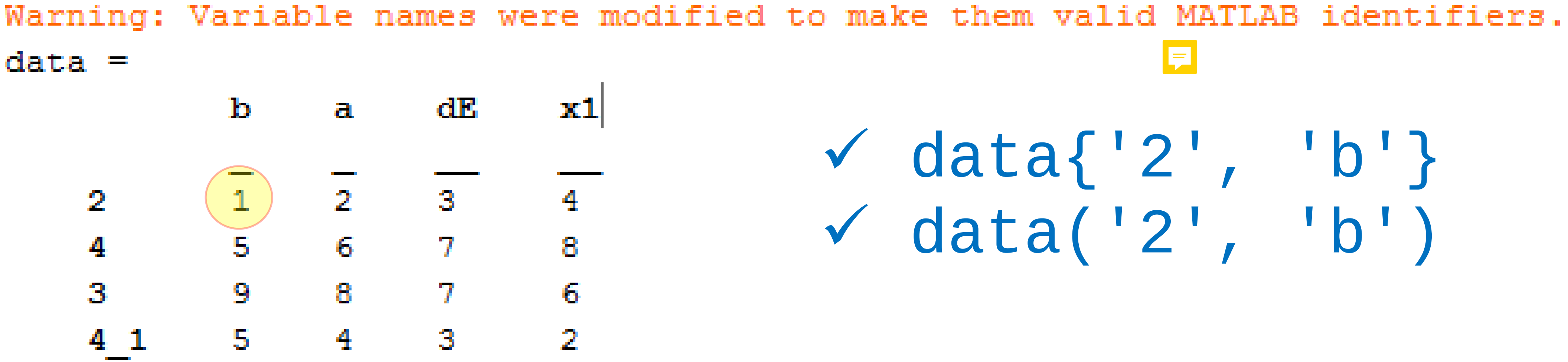
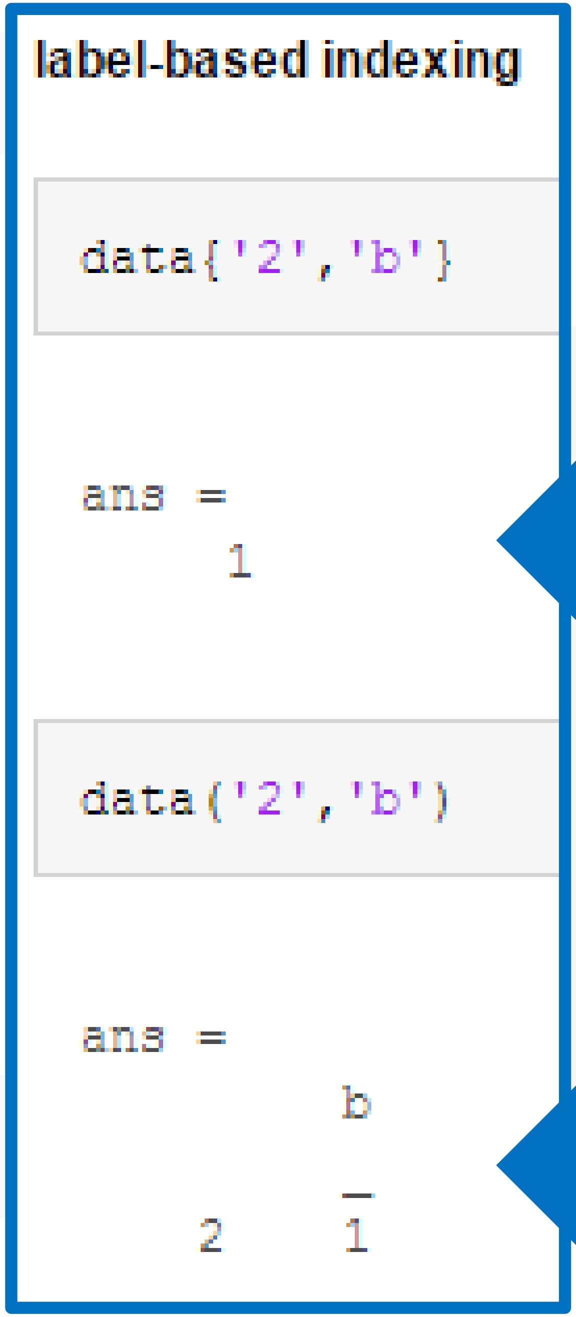


```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =
            b    a    dE    x1
            _    _    __    __
    2       1    2    3     4
    4       5    6    7     8
    3       9    8    7     6
    4_1     5    4    3     2
```

✓ `data{'2', 'b'}`
✓ `data('2', 'b')`



label-based indexing

```
data{'2','b'}

ans =

     1

data('2','b')

ans =

            b
            _

     2      1
```

1x1 **double**

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1x1 **table**

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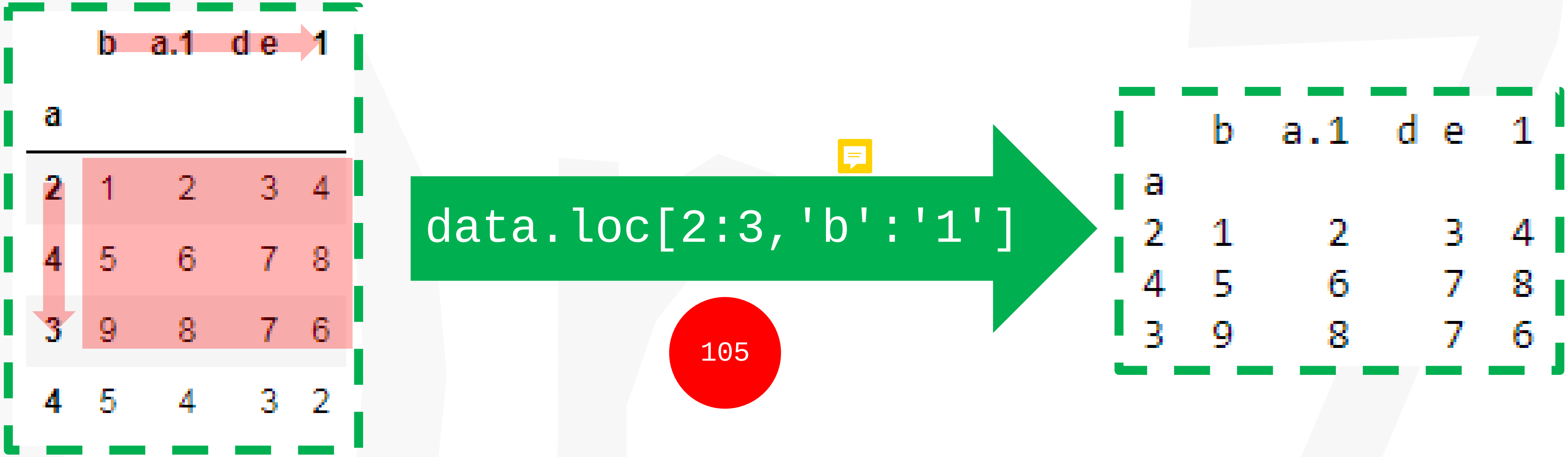
(continued)

label-based slicing (1)



```
   b  a.1  d e  1
a
2  1   2   3  4
4  5   6   7  8
3  9   8   7  6
4  5   4   3  2
```

data.loc[2:3,'b':'1']

```
    b   a.1   d e   1
a
2   1     2     3   4
4   5     6     7   8
3   9     8     7   6
```

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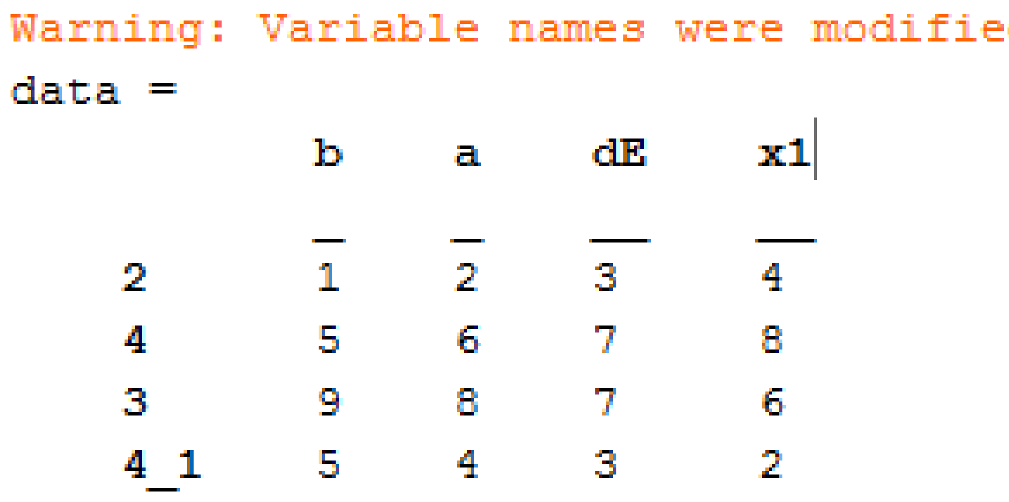


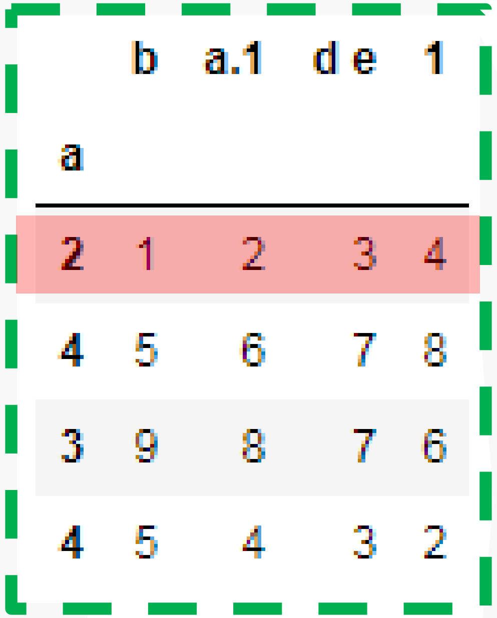
```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =

          b     a     dE     x1
          _     _     __     __

  2       1     2     3      4
  4       5     6     7      8
  3       9     8     7      6
  4_1     5     4     3      2
```

https://www.mathworks.com/help/matlab/matlab_prog/access-data-in-a-table.html

(continued)

label-based slicing (2)

(row with label 2)



```
   b  a.1  d e  1
a
2  1   2    3   4
4  5   6    7   8
3  9   8    7   6
4  5   4    3   2
```

data.loc[2,:]

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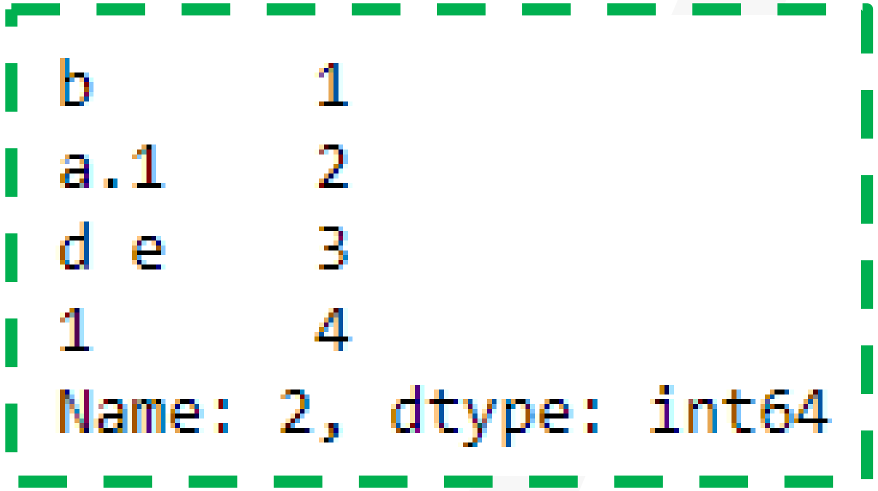
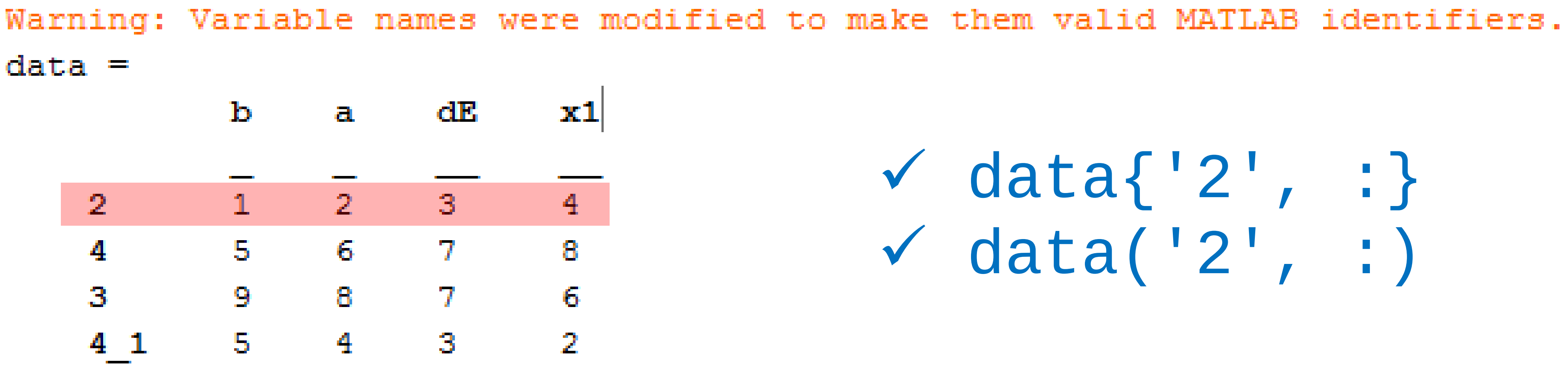


```
b        1
a.1      2
d e      3
1        4
Name: 2, dtype: int64
```



```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =
              b     a     dE     x1
              _     _     __     __
    2         1     2     3      4
    4         5     6     7      8
    3         9     8     7      6
    4_1       5     4     3      2
```

✓ data{'2', :}
✓ data('2', :)

https://www.mathworks.com/help/matlab/matlab_prog/access-data-in-a-table.html

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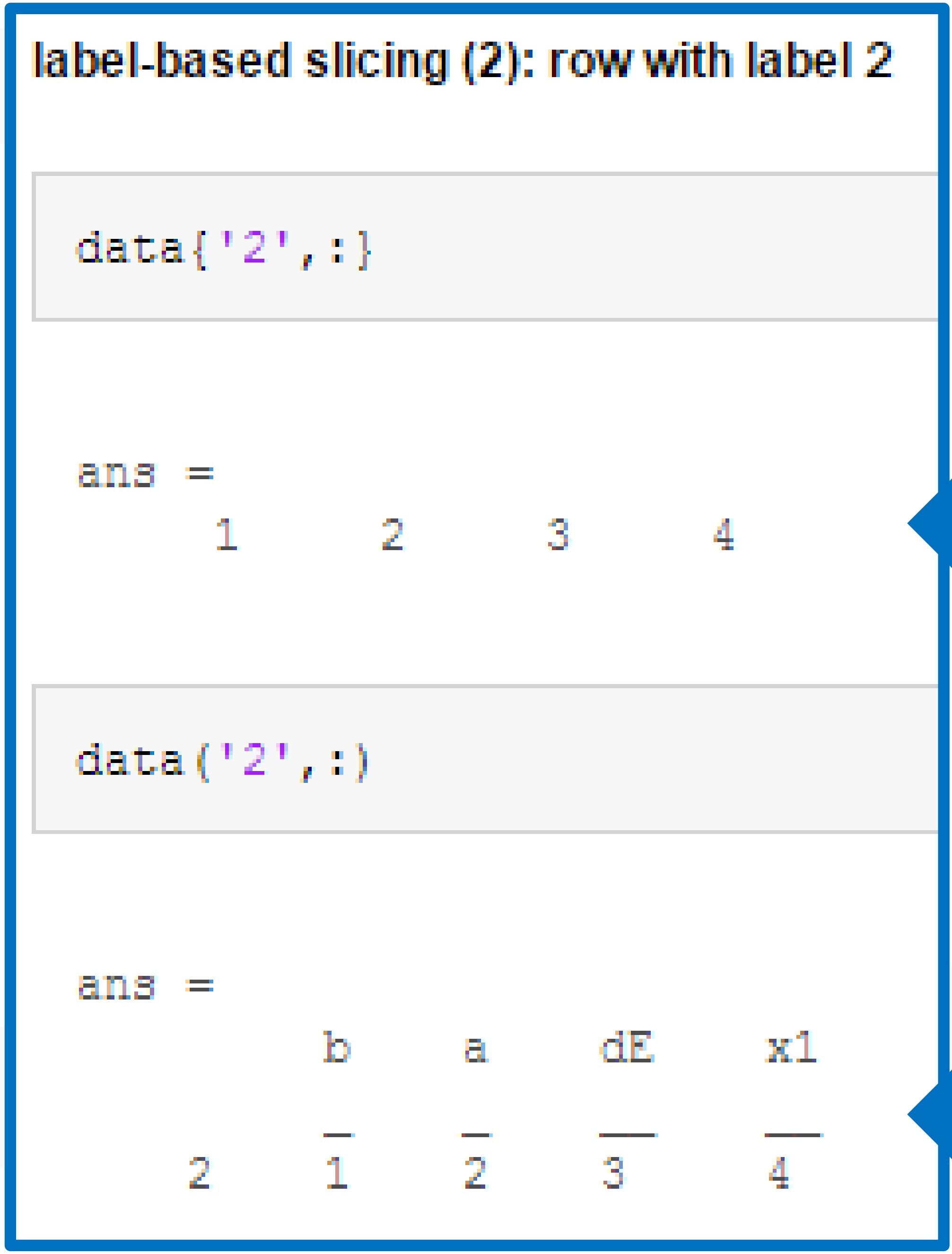

label-based slicing (2): row with label 2

```
data{'2',:}
```

```
ans =
        1         2         3         4
```

```
data('2',:)
```

```
ans =
            b       a       dE       x1
            _       _       __       __
     2      1       2       3        4
```

1x4 **double**

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1x4 **table**

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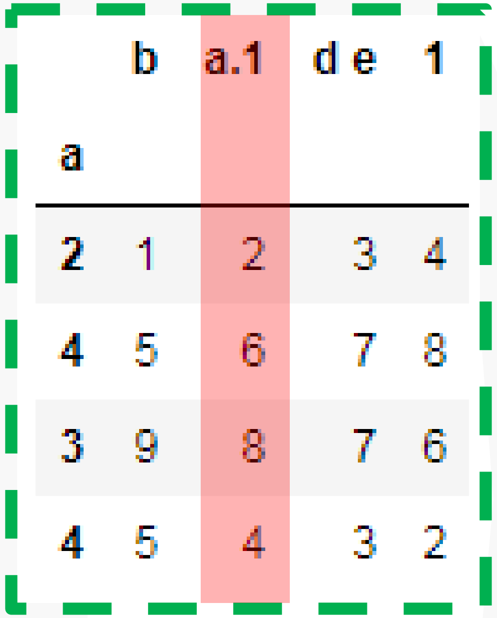
(continued)

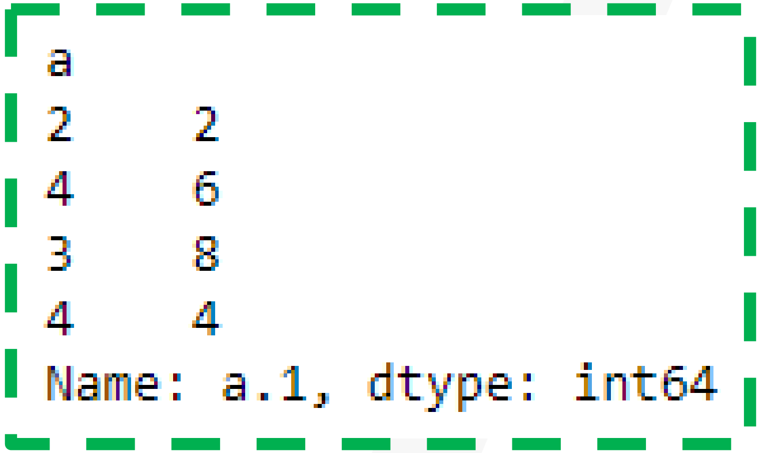
label-based slicing (3)

(column with label a.1)



	b	a.1	d e	1
a				
2	1	2	3	4
4	5	6	7	8
3	9	8	7	6
4	5	4	3	2

`data.loc[:, 'a.1']`



```
a
2     2
4     6
3     8
4     4
Name: a.1, dtype: int64
```

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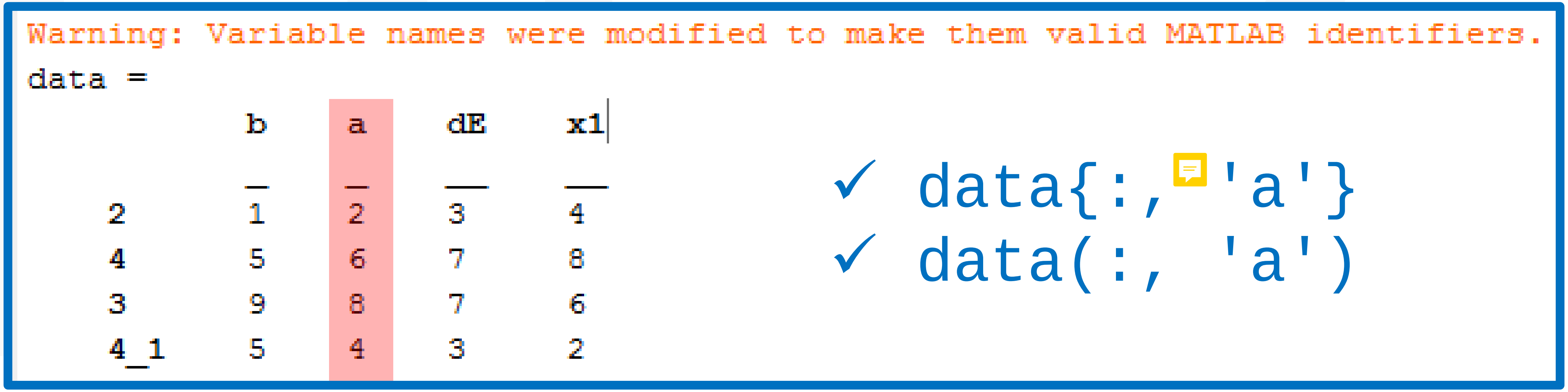

```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =

                b     a     dE     x1
                _     _     __     __
    2           1     2     3      4
    4           5     6     7      8
    3           9     8     7      6
    4_1         5     4     3      2
```

✓ `data{:,'a'}`

✓ `data(:, 'a')`

https://www.mathworks.com/help/matlab/matlab_prog/access-data-in-a-table.html

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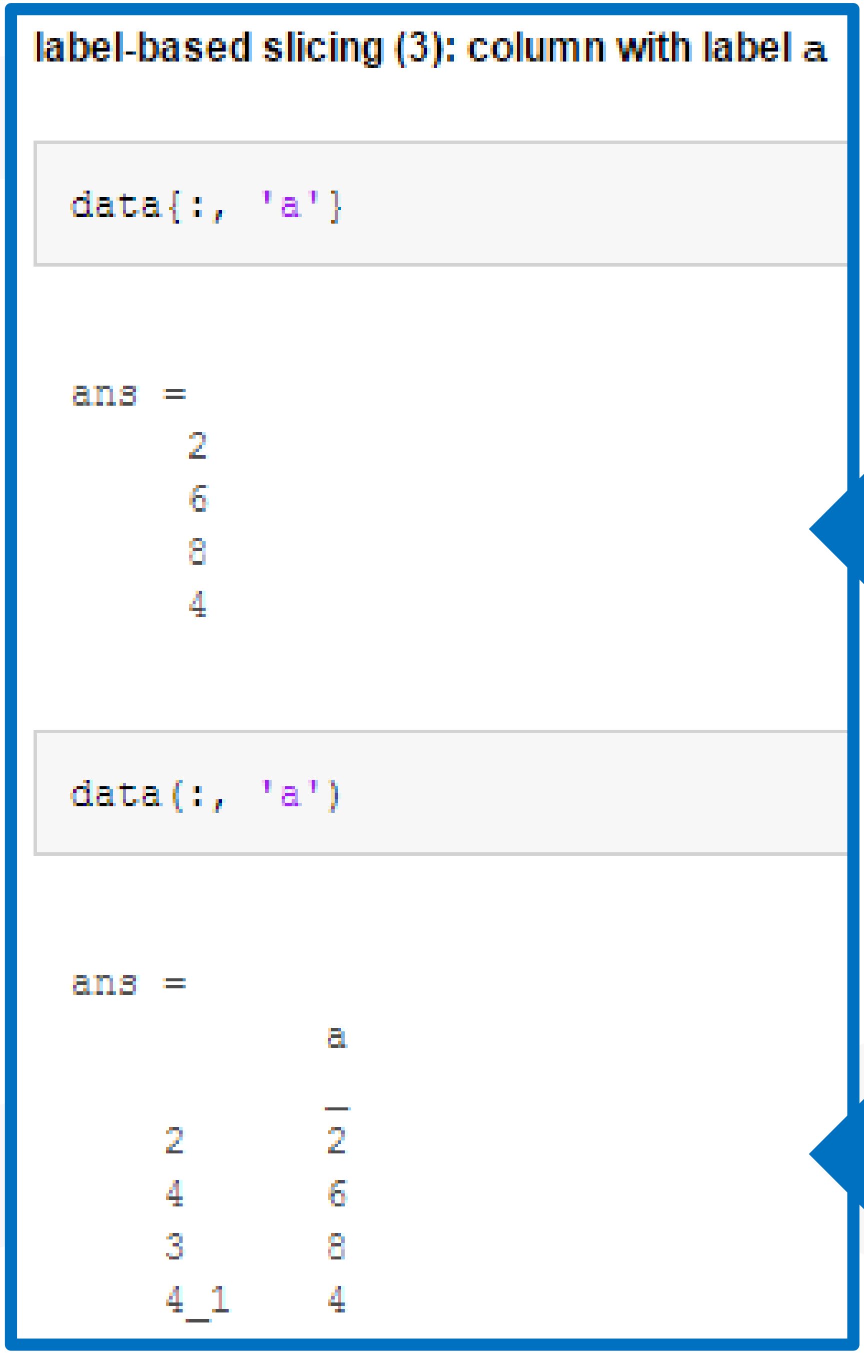

label-based slicing (3): column with label a

```
data{:, 'a'}
```

```
ans =
      2
      6
      8
      4
```

```
data(:, 'a')
```

```
ans =
                 a
                 _
    2            2
    4            6
    3            8
    4_1          4
```

4x1 **double**

4x1 **table**

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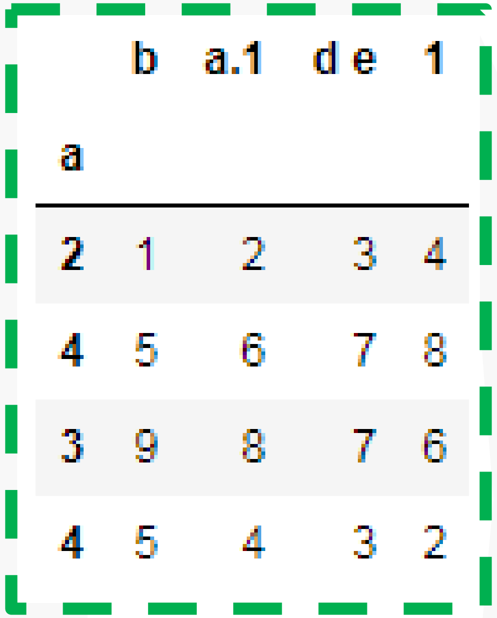
(continued)

label-based fancy indexing



a	b	a.1	d e	1
2	1	2	3	4
4	5	6	7	8
3	9	8	7	6
4	5	4	3	2

`data.loc[[2,3],['b','1']]`

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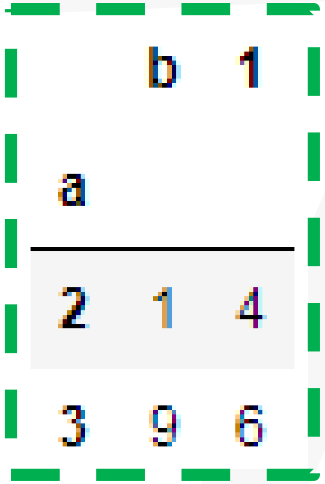
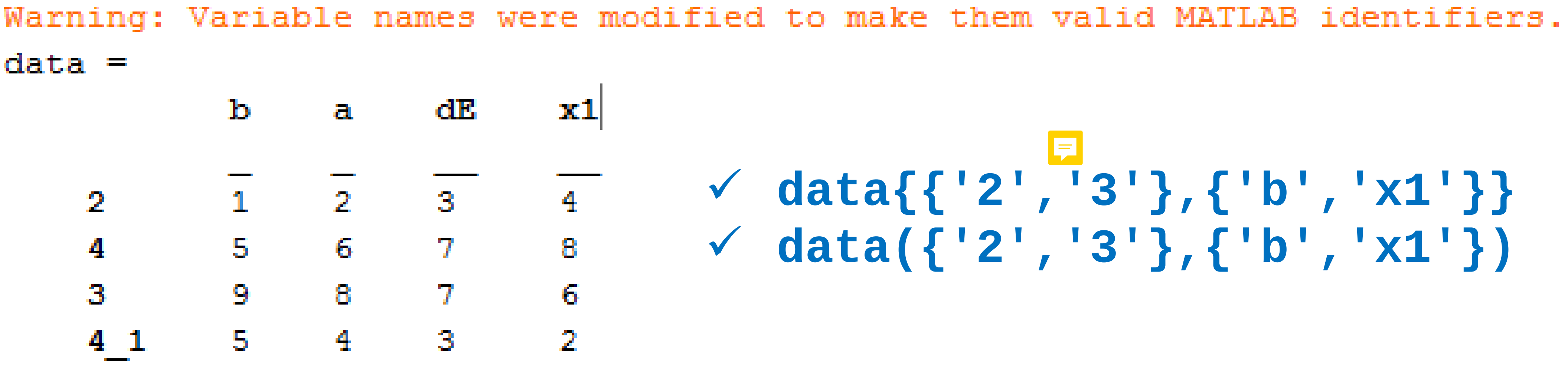


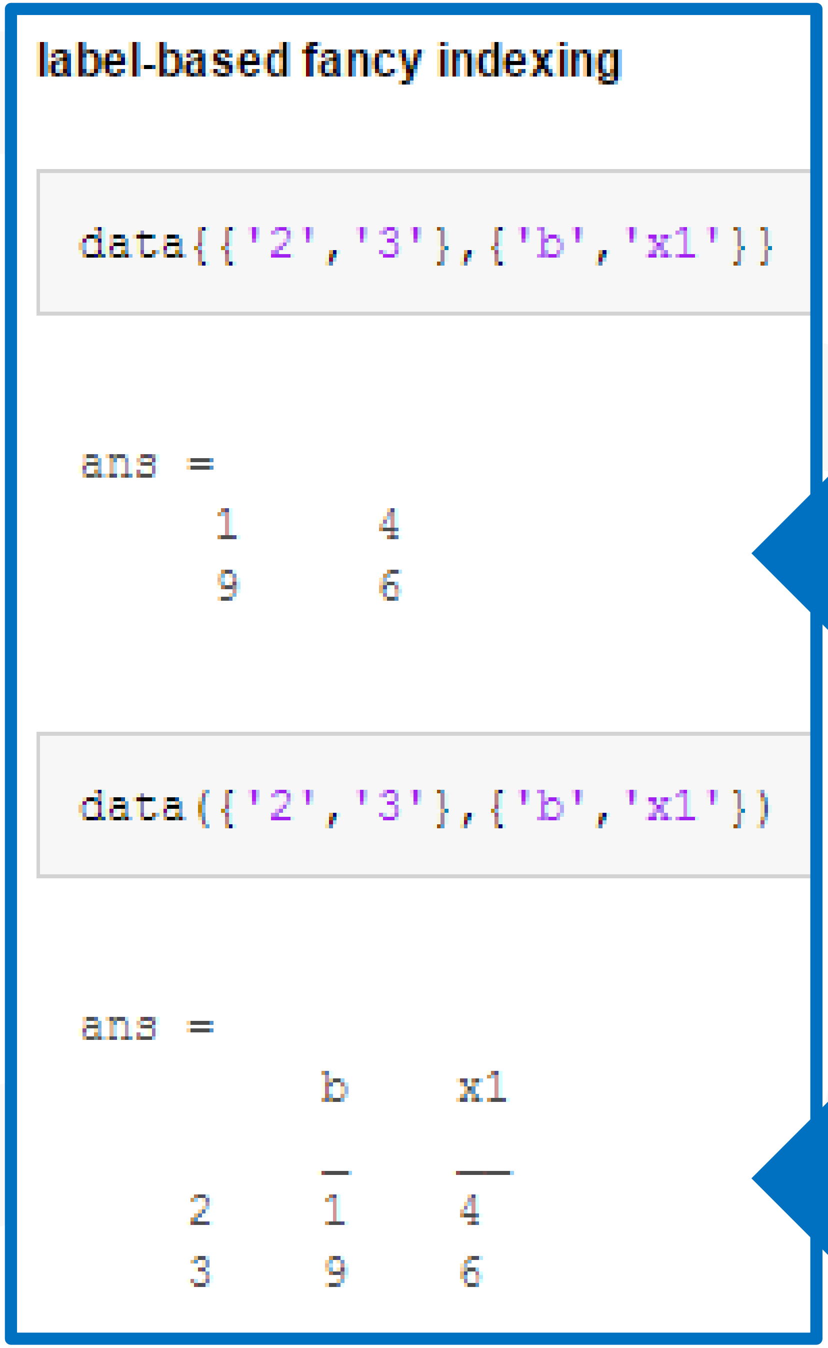
a	b	1
2	1	4
3	9	6



```
Warning: Variable names were modified to make them valid MATLAB identifiers.
data =
                 b        a        dE        x1
                 _        _        __        __
     2           1        2        3         4
     4           5        6        7         8
     3           9        8        7         6
     4_1         5        4        3         2
```

✓ `data{{'2','3'},{'b','x1'}}`
✓ `data({'2','3'},{'b','x1'})`

https://www.mathworks.com/help/matlab/matlab_prog/access-data-in-a-table.html



label-based fancy indexing

```
data{{'2','3'},{'b','x1'}}
```

```
ans =

     1     4
     9     6
```

```
data({'2','3'},{'b','x1'})
```

```
ans =

          b    x1
          _    __

    2     1    4
    3     9    6
```

2x2 **double**

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2x2 **table**

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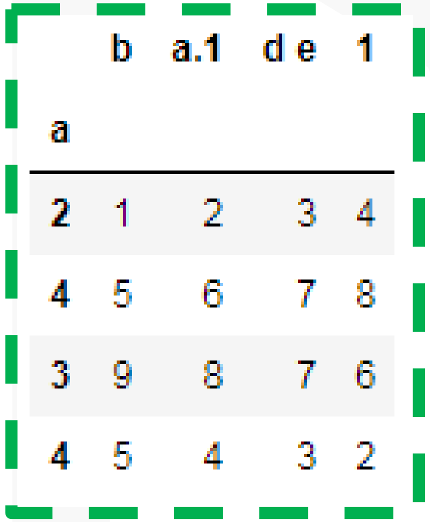
HT004: Use one command to add a column to **data** with a specific name.

1. a number
2. an iterable
3. A Numpy array
4. a Series
5. a DataFrame



	b	a.1	d e	1
a				
2	1	2	3	4
4	5	6	7	8
3	9	8	7	6
4	5	4	3	2

```
✓ data['f1']=1
✓ data.loc[:,'f1']=1
```

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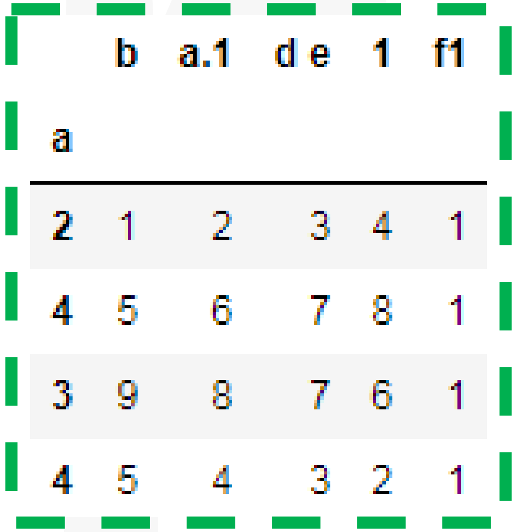
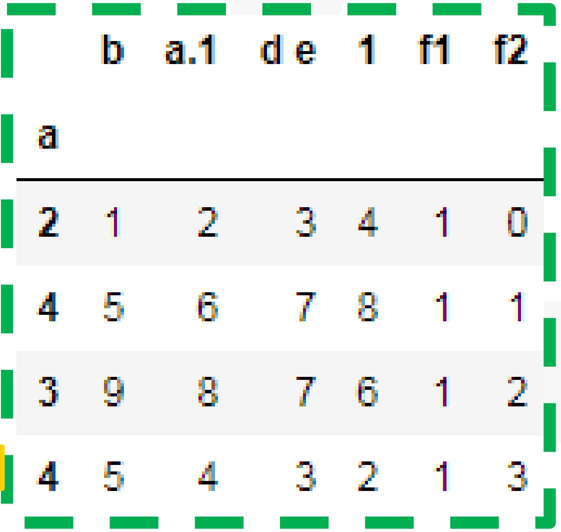


	b	a.1	d e	1	f1
a					
2	1	2	3	4	1
4	5	6	7	8	1
3	9	8	7	6	1
4	5	4	3	2	1

```
✓   data['f2']=range(4)
✓ data.loc[:,'f2']=range(4)
✓                 …=[0,1,2,3]
✓         …=[[0],[1],[2],[3]]
×              …=[[0,1,2,3]]
```



	b	a.1	d e	1	f1	f2
a						
2	1	2	3	4	1	0
4	5	6	7	8	1	1
3	9	8	7	6	1	2
4	5	4	3	2	1	3

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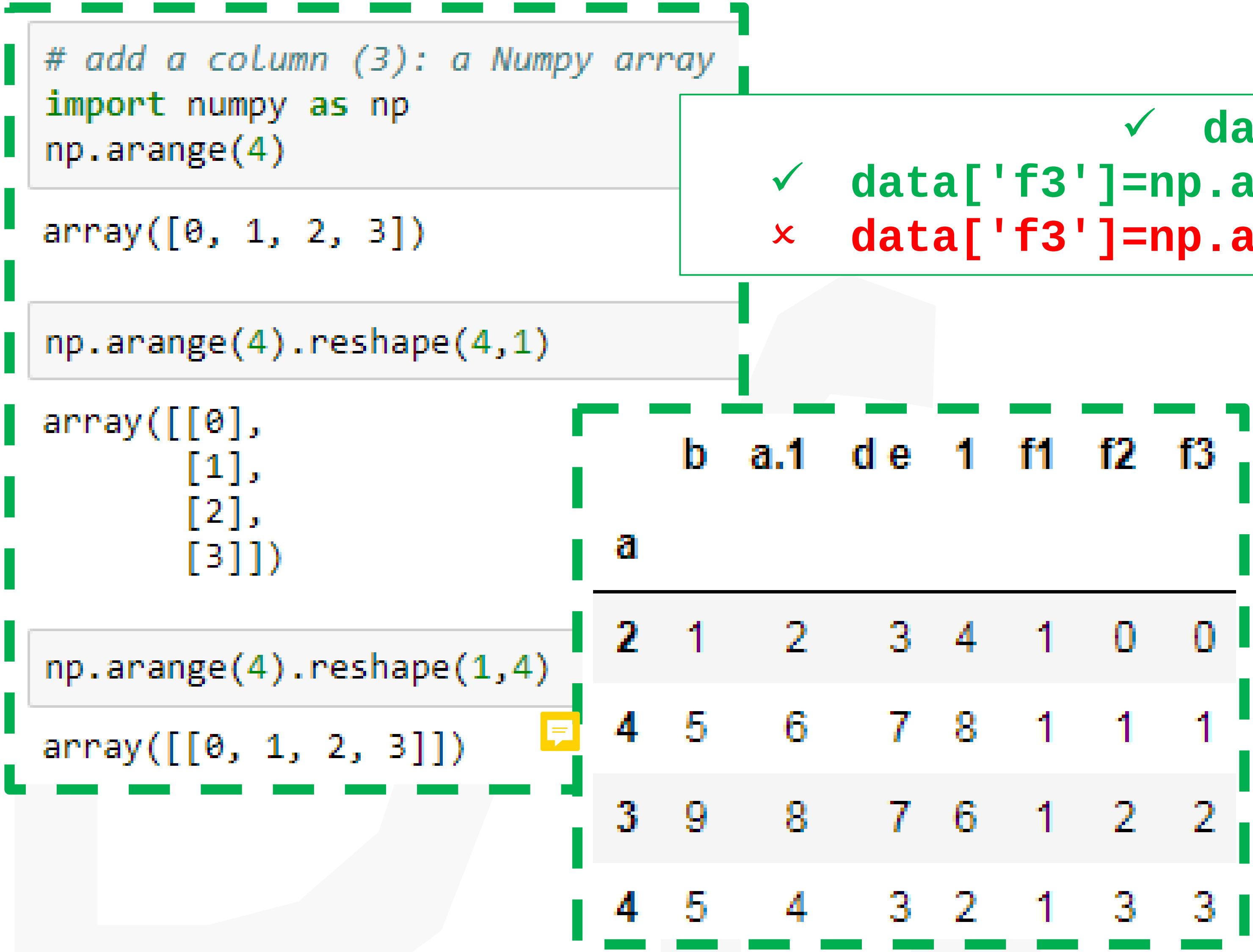

```
# add a column (3): a Numpy array
import numpy as np
np.arange(4)
```

```
array([0, 1, 2, 3])
```

```
np.arange(4).reshape(4,1)
```

```
array([[0],
       [1],
       [2],
       [3]])
```

```
np.arange(4).reshape(1,4)
```

```
array([[0, 1, 2, 3]])
```

	b	a.1	d e	1	f1	f2	f3
a							
2	1	2	3	4	1	0	0
4	5	6	7	8	1	1	1
3	9	8	7	6	1	2	2
4	5	4	3	2	1	3	3

✓ `data['f3']=np.arange(4)`

✓ `data['f3']=np.arange(4).reshape(4,1)`

× `data['f3']=np.arange(4).reshape(1,4)`

1D array or 2D column array

1. a number
2. an iterable
3. A Numpy array
4. a Series
5. a DataFrame

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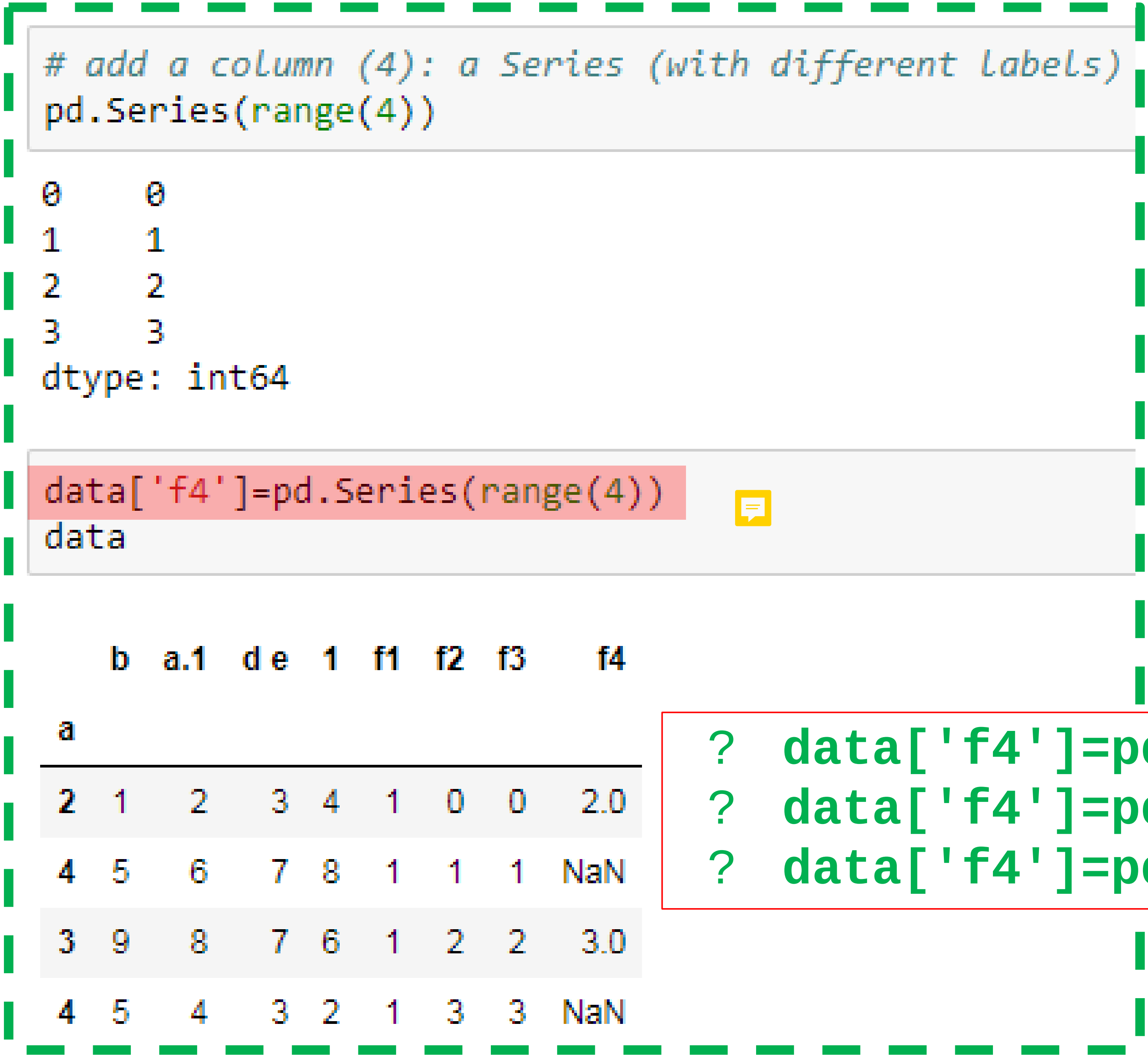

```
# add a column (4): a Series (with different labels)
pd.Series(range(4))
```

```
0    0
1    1
2    2
3    3
dtype: int64
```

```
data['f4']=pd.Series(range(4))
data
```

	b	a.1	d	e	1	f1	f2	f3	f4
a									
2	1	2		3	4	1	0	0	2.0
4	5	6		7	8	1	1	1	NaN
3	9	8		7	6	1	2	2	3.0
4	5	4		3	2	1	3	3	NaN

1. a number
2. an iterable
3. A Numpy array
4. a Series
5. a DataFrame

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```
? data['f4']=pd.Series(range(3))
? data['f4']=pd.Series(range(4))
? data['f4']=pd.Series(range(5))
```

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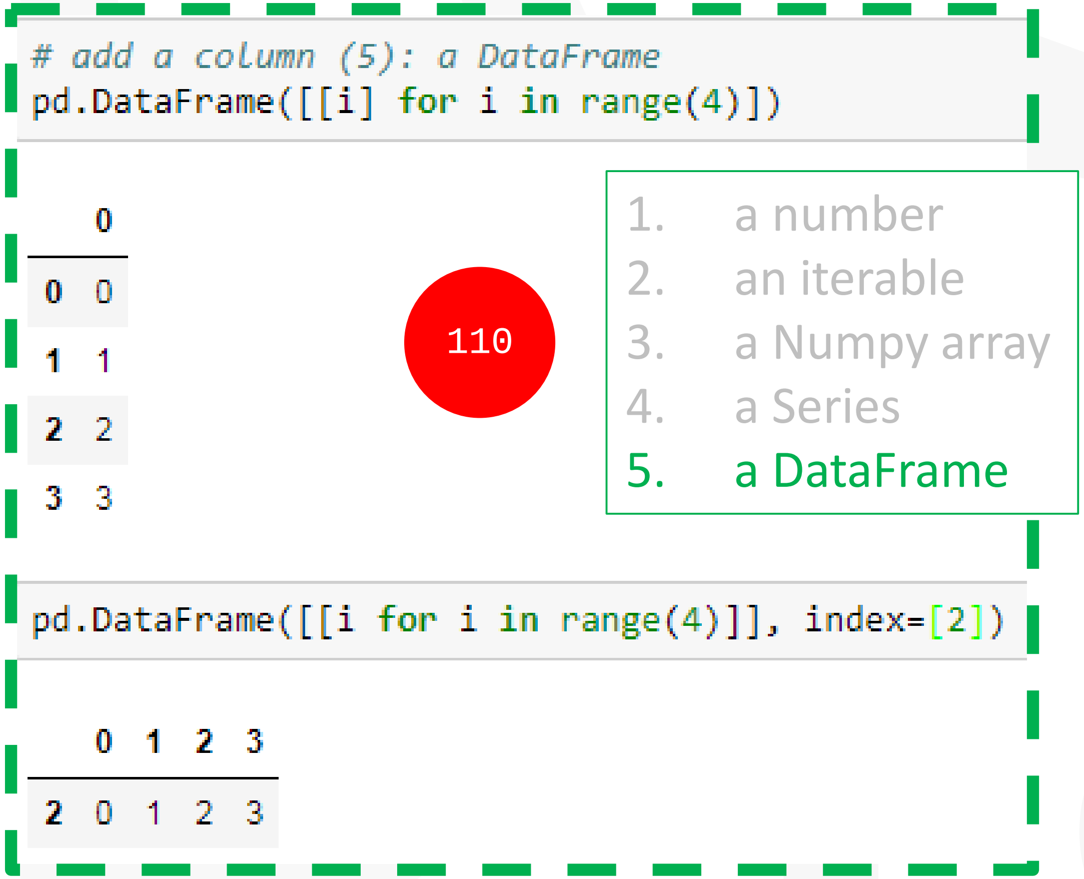
```
? data['f5']=pd.DataFrame([[i] for i in range(3)])
? data['f5']=pd.DataFrame([[i] for i in range(4)])
? data['f5']=pd.DataFrame([[i] for i in range(5)])
```



```
# add a column (5): a DataFrame
pd.DataFrame([[i] for i in range(4)])
```

```
   0
0  0
1  1
2  2
3  3
```

```
pd.DataFrame([[i for i in range(4)]], index=[2])
```

```
   0  1  2  3
2  0  1  2  3
```

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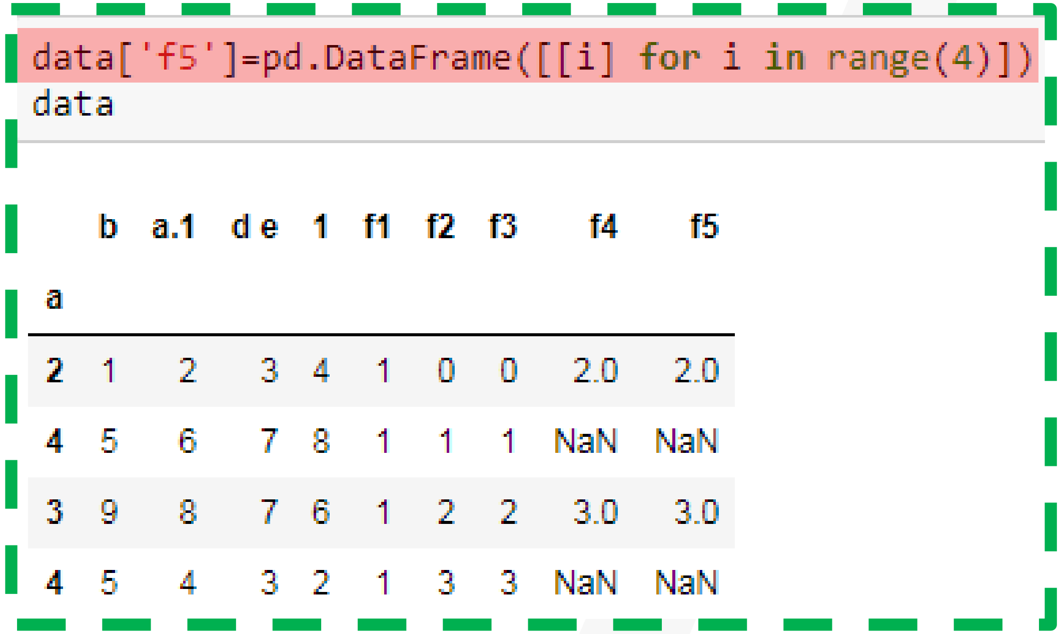
1. a number
2. an iterable
3. a Numpy array
4. a Series
5. a DataFrame



```
data['f5']=pd.DataFrame([[i] for i in range(4)])
data
```

```
   b  a.1  d  e  1  f1  f2  f3   f4   f5
a
2  1   2   3  4  1   0   0  2.0  2.0
4  5   6   7  8  1   1   1  NaN  NaN
3  9   8   7  6  1   2   2  3.0  3.0
4  5   4   3  2  1   3   3  NaN  NaN
```

So, how to assign a row’s value to a column in a DataFrame??

```
× data['f5']=pd.DataFrame([[i for i in range(4)]],index=[2])
```

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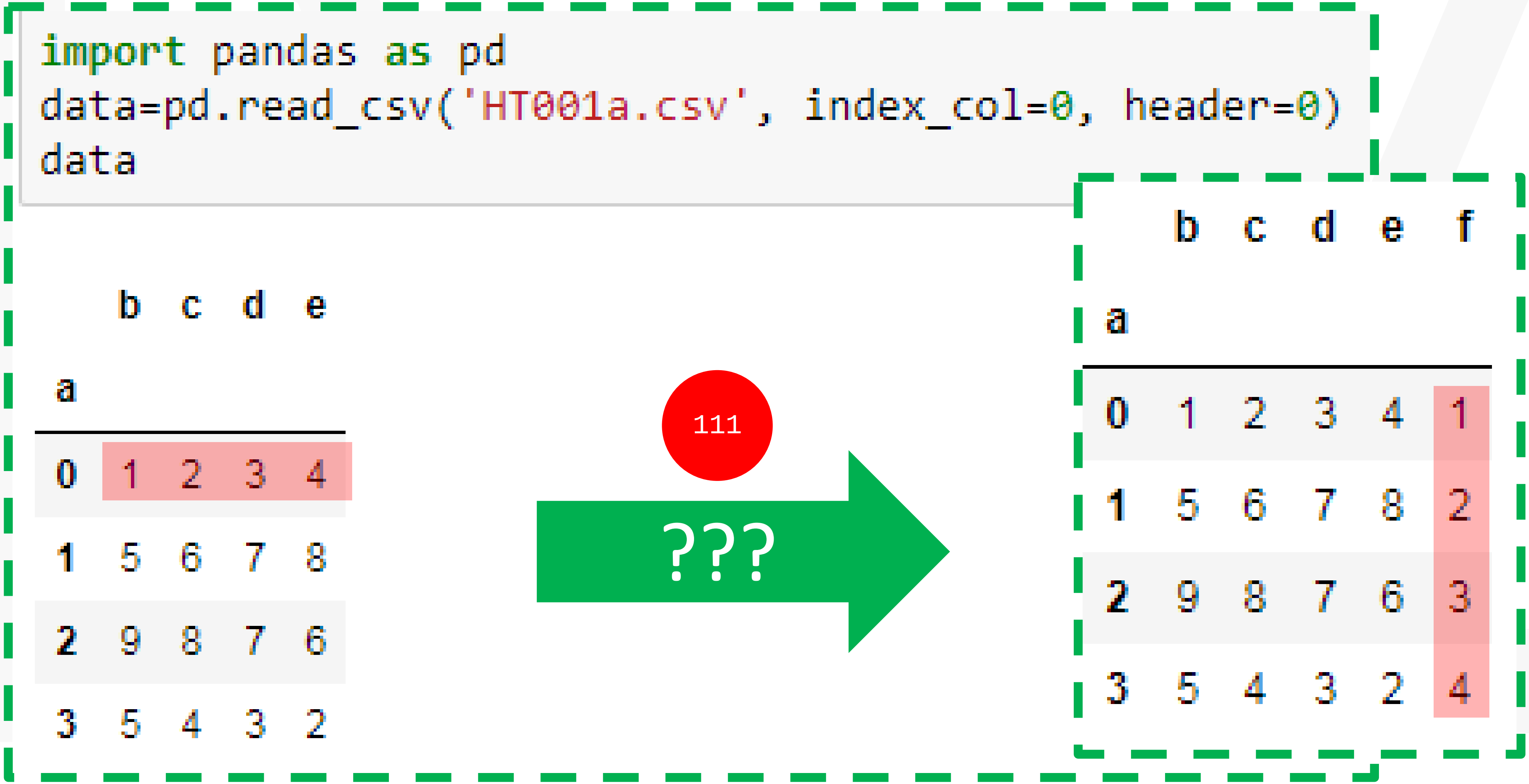
Homework: Use one command to add a column to **data**, using the first row of **data**, and name this column **f**.



```
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
data
```

	b	c	d	e
a				
0	1	2	3	4
1	5	6	7	8
2	9	8	7	6
3	5	4	3	2

	b	c	d	e	f
a					
0	1	2	3	4	1
1	5	6	7	8	2
2	9	8	7	6	3
3	5	4	3	2	4

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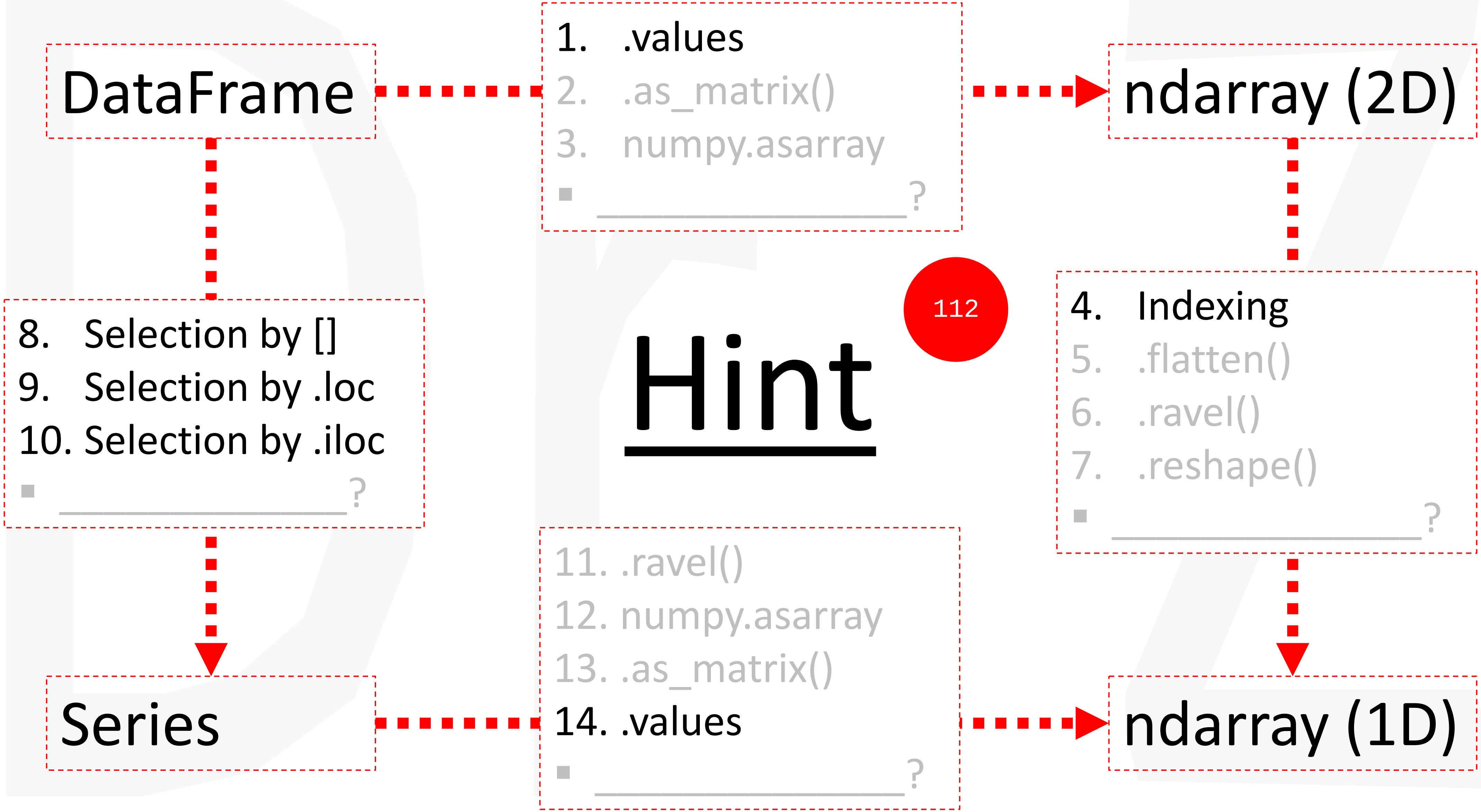

DataFrame

1. .values
2. .as_matrix()
3. numpy.asarray
▪ ________________?

ndarray (2D)

4. Indexing
5. .flatten()
6. .ravel()
7. .reshape()
▪ ________________?

8. Selection by []
9. Selection by .loc
10. Selection by .iloc
▪ ________________?

Hint

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Series

11. .ravel()
12. numpy.asarray
13. .as_matrix()
14. .values
▪ ________________?

ndarray (1D)

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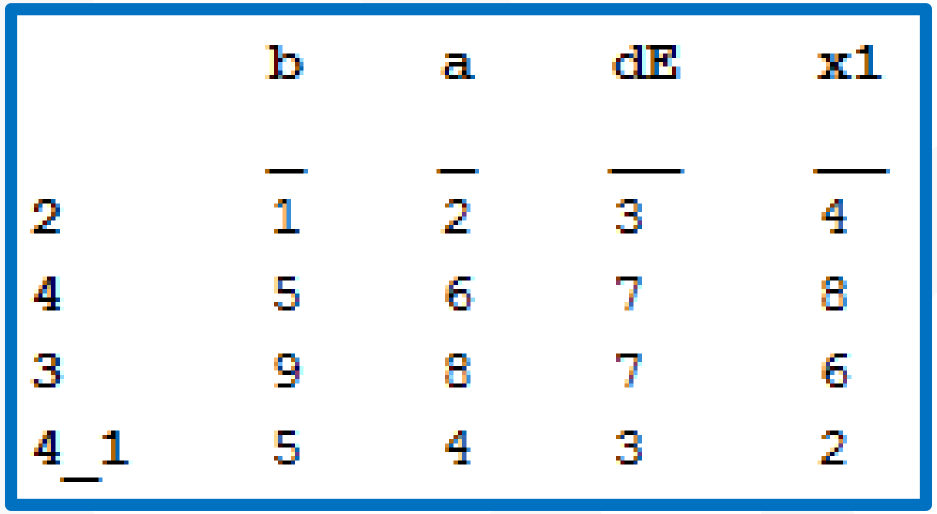
HT004: Use one command to add a column to **data** with a specific name.



```
          b     a     dE     x1
          _     _     __     __
2         1     2     3      4
4         5     6     7      8
3         9     8     7      6
4_1       5     4     3      2
```

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× `data.f1=1`

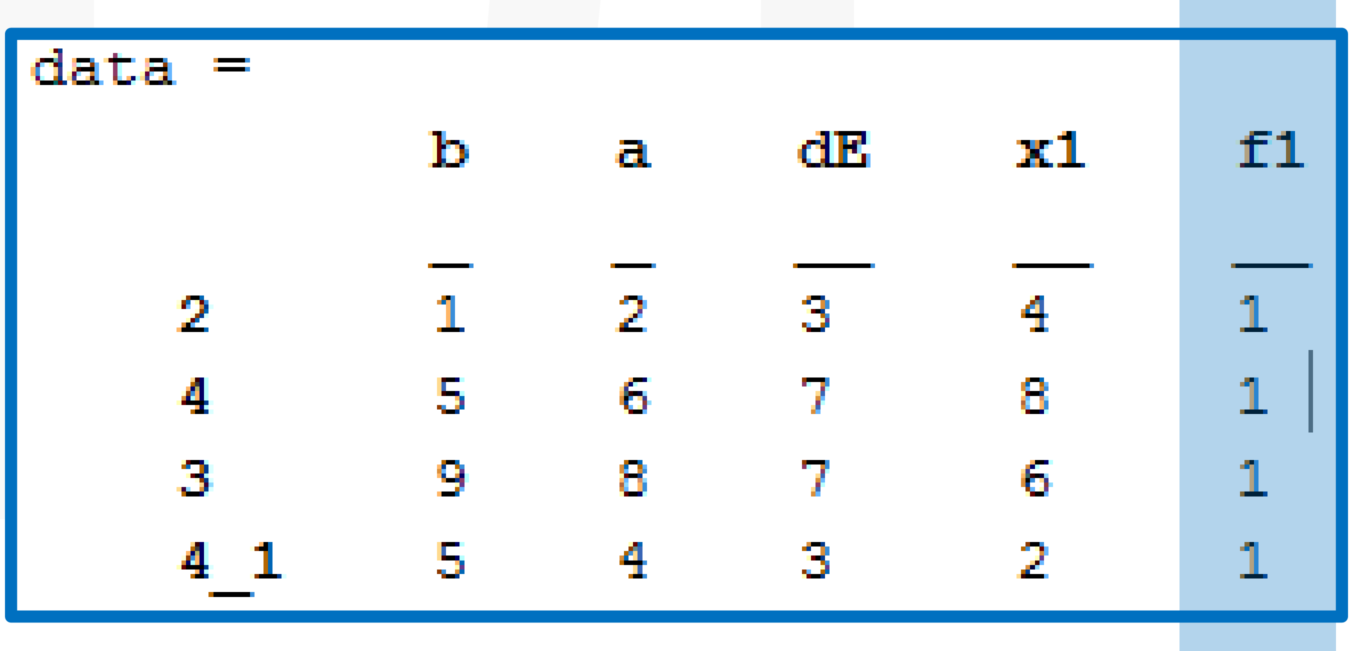
⇨ `data.f1(:)=1`

✓ `data.f1(:,1)=1`

✓ `data{:,'f1'}=1`

× `data(:,'f1')=1`

✓ `data(:,'f1')={1}`



```
data =

               b     a     dE     x1     f1
               _     _     __     __     __
        2      1     2     3      4      1
        4      5     6     7      8      1
        3      9     8     7      6      1
        4_1    5     4     3      2      1
```

1. a number
2. an array

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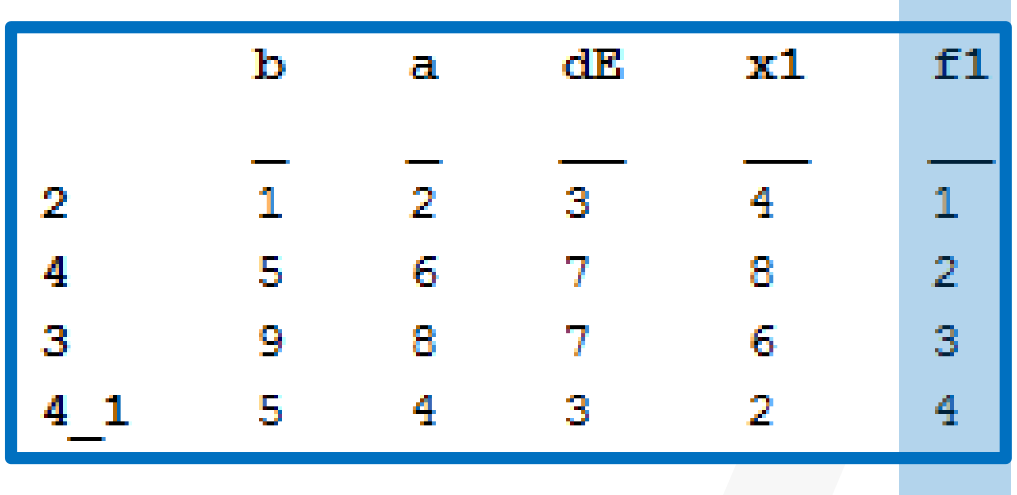
1. a number
2. an array

```
× data.f1=[1,2,3,4]
✓ data.f1=[1;2;3;4]
? data.f1={1;2;3;4}
× data.f1(:)=[1;2;3;4]
× data.f1(:)={1;2;3;4}
× data.f1(:)=1:4
✓ data.f1(:,1)=[1;2;3;4]
✓ data.f1(:,1)=1:4
✓ data{:,'f1'}=[1;2;3;4]
? data{:,'f1'}=1:4
```



	b	a	dE	x1	f1
2	1	2	3	4	1
4	5	6	7	8	2
3	9	8	7	6	3
4_1	5	4	3	2	4

To **assign to** or **create** a **variable** in a table, **the number of rows must match the height of the table**.

In an assignment A(:) = B, the number of elements in A and B must be the same.

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[1;2;3;4]⇔(1:4)’

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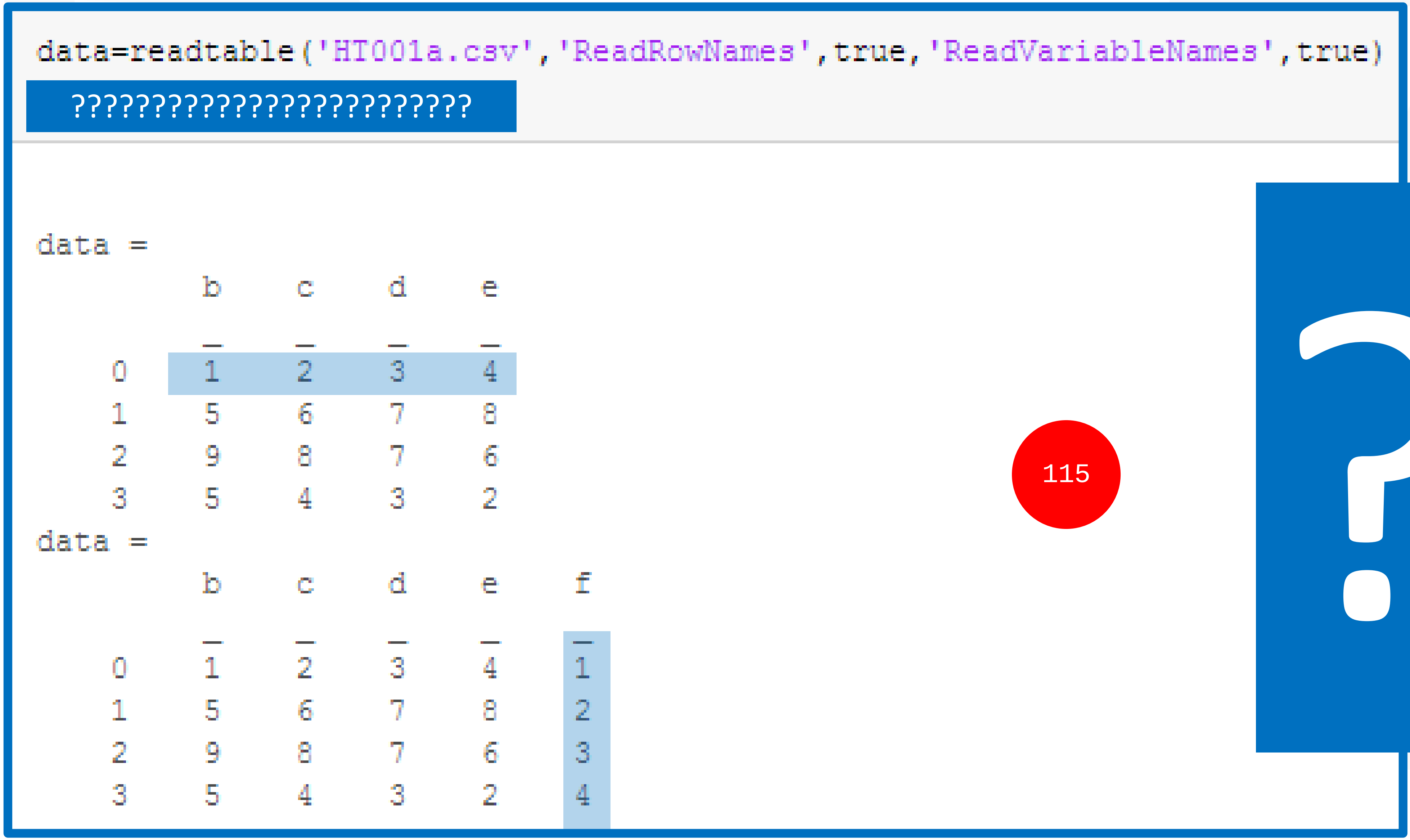
Homework: Use one command to add a column to **data**, using the first row of **data**, and name this column **f**.



```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
????????????????????????
```

```
data =

          b    c    d    e
          _    _    _    _

     0    1    2    3    4
     1    5    6    7    8
     2    9    8    7    6
     3    5    4    3    2
data =

          b    c    d    e    f
          _    _    _    _    _

     0    1    2    3    4    1
     1    5    6    7    8    2
     2    9    8    7    6    3
     3    5    4    3    2    4
```

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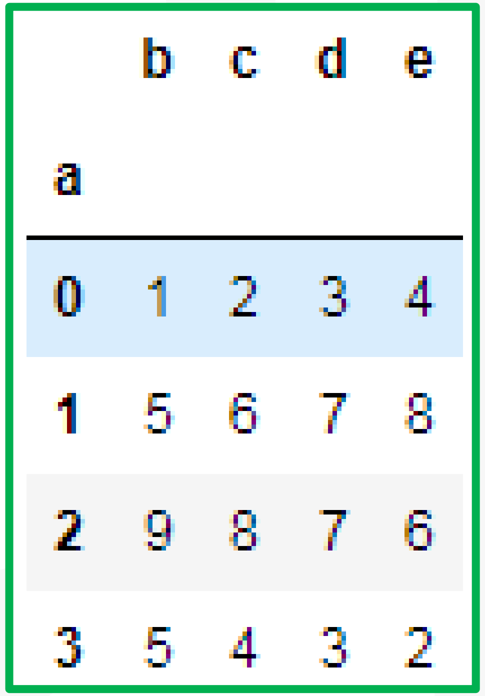
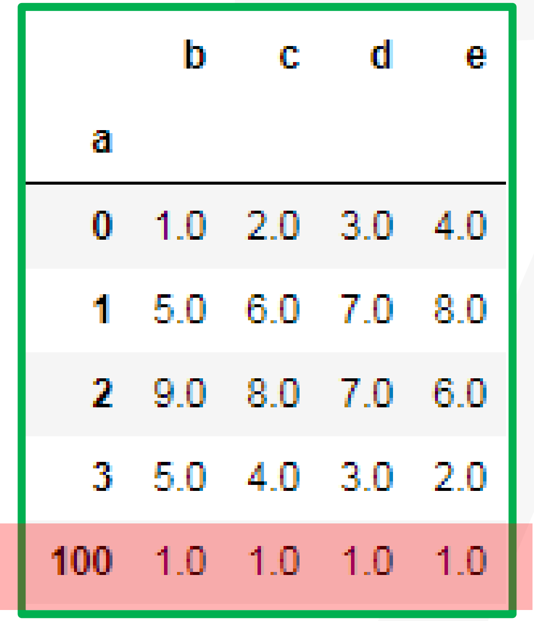
HT005: Use one command to add a row to **data** with a specific name.

- ✓ `data.loc[rowname,:]=…`
- ✓ `data=data.append(…)`



	b	c	d	e
a				
0	1	2	3	4
1	5	6	7	8
2	9	8	7	6
3	5	4	3	2



	b	c	d	e
a				
0	1.0	2.0	3.0	4.0
1	5.0	6.0	7.0	8.0
2	9.0	8.0	7.0	6.0
3	5.0	4.0	3.0	2.0
100	1.0	1.0	1.0	1.0

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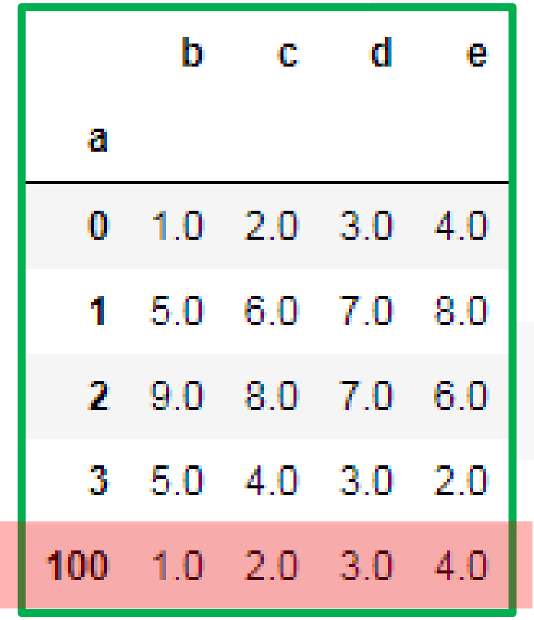

	b	c	d	e
a				
0	1.0	2.0	3.0	4.0
1	5.0	6.0	7.0	8.0
2	9.0	8.0	7.0	6.0
3	5.0	4.0	3.0	2.0
100	1.0	2.0	3.0	4.0

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✓ `data.loc[rowname,:]=…`
✓ `data.append(…)`

HT005: Use one command to add a row to **`data`** with a specific name.

✓ `data.loc[100,:]=1`

✓ `data.loc[100,:]=[1]`

× `data.loc[100,:]=[[1]]`

✓ `data.loc[100,:]=np.array(1)`

✓ `data.loc[100,:]=np.array([1])`

✓ `data.loc[100,:]=np.array([[1]])`

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- ✓ `data.loc[rowname,:]=…`
- ✓ `data.append(…)`

HT005: Use one command to add a row to **data** with a specific name.

- ✓ `data.loc[100,:]=range(1,5)`
- ✓ `data.loc[100,:]=[1, 2, 3, 4]`
- × `data.loc[100,:]=[[1, 2, 3, 4]]`
- × `data.loc[100,:]=[[1],[2],[3],[4]]`
- ✓ `data.loc[100,:]=np.array([1,2,3,4])`
- ✓ `data.loc[100,:]=np.array([[1,2,3,4]])`
- × `data.loc[100,:]=np.array([[1],[2],[3],[4]])`

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Dr. Z: 1D for 1D (100%).

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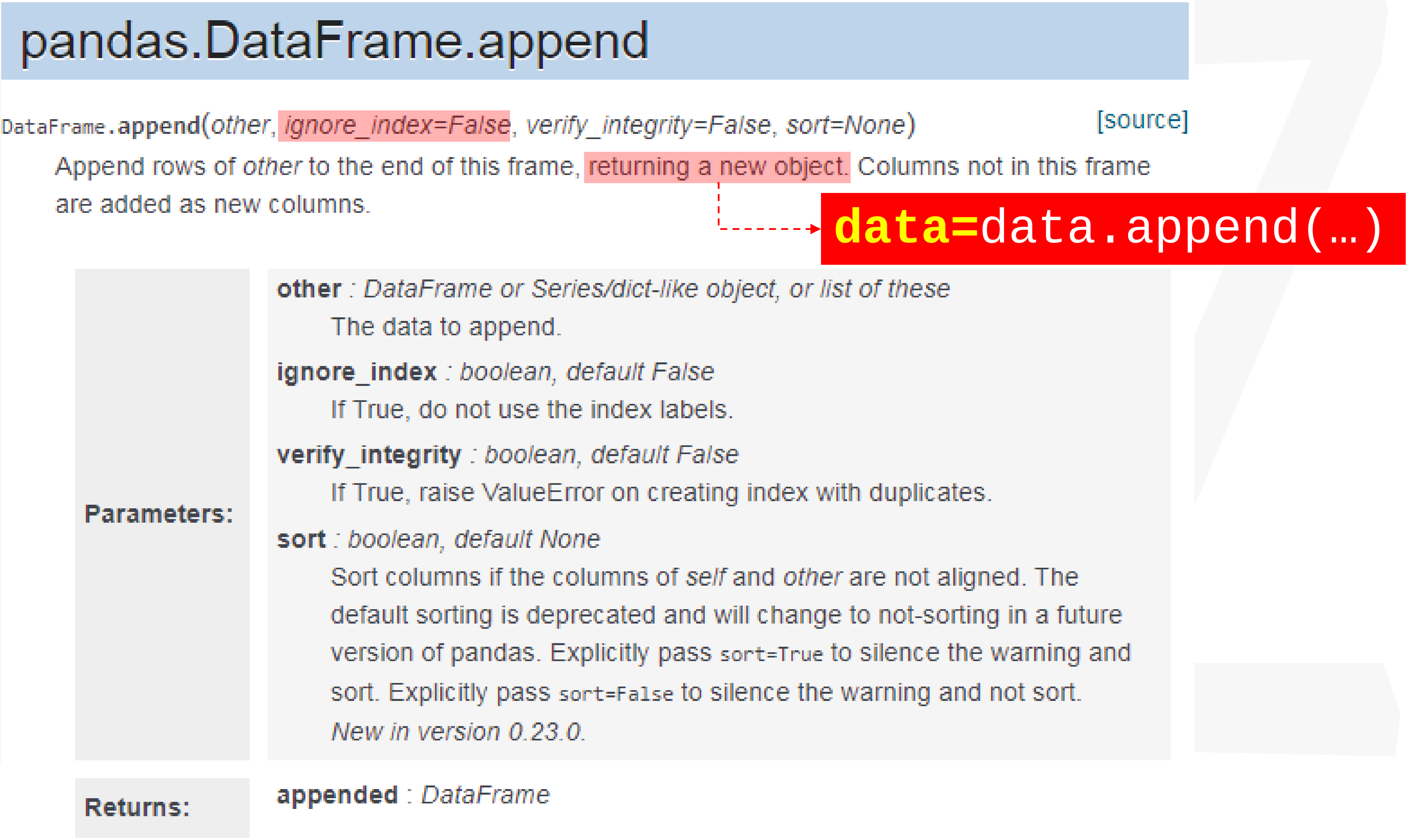
https://pandas.pydata.org/pandas-docs/stable/generated/pandas.DataFrame.append.html



pandas.DataFrame.append

`DataFrame.append`(*other*, *ignore_index=False*, *verify_integrity=False*, *sort=None*) [source]

Append rows of *other* to the end of this frame, returning a new object. Columns not in this frame are added as new columns.

`data=data.append(…)`

Parameters:

other : *DataFrame or Series/dict-like object, or list of these*

The data to append.

ignore_index : *boolean, default False*

If True, do not use the index labels.

verify_integrity : *boolean, default False*

If True, raise ValueError on creating index with duplicates.

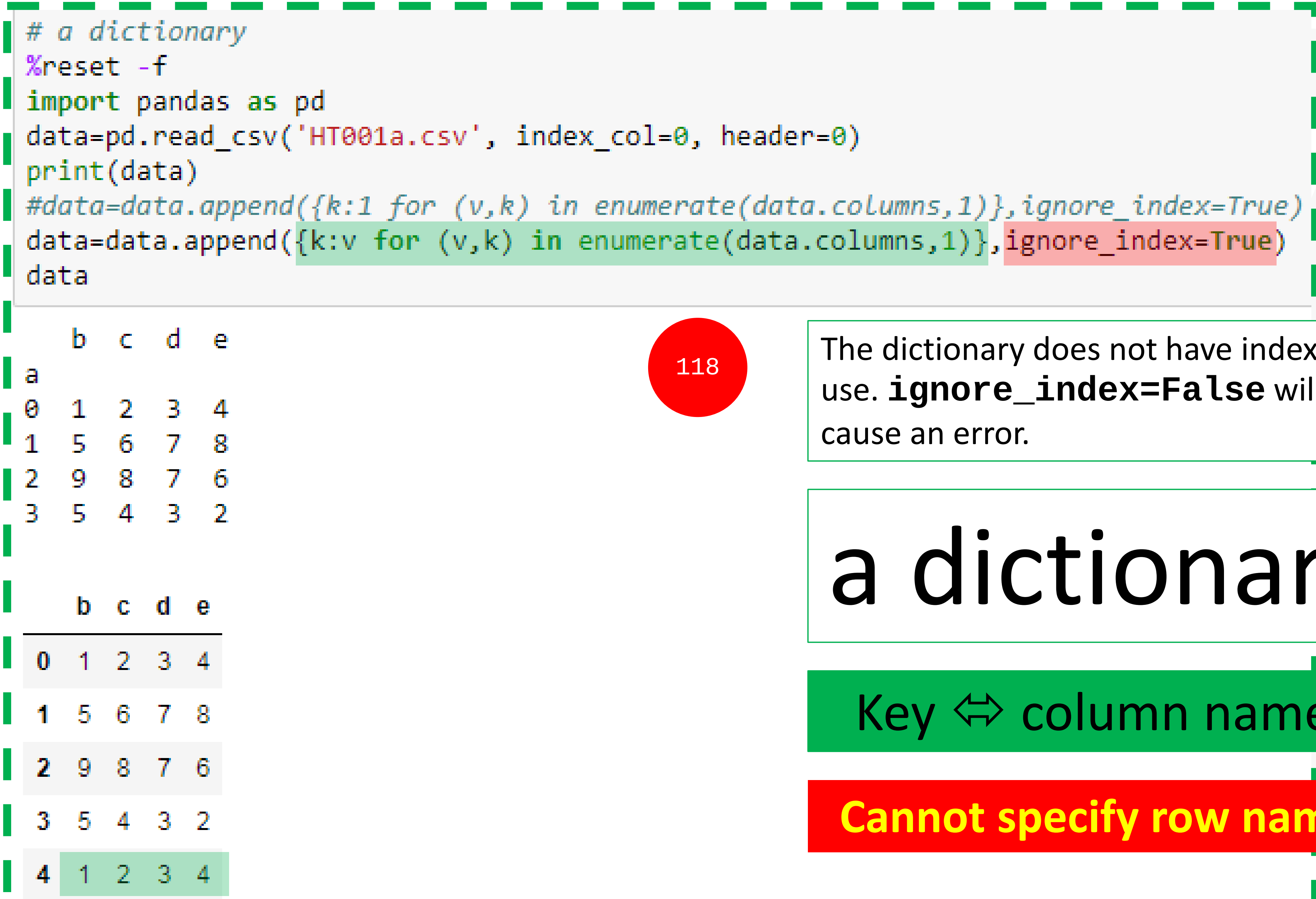
sort : *boolean, default None*

Sort columns if the columns of *self* and *other* are not aligned. The default sorting is deprecated and will change to not-sorting in a future version of pandas. Explicitly pass `sort=True` to silence the warning and sort. Explicitly pass `sort=False` to silence the warning and not sort.

New in version 0.23.0.

Returns:

appended : *DataFrame*



```
# a dictionary
%reset -f
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
#data=data.append({k:1 for (v,k) in enumerate(data.columns,1)},ignore_index=True)
data=data.append({k:v for (v,k) in enumerate(data.columns,1)},ignore_index=True)
data
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

	b	c	d	e
0	1	2	3	4
1	5	6	7	8
2	9	8	7	6
3	5	4	3	2
4	1	2	3	4

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The dictionary does not have index to use. **`ignore_index=False`** will cause an error.

a dictionary

Key ⇔ column names

Cannot specify row name.

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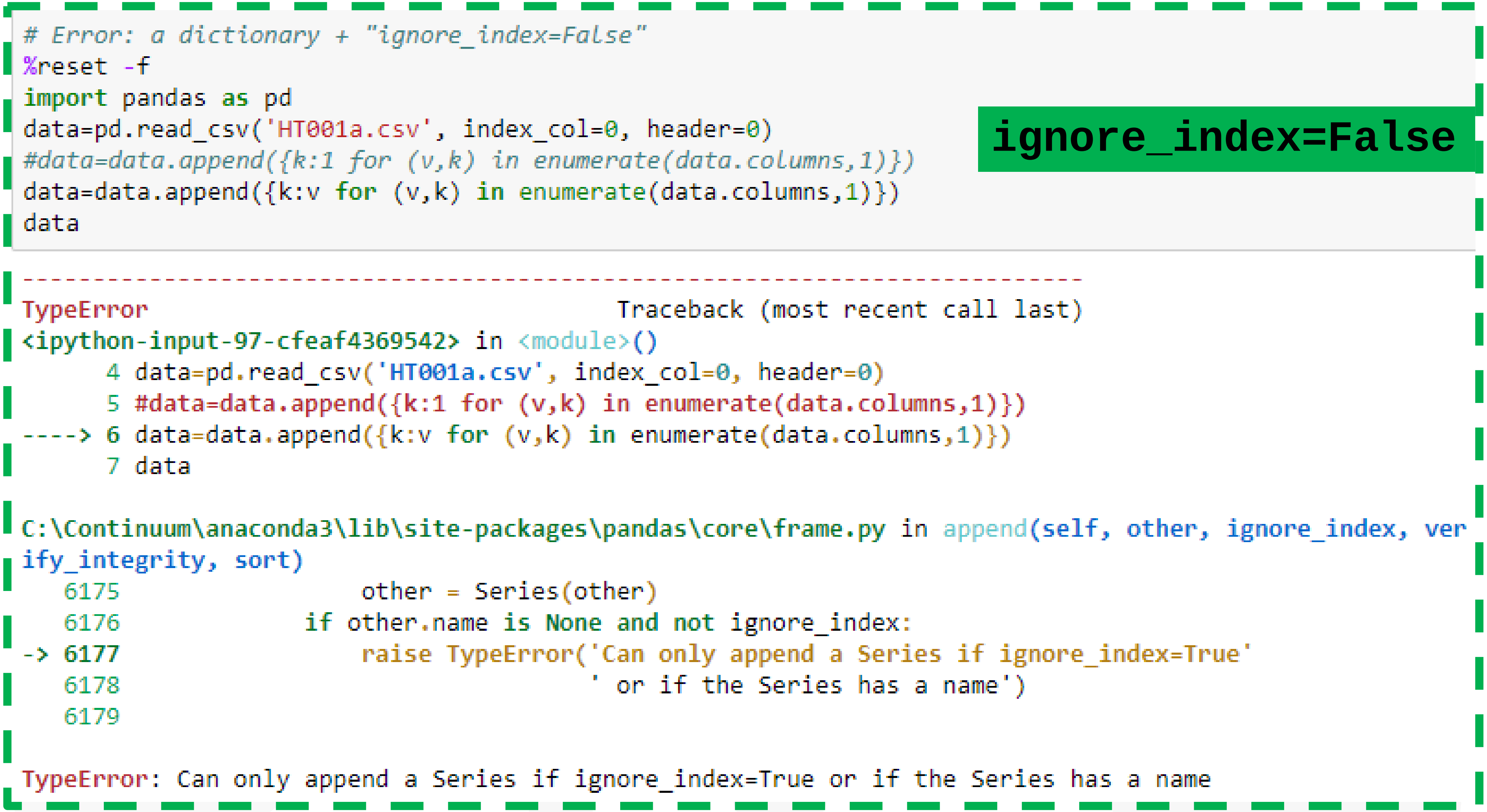

ignore_index=False

```
# Error: a dictionary + "ignore_index=False"
%reset -f
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
#data=data.append({k:1 for (v,k) in enumerate(data.columns,1)})
data=data.append({k:v for (v,k) in enumerate(data.columns,1)})
data
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-97-cfeaf4369542> in <module>()
      4 data=pd.read_csv('HT001a.csv', index_col=0, header=0)
      5 #data=data.append({k:1 for (v,k) in enumerate(data.columns,1)})
----> 6 data=data.append({k:v for (v,k) in enumerate(data.columns,1)})
      7 data

C:\Continuum\anaconda3\lib\site-packages\pandas\core\frame.py in append(self, other, ignore_index, ver
ify_integrity, sort)
   6175                 other = Series(other)
   6176             if other.name is None and not ignore_index:
-> 6177                 raise TypeError('Can only append a Series if ignore_index=True'
   6178                                 ' or if the Series has a name')
   6179

TypeError: Can only append a Series if ignore_index=True or if the Series has a name
```

(Dr. Z: The dictionary does not suggest any name.)

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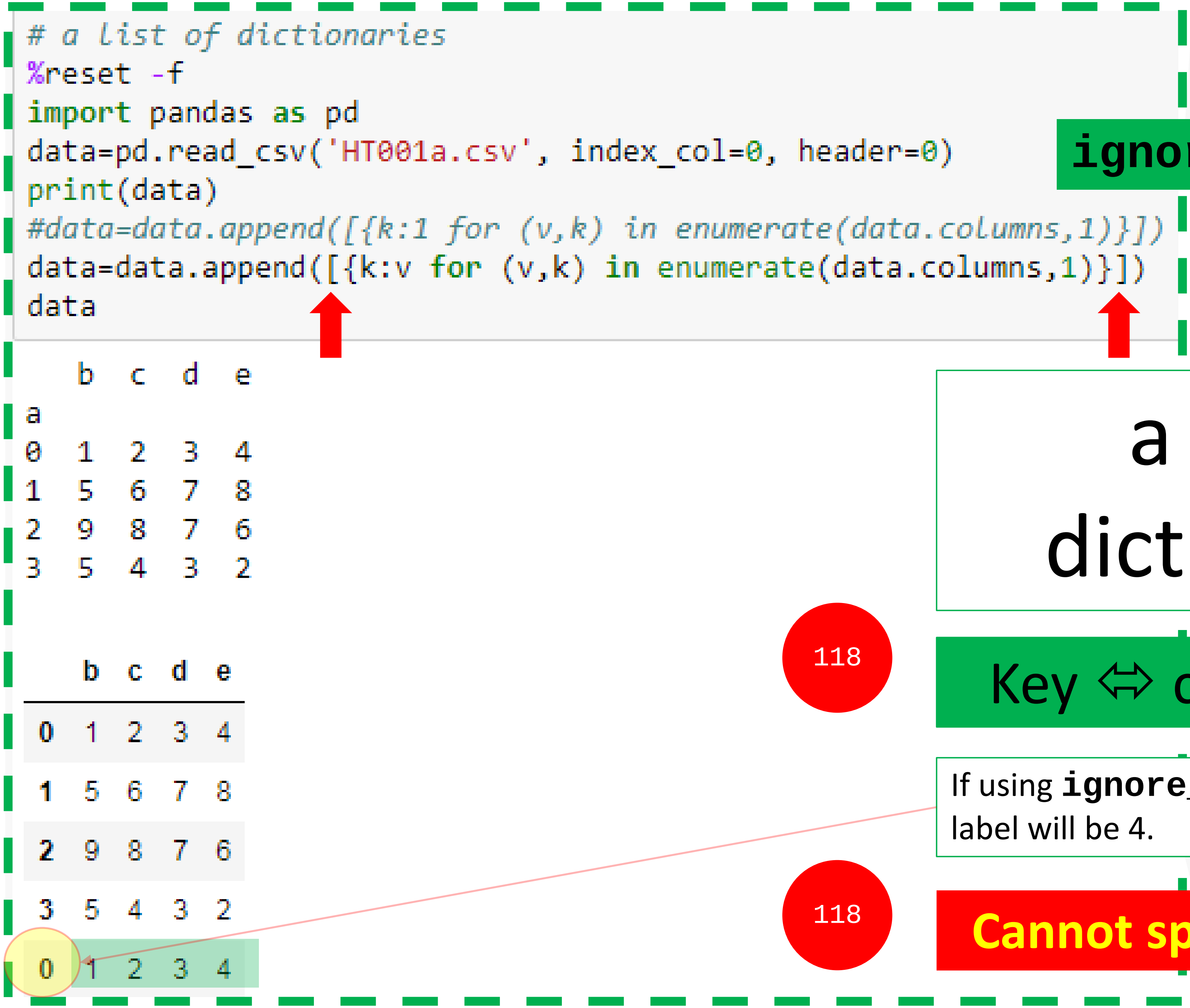

```
# a list of dictionaries
%reset -f
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
#data=data.append([{k:1 for (v,k) in enumerate(data.columns,1)}])
data=data.append([{k:v for (v,k) in enumerate(data.columns,1)}])
data
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

```
   b  c  d  e
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
0  1  2  3  4
```

ignore_index=False

a list of dictionaries

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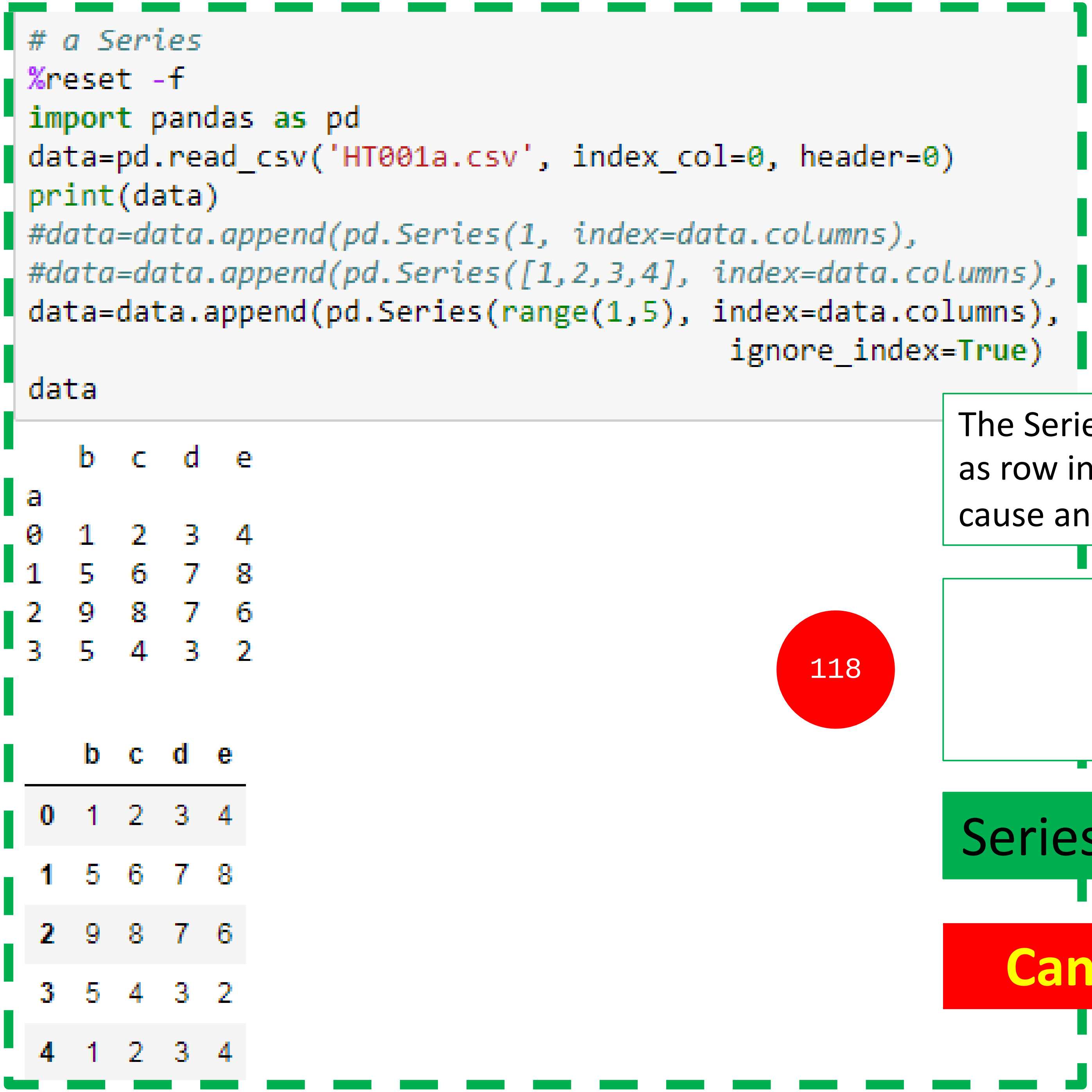
Key ⇔ column names

If using **ignore_index=True**, the row label will be 4.

118

Cannot specify row name.



```python
# a Series
%reset -f
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
#data=data.append(pd.Series(1, index=data.columns),
#data=data.append(pd.Series([1,2,3,4], index=data.columns),
data=data.append(pd.Series(range(1,5), index=data.columns),
                                        ignore_index=True)
data
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

	b	c	d	e
0	1	2	3	4
1	5	6	7	8
2	9	8	7	6
3	5	4	3	2
4	1	2	3	4

118

The Series does not have an index to be used as row index. **`ignore_index=False`** will cause an error.

a Series

Series Index ⇔ column names

Cannot specify row name.

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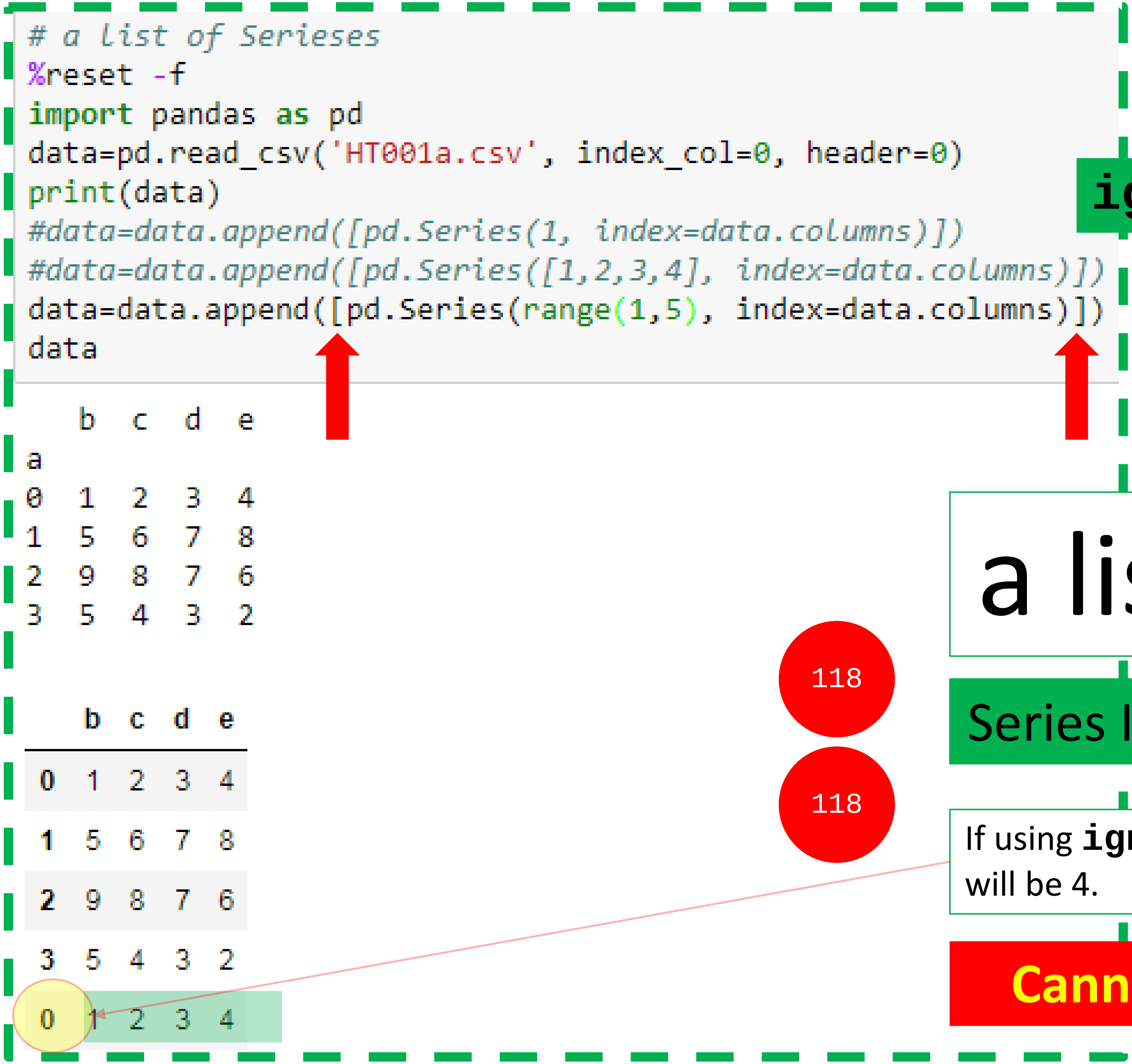

```
# a list of Serieses
%reset -f
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
#data=data.append([pd.Series(1, index=data.columns)])
#data=data.append([pd.Series([1,2,3,4], index=data.columns)])
data=data.append([pd.Series(range(1,5), index=data.columns)])
data
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

```
   b  c  d  e
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
0  1  2  3  4
```

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ignore_index=False

a list of Series

Series Index ⇔ column names

If using **ignore_index=True**, the row label will be 4.

Cannot specify row name.

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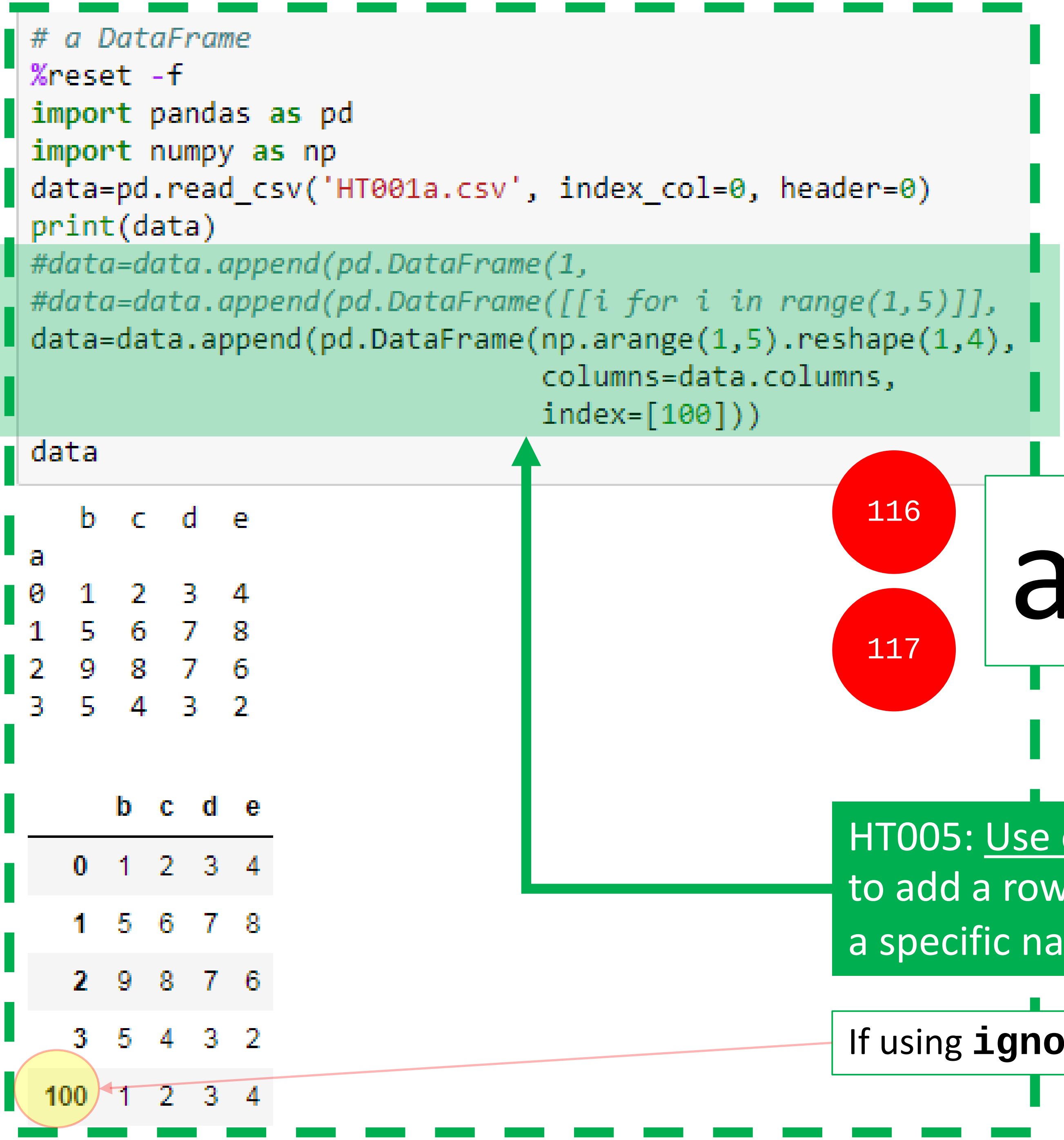

```
# a DataFrame
%reset -f
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
#data=data.append(pd.DataFrame(1,
#data=data.append(pd.DataFrame([[i for i in range(1,5)]],
data=data.append(pd.DataFrame(np.arange(1,5).reshape(1,4),
                              columns=data.columns,
                              index=[100]))
data
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

```
     b  c  d  e
  0  1  2  3  4
  1  5  6  7  8
  2  9  8  7  6
  3  5  4  3  2
100  1  2  3  4
```

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ignore_index=False

index=[100]

Index or array-like

a DataFrame

HT005: Use one command to add a row to **data** with a specific name.

If using **ignore_index=True**, the row label will be 4.

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HT005: Use one command to add a row to **data** with a specific name.

✓ Add a column

× data.f1=1

⇨ data.f1(:)=1

✓ data.f1(:,1)=1

✓ data{:,'f1'}=1

× data(:,'f1')=1

✓ data(:,'f1')={1}

× data.f1=[1,2,3,4]

✓ data.f1=[1;2;3;4]

? data.f1={1;2;3;4}

× data.f1(:)=[1;2;3;4]

× data.f1(:)={1;2;3;4}

× data.f1(:)=1:4

✓ data.f1(:,1)=[1;2;3;4]

✓ data.f1(:,1)=1:4

✓ data{:,'f1'}=[1;2;3;4]

? data{:,'f1'}=1:4

✓ Add a row

~~× data.f1=1~~

~~× data.f1(:)=1~~

~~✓ data.f1(1,:)=1~~

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✓ data{'4',:}=1

~~× data('4',:)=1~~

✓ data('4',:)={1}

~~× data.f1=[1,2,3,4]~~

~~× data.f1=[1;2;3;4]~~

~~× data.f1={1;2;3;4}~~

~~× data.f1(:)=[1;2;3;4]~~

~~× data.f1(:)={1;2;3;4}~~

~~× data.f1(:)=1:4~~

~~× data.f1(1,:)=[1;2;3;4]~~

~~× data.f1(1,:)=1:4~~

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✓ data{'4',:}=[1,2,3,4]

✓ data{'4',:}=1:4

HT006: Delete a row/column from **data**

1. Delete a column as deleting an item in a dictionary

```
del data['b']
```

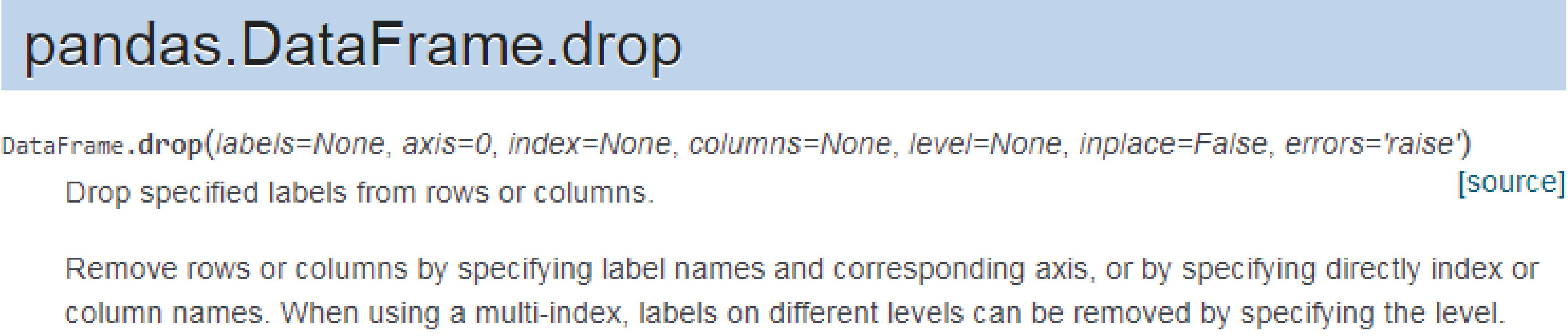
(in-place delete)

2. Use **`pandas.DataFrame.drop`**

```
axis=0, inplace=False
```

(default)

```
0 or 'index', 1 or 'columns'
```



pandas.DataFrame.drop

`DataFrame.drop`(*labels=None*, *axis=0*, *index=None*, *columns=None*, *level=None*, *inplace=False*, *errors='raise'*)

[source]

Drop specified labels from rows or columns.

Remove rows or columns by specifying label names and corresponding axis, or by specifying directly index or column names. When using a multi-index, labels on different levels can be removed by specifying the level.

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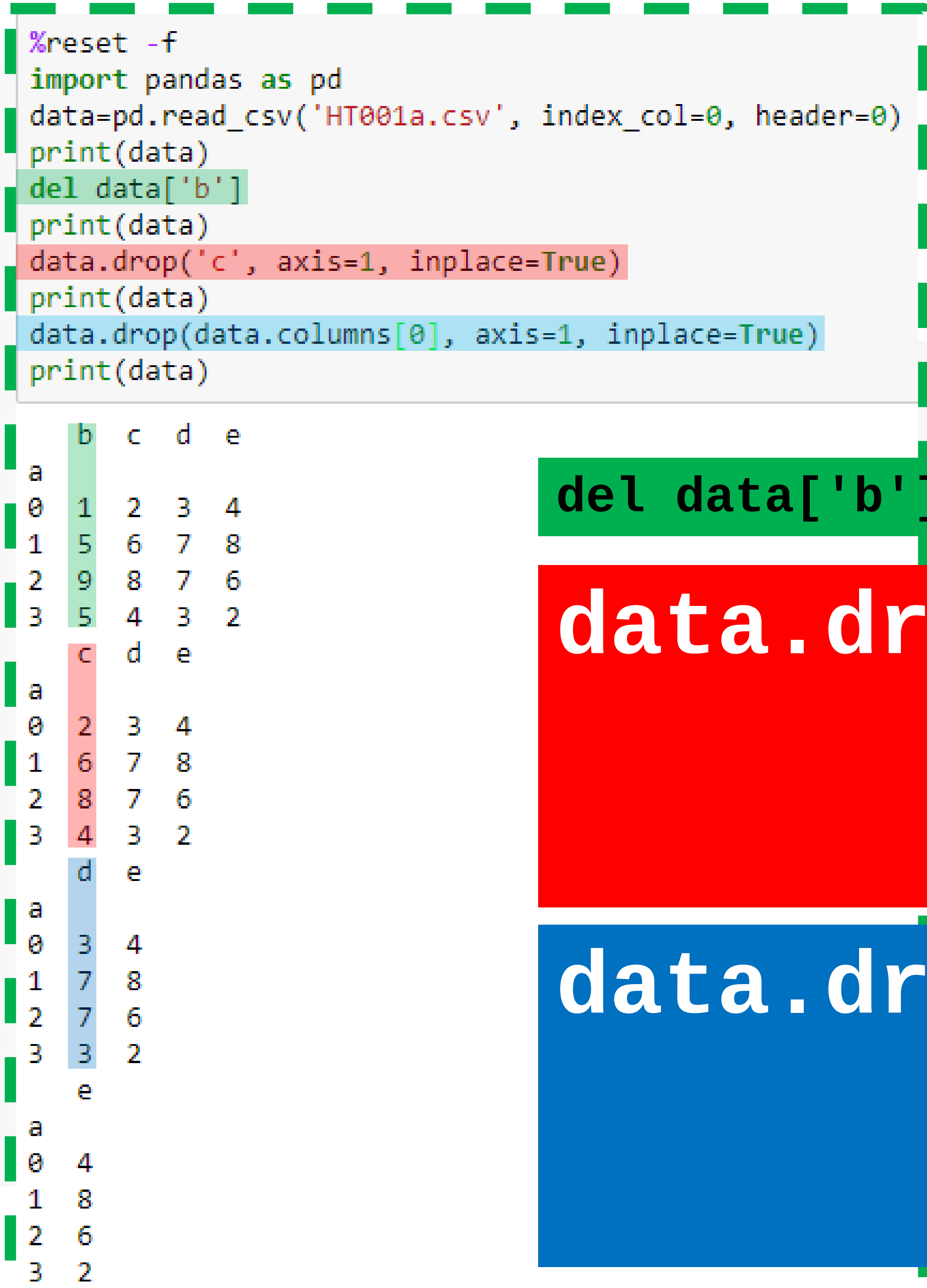

```
%reset -f
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
del data['b']
print(data)
data.drop('c', axis=1, inplace=True)
print(data)
data.drop(data.columns[0], axis=1, inplace=True)
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   c  d  e
a
0  2  3  4
1  6  7  8
2  8  7  6
3  4  3  2
   d  e
a
0  3  4
1  7  8
2  7  6
3  3  2
   e
a
0  4
1  8
2  6
3  2
```

121 122

`del data['b']` or `del data[data.columns[0]]`

```
data.drop('c',
          axis=1,
          inplace=True)
```

```
data.drop(data.columns[0],
          axis=1,
          inplace=True)
```

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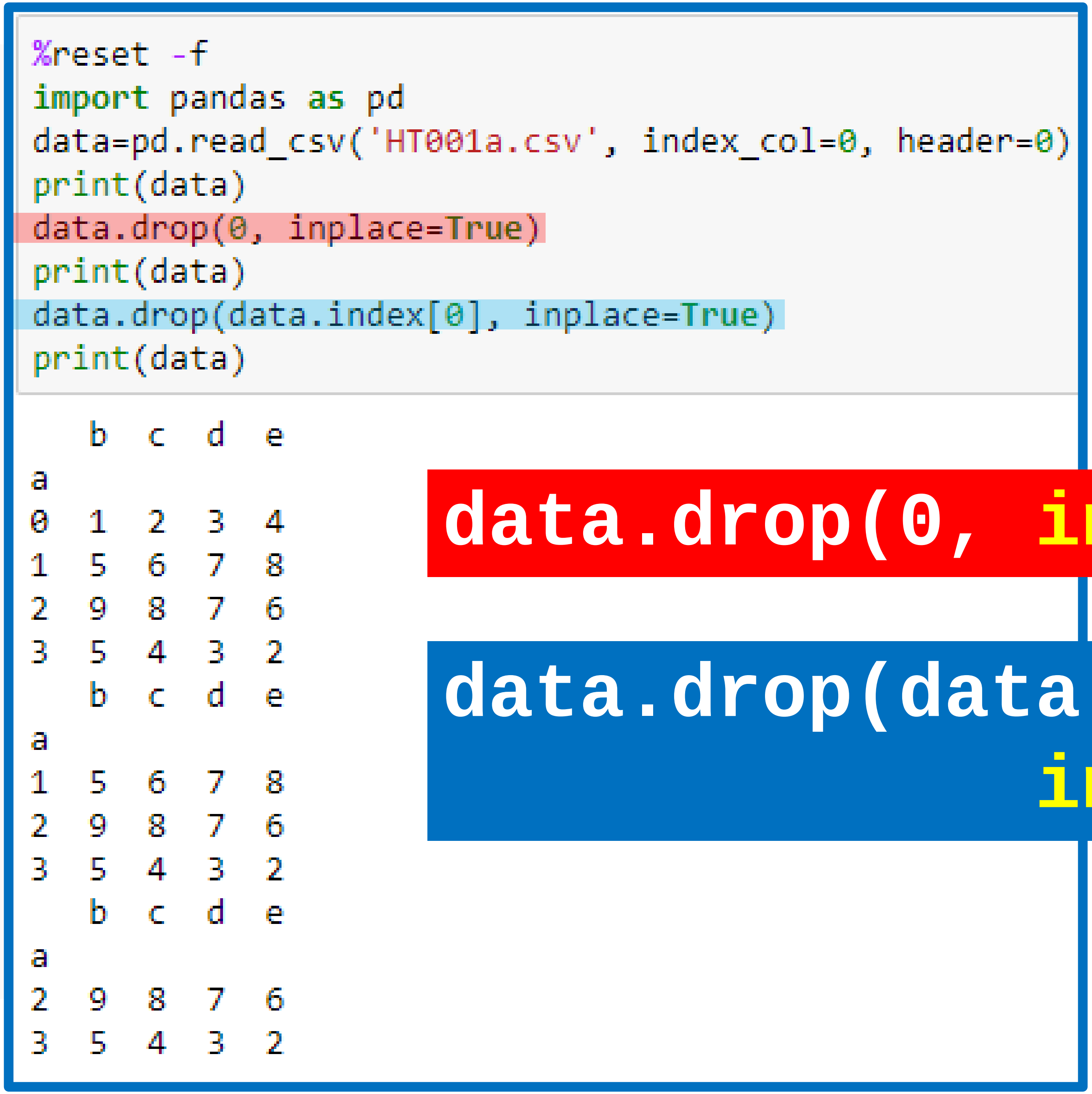
HT006: Delete a row/column from `data`

```
pandas.DataFrame.drop

data.index

axis=0

inplace=True
```



```
%reset -f
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.drop(0, inplace=True)
print(data)
data.drop(data.index[0], inplace=True)
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
2  9  8  7  6
3  5  4  3  2
```

123 124

```
data.drop(0, inplace=True)
```

```
data.drop(data.index[0],
                 inplace=True)
```

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HT006: Delete a row/column from **data**

✓ Delete a column using the “dot syntax”

```
data.b=[]
```

✓ Delete a column using the indexing (position-based and label-based)

```
data(:,1)=[]
```

```
data(:,'b')=[]
```

✓ Delete a row by the row number

```
data(1,:)=[]
```

✓ Delete a row by the row name

```
data('0',:)=[]
```

125 126

127 128

✓ ( )

× { }

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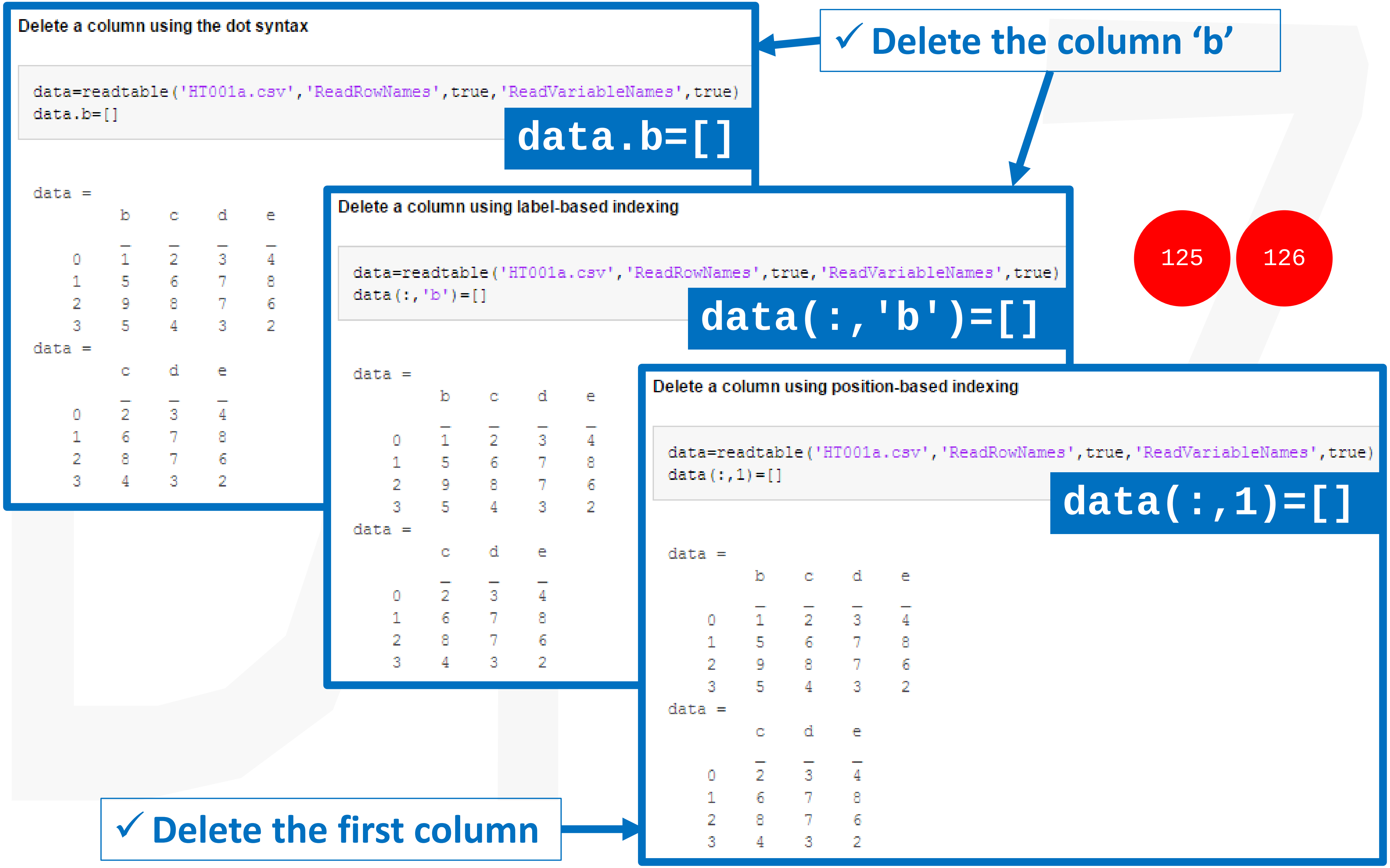


✓ Delete the column ‘b’

Delete a column using the dot syntax

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data.b=[]
```

data.b=[]

```
data =
          b    c    d    e
          _    _    _    _
     0    1    2    3    4
     1    5    6    7    8
     2    9    8    7    6
     3    5    4    3    2
data =
          c    d    e
          _    _    _
     0    2    3    4
     1    6    7    8
     2    8    7    6
     3    4    3    2
```

Delete a column using label-based indexing

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data(:,'b')=[]
```

data(:,'b')=[]

```
data =
          b    c    d    e
          _    _    _    _
     0    1    2    3    4
     1    5    6    7    8
     2    9    8    7    6
     3    5    4    3    2
data =
          c    d    e
          _    _    _
     0    2    3    4
     1    6    7    8
     2    8    7    6
     3    4    3    2
```

Delete a column using position-based indexing

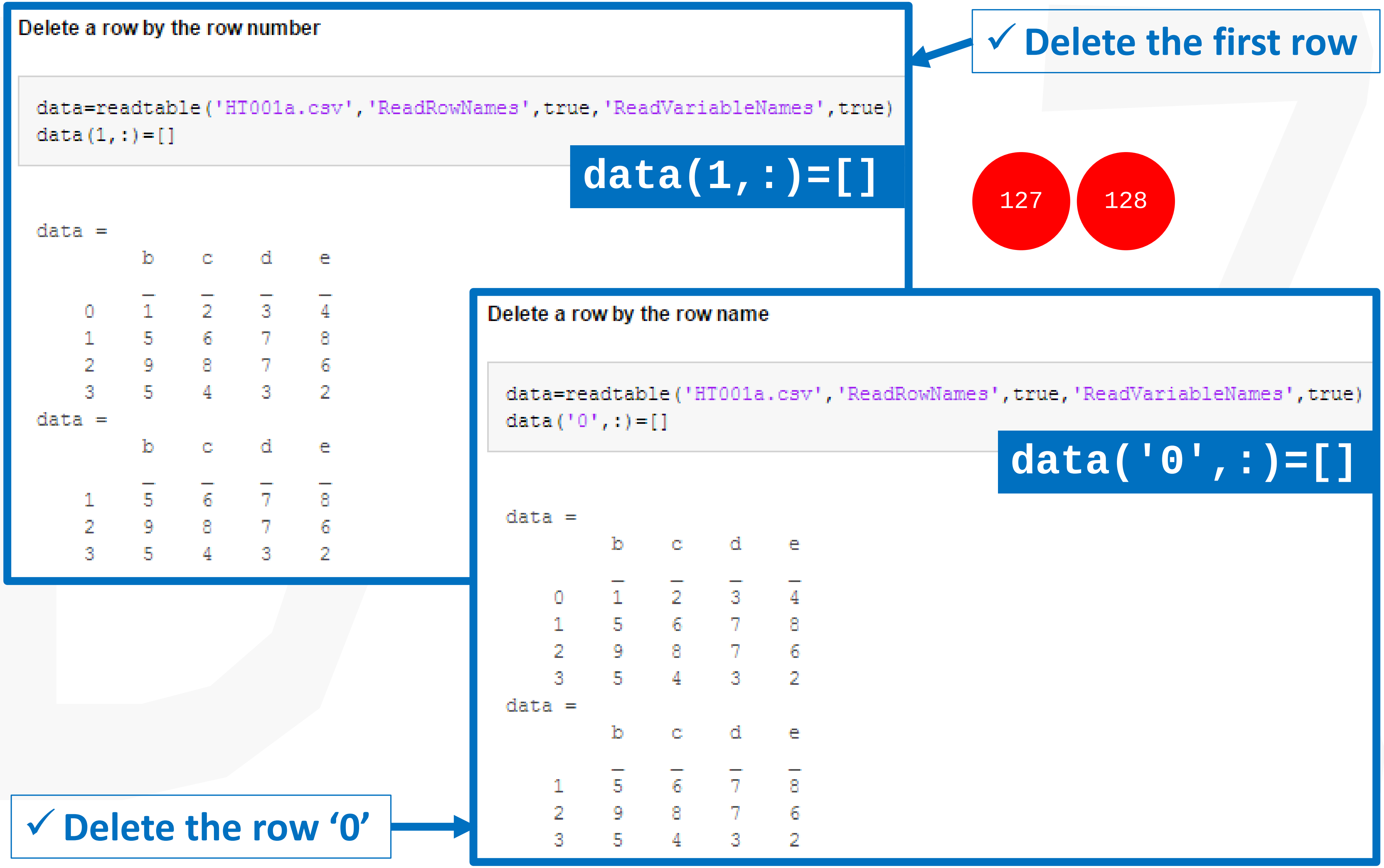
```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data(:,1)=[]
```

data(:,1)=[]

```
data =
          b    c    d    e
          _    _    _    _
     0    1    2    3    4
     1    5    6    7    8
     2    9    8    7    6
     3    5    4    3    2
data =
          c    d    e
          _    _    _
     0    2    3    4
     1    6    7    8
     2    8    7    6
     3    4    3    2
```

✓ Delete the first column

125 126



Delete a row by the row number

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data(1,:)=[]
```

```
data =
            b    c    d    e

            _    _    _    _
      0     1    2    3    4
      1     5    6    7    8
      2     9    8    7    6
      3     5    4    3    2
data =
            b    c    d    e

            _    _    _    _
      1     5    6    7    8
      2     9    8    7    6
      3     5    4    3    2
```

`data(1,:)=[]`

✓ Delete the first row

127 128

Delete a row by the row name

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data('0',:)=[]
```

```
data =
            b    c    d    e

            _    _    _    _
      0     1    2    3    4
      1     5    6    7    8
      2     9    8    7    6
      3     5    4    3    2
data =
            b    c    d    e

            _    _    _    _
      1     5    6    7    8
      2     9    8    7    6
      3     5    4    3    2
```

`data('0',:)=[]`

✓ Delete the row ‘0’

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Q: How to swap two values in variables **a** and **b**?

??????????????????????????

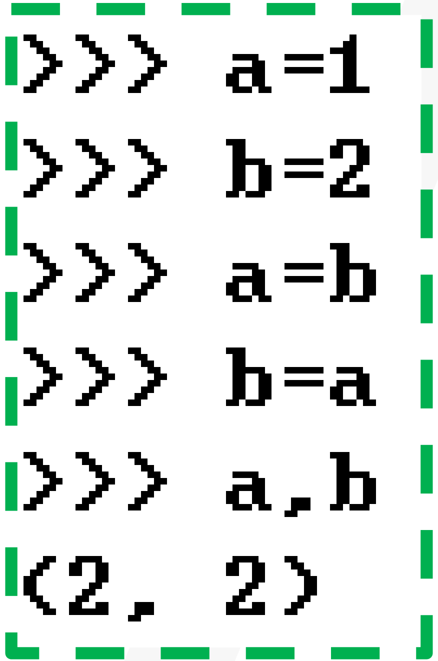
?

? a=b

? b=a

?

??????????????????????????



```
>>> a=1
>>> b=2
>>> a=b
>>> b=a
>>> a,b
(2, 2)
```

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(continued)

```
temp=a
a=b
b=temp
```

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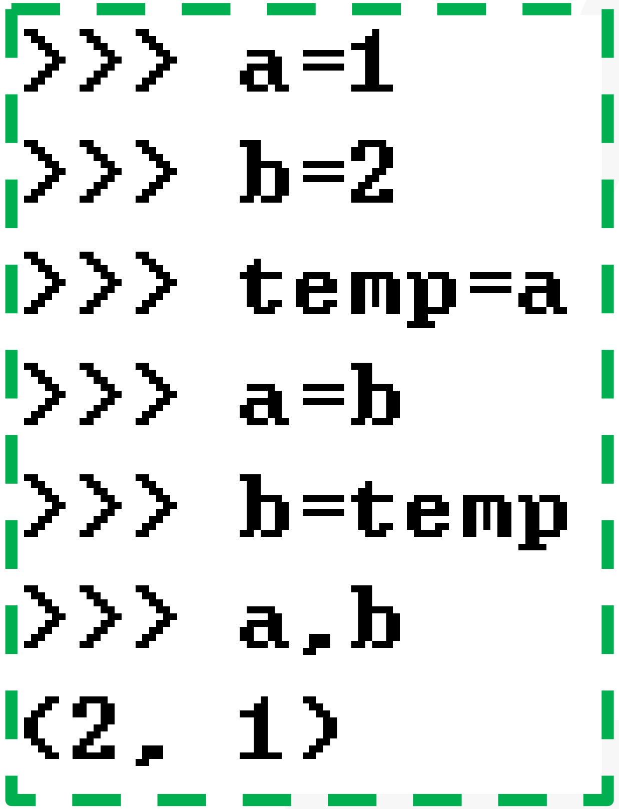

```
>>> a=1
>>> b=2
>>> temp=a
>>> a=b
>>> b=temp
>>> a,b
(2, 1)
```

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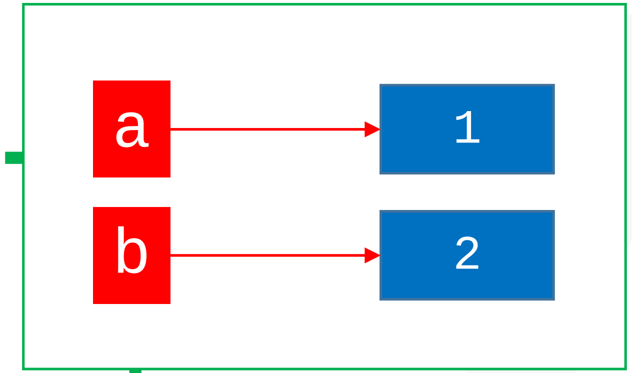
(continued)

```
>>> a=1
>>> b=2
>>> a, b=b, a
>>> a,b
(2, 1)
```



expr3, expr4=expr1, expr2

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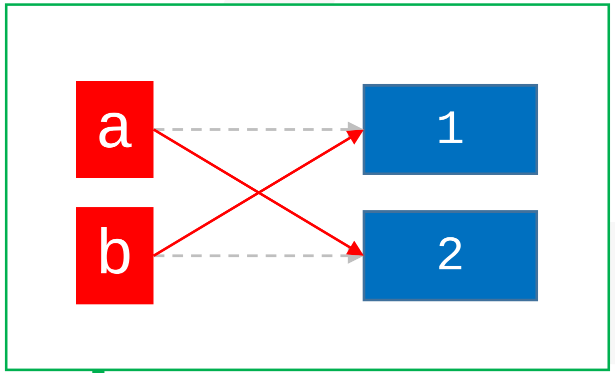

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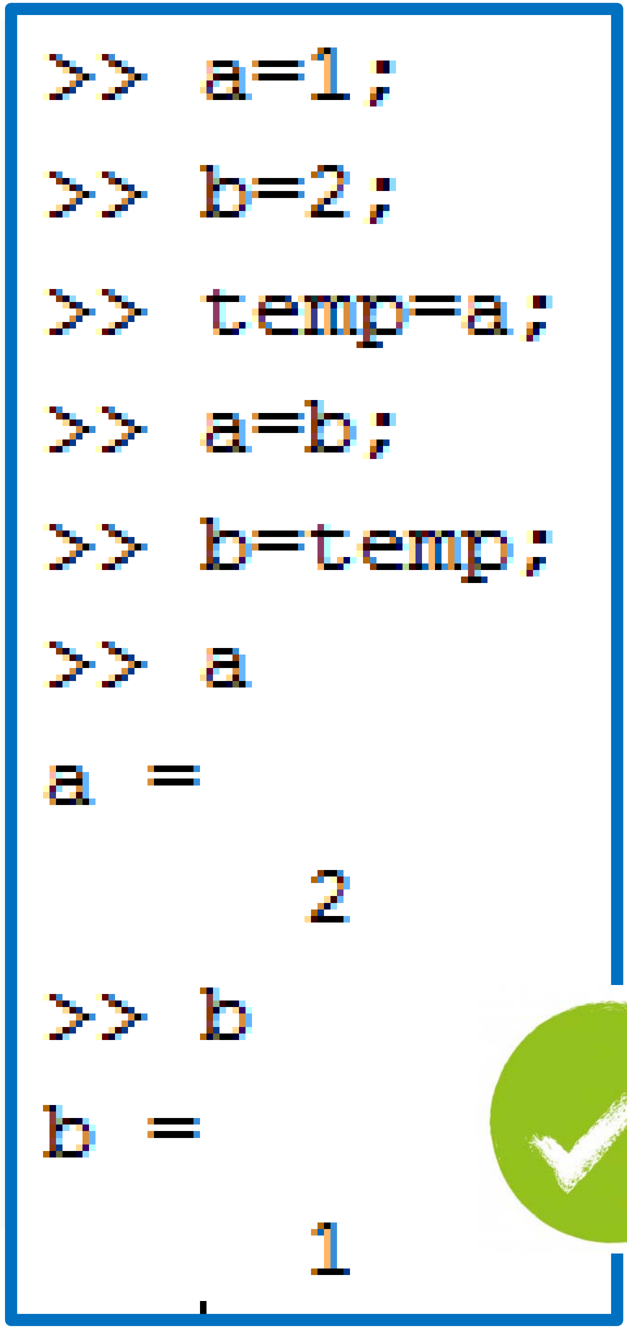
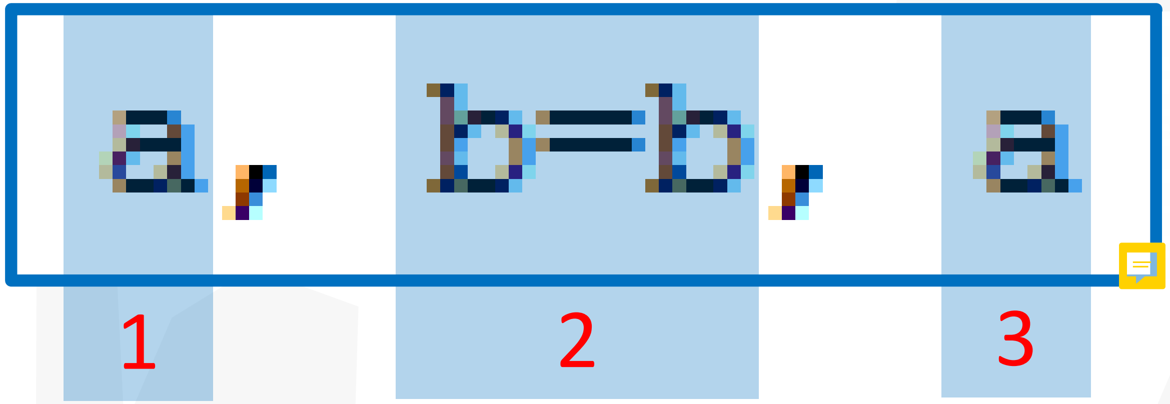


```
>> a=1;
>> b=2;
>> temp=a;
>> a=b;
>> b=temp;
>> a
a =
     2
>> b
b =
     1
```



```
a, b=b, a
```

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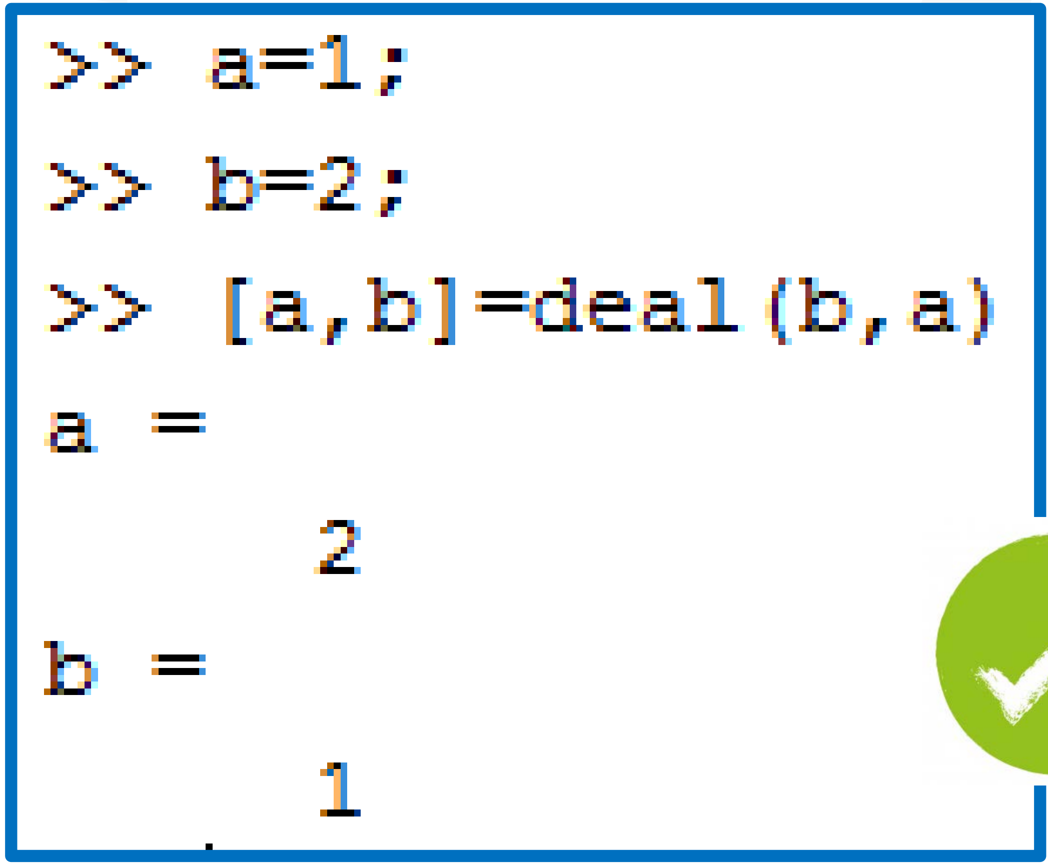

```
>> a=1;
>> b=2;
>> [a,b]=deal(b,a)
a =
     2
b =
     1
```

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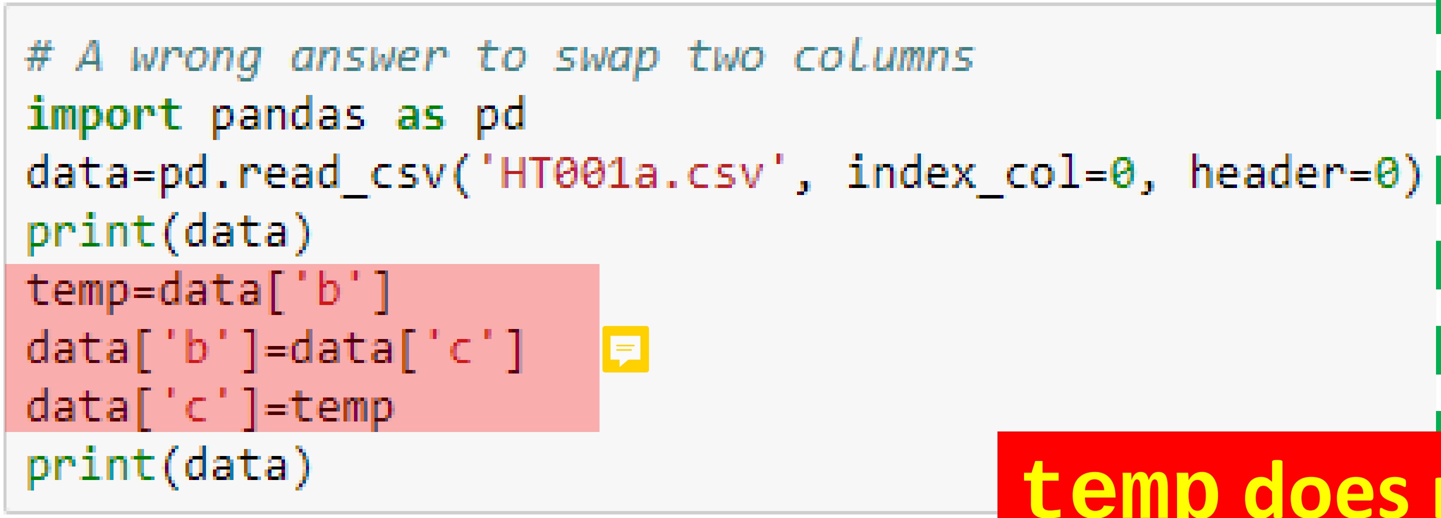
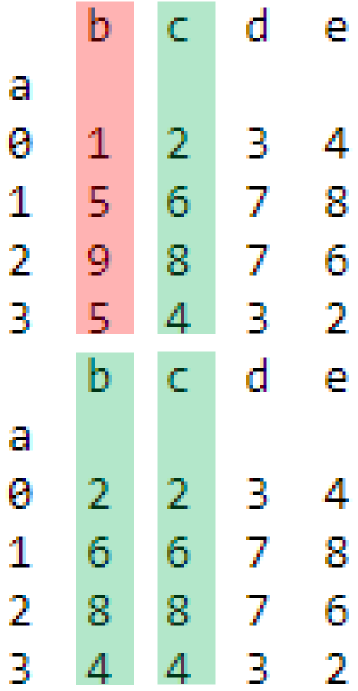
HT007: Swap two rows/columns in **data**



```
# A wrong answer to swap two columns
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
temp=data['b']
data['b']=data['c']
data['c']=temp
print(data)
```



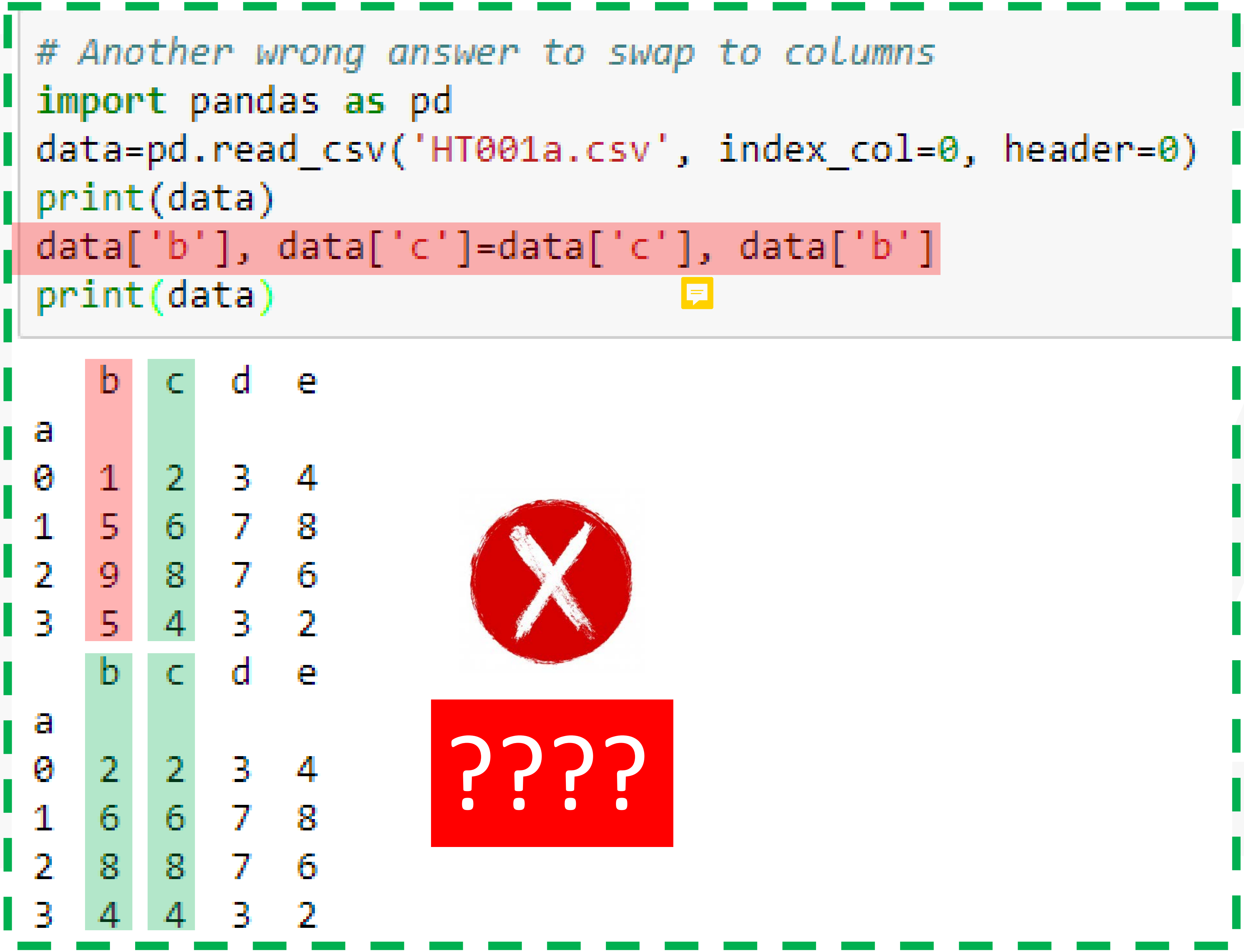
```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  2  2  3  4
1  6  6  7  8
2  8  8  7  6
3  4  4  3  2
```

????

1. Select data via `[]`
2. Select data via `.loc` or `.iloc`

temp does not work!

`data['b']` and **`data['c']`** are views. A view is something like a “pointer”. Assignment to a view is function to use the pointer to assign values.



```python
# Another wrong answer to swap to columns
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data['b'], data['c']=data['c'], data['b']
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  2  2  3  4
1  6  6  7  8
2  8  8  7  6
3  4  4  3  2
```

????

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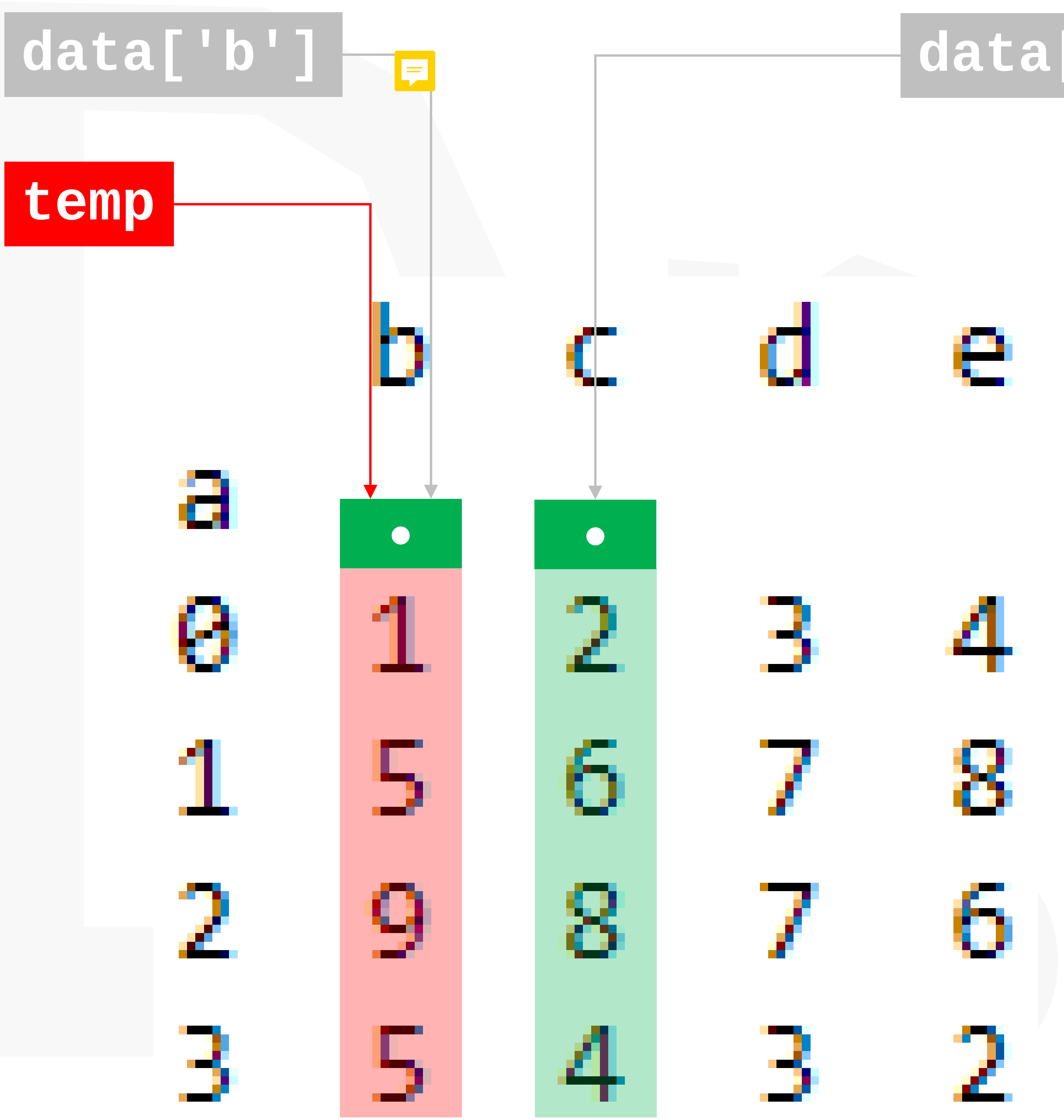
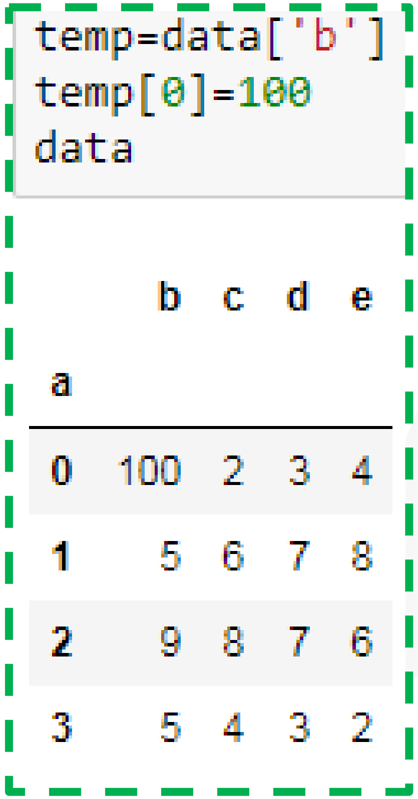


	b	c	d	e
a	●	●		
0	1	2	3	4
1	5	6	7	8
2	9	8	7	6
3	5	4	3	2

```
temp=data['b']
data['b']=data['c']
data['c']=temp
```



```
temp=data['b']
temp[0]=100
data
```

```
     b  c  d  e
a
0  100  2  3  4
1    5  6  7  8
2    9  8  7  6
3    5  4  3  2
```

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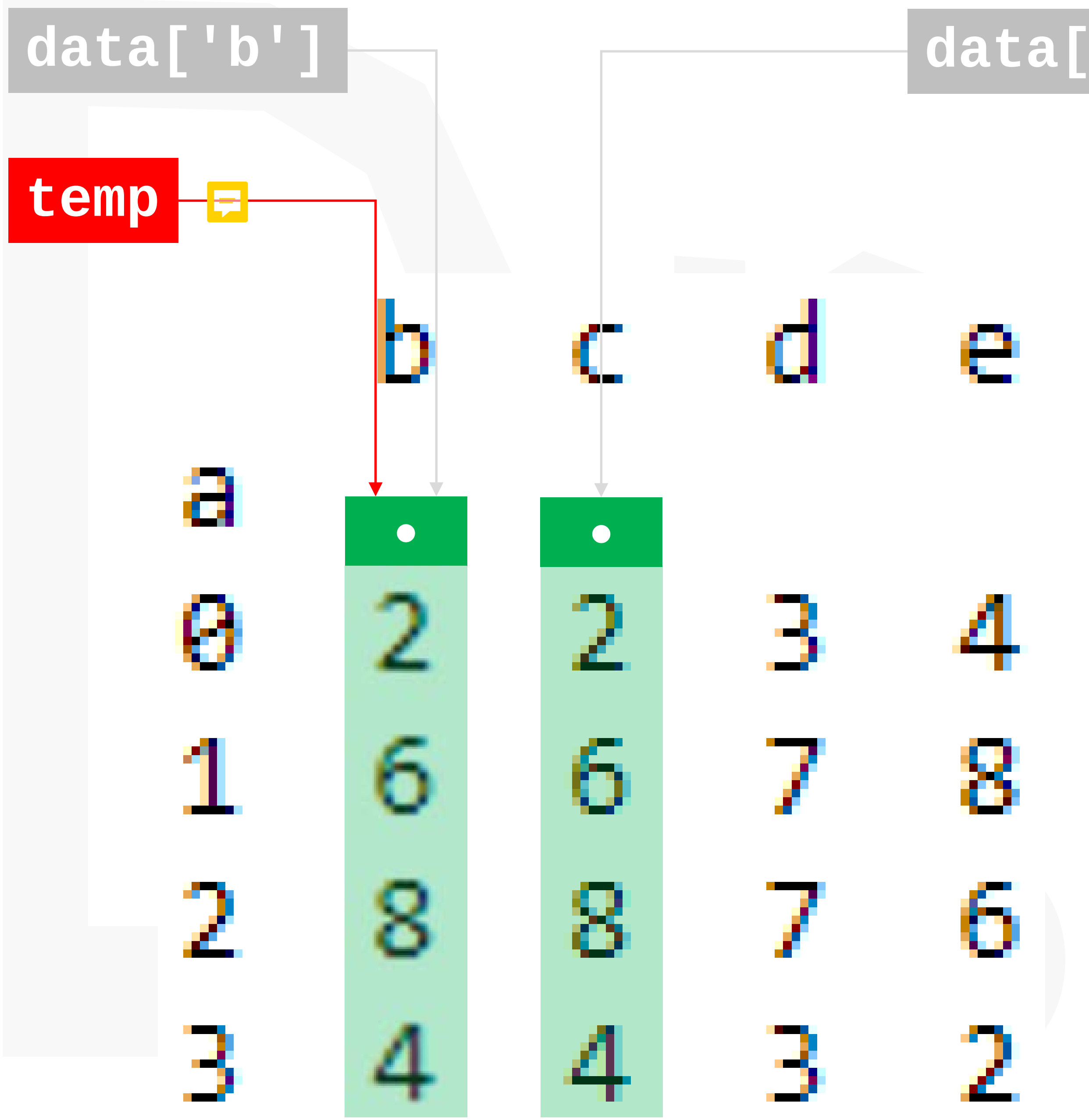
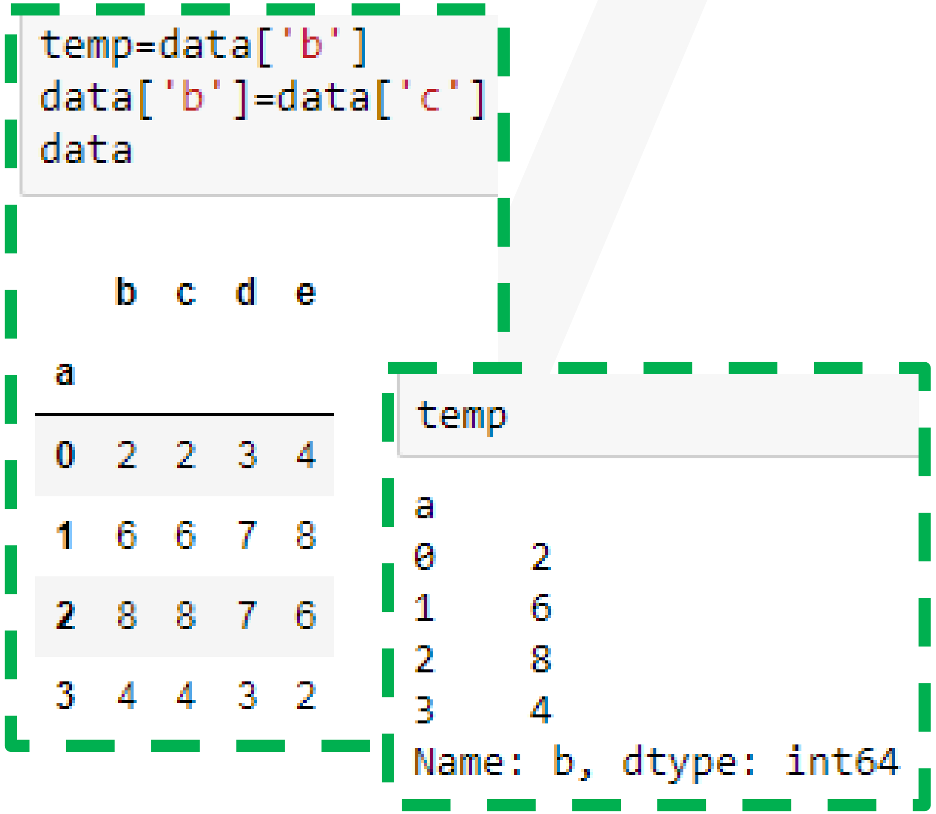


	b	c	d	e
a	●	●		
0	2	2	3	4
1	6	6	7	8
2	8	8	7	6
3	4	4	3	2

```
temp=data['b']
data['b']=data['c']
data['c']=temp
```



```
temp=data['b']
data['b']=data['c']
data
```

```
   b  c  d  e
a
0  2  2  3  4
1  6  6  7  8
2  8  8  7  6
3  4  4  3  2
```

```
temp
```

```
a
0    2
1    6
2    8
3    4
Name: b, dtype: int64
```

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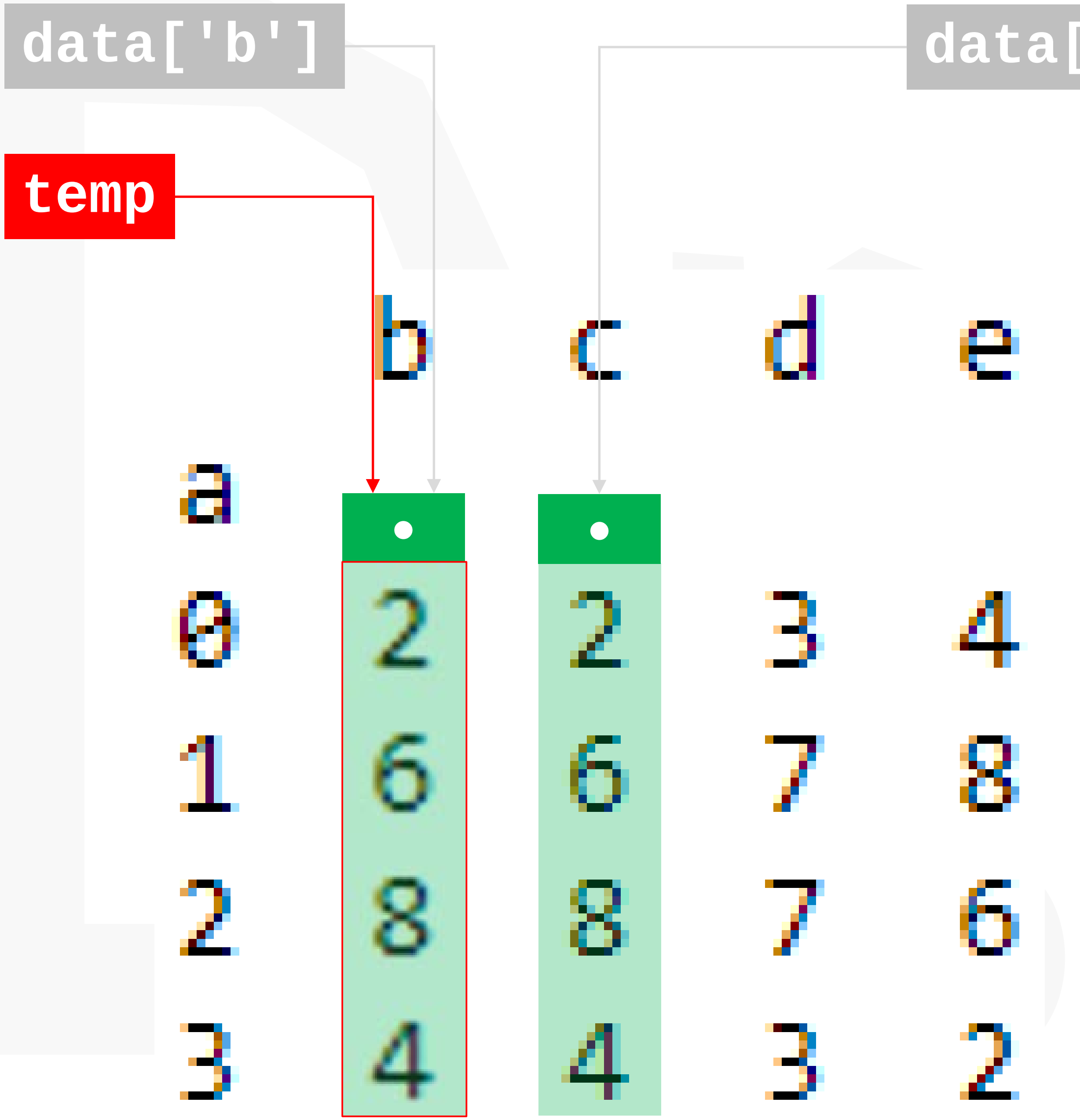

	b	c	d	e
a	•	•		
0	2	2	3	4
1	6	6	7	8
2	8	8	7	6
3	4	4	3	2

```
temp=data['b']
data['b']=data['c']
data['c']=temp
```

Dr. Z’s interpretation on the assignment to a view

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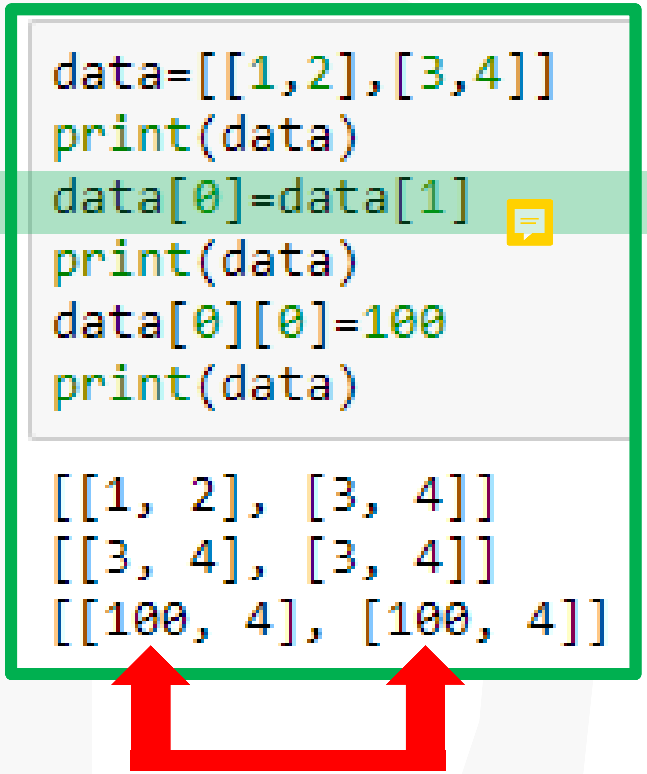
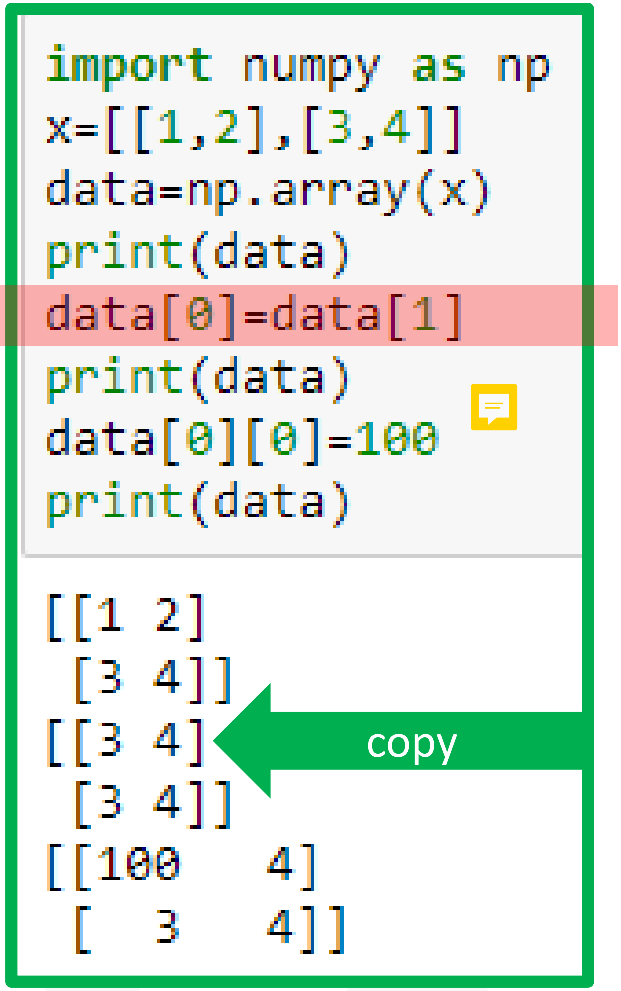


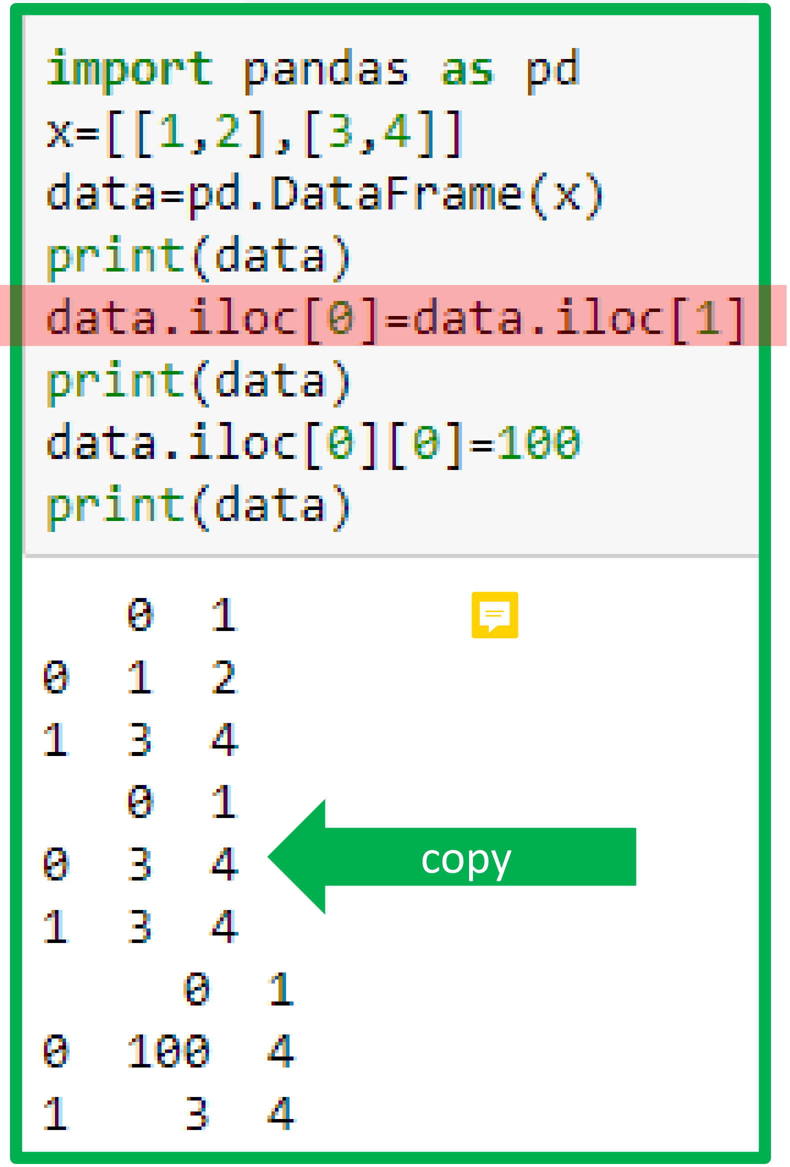
```
data=[[1,2],[3,4]]
print(data)
data[0]=data[1]
print(data)
data[0][0]=100
print(data)
```

```
[[1, 2], [3, 4]]
[[3, 4], [3, 4]]
[[100, 4], [100, 4]]
```



```
import numpy as np
x=[[1,2],[3,4]]
data=np.array(x)
print(data)
data[0]=data[1]
print(data)
data[0][0]=100
print(data)
```

```
[[1 2]
 [3 4]]
[[3 4]
 [3 4]]
[[100   4]
 [  3   4]]
```



```
import pandas as pd
x=[[1,2],[3,4]]
data=pd.DataFrame(x)
print(data)
data.iloc[0]=data.iloc[1]
print(data)
data.iloc[0][0]=100
print(data)
```

```
   0  1
0  1  2
1  3  4
   0  1
0  3  4
1  3  4
     0  1
0  100  4
1    3  4
```

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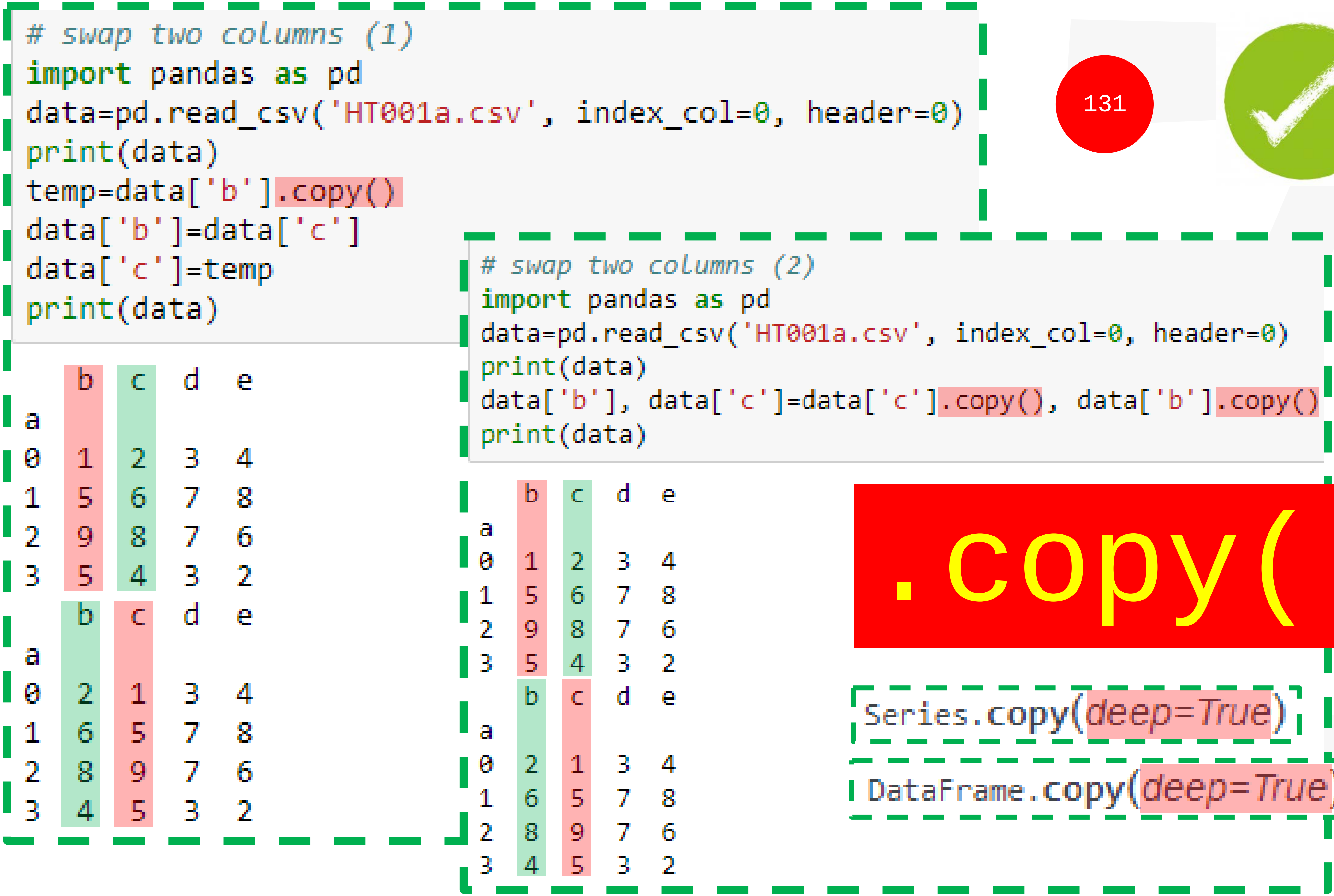

```
# swap two columns (1)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
temp=data['b'].copy()
data['b']=data['c']
data['c']=temp
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  2  1  3  4
1  6  5  7  8
2  8  9  7  6
3  4  5  3  2
```

```
# swap two columns (2)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data['b'], data['c']=data['c'].copy(), data['b'].copy()
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  2  1  3  4
1  6  5  7  8
2  8  9  7  6
3  4  5  3  2
```

.copy()

Series.copy(deep=True)

DataFrame.copy(deep=True)

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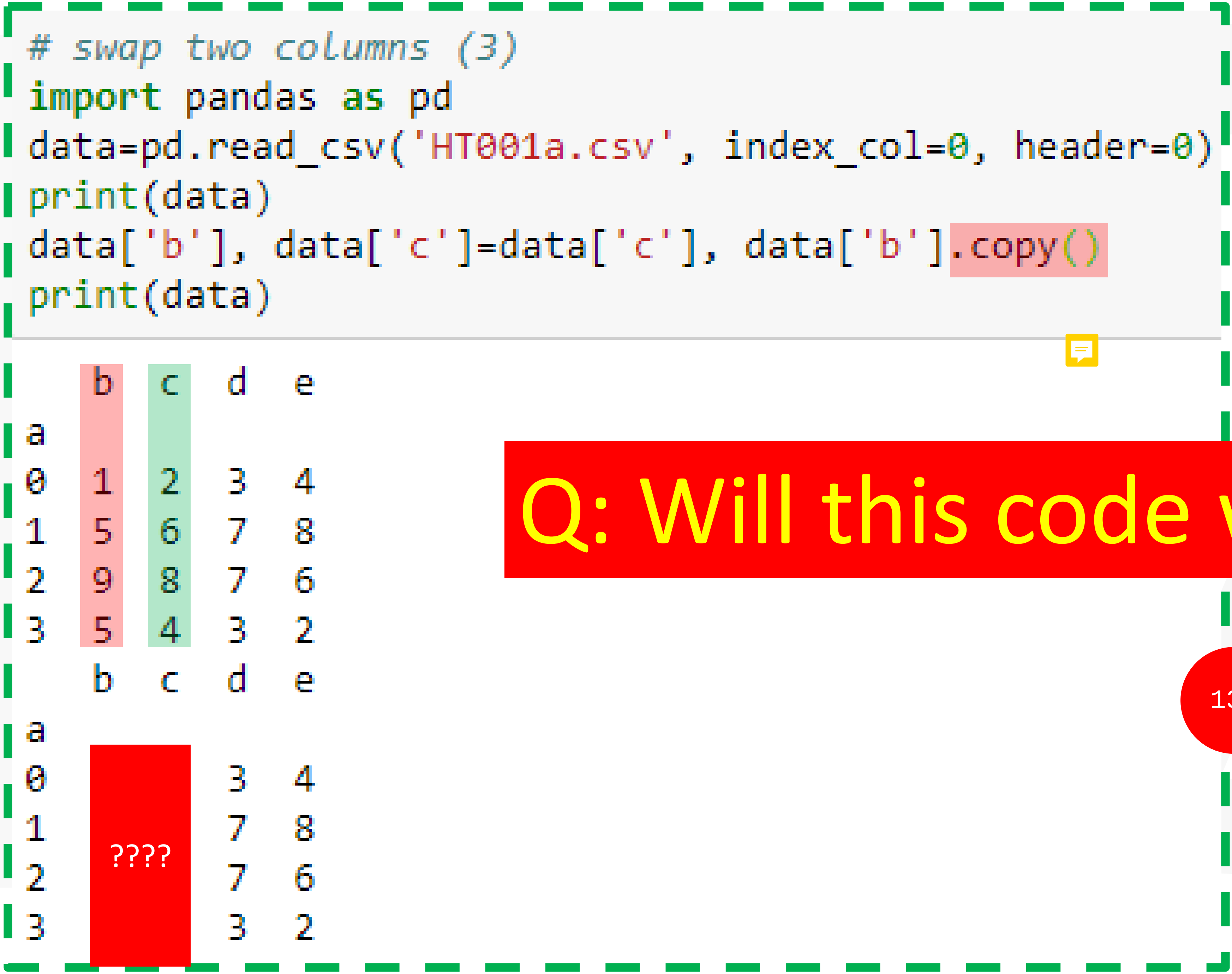

```
# swap two columns (3)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data['b'], data['c']=data['c'], data['b'].copy()
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0        3  4
1        7  8
2  ????  7  6
3        3  2
```

Q: Will this code work?

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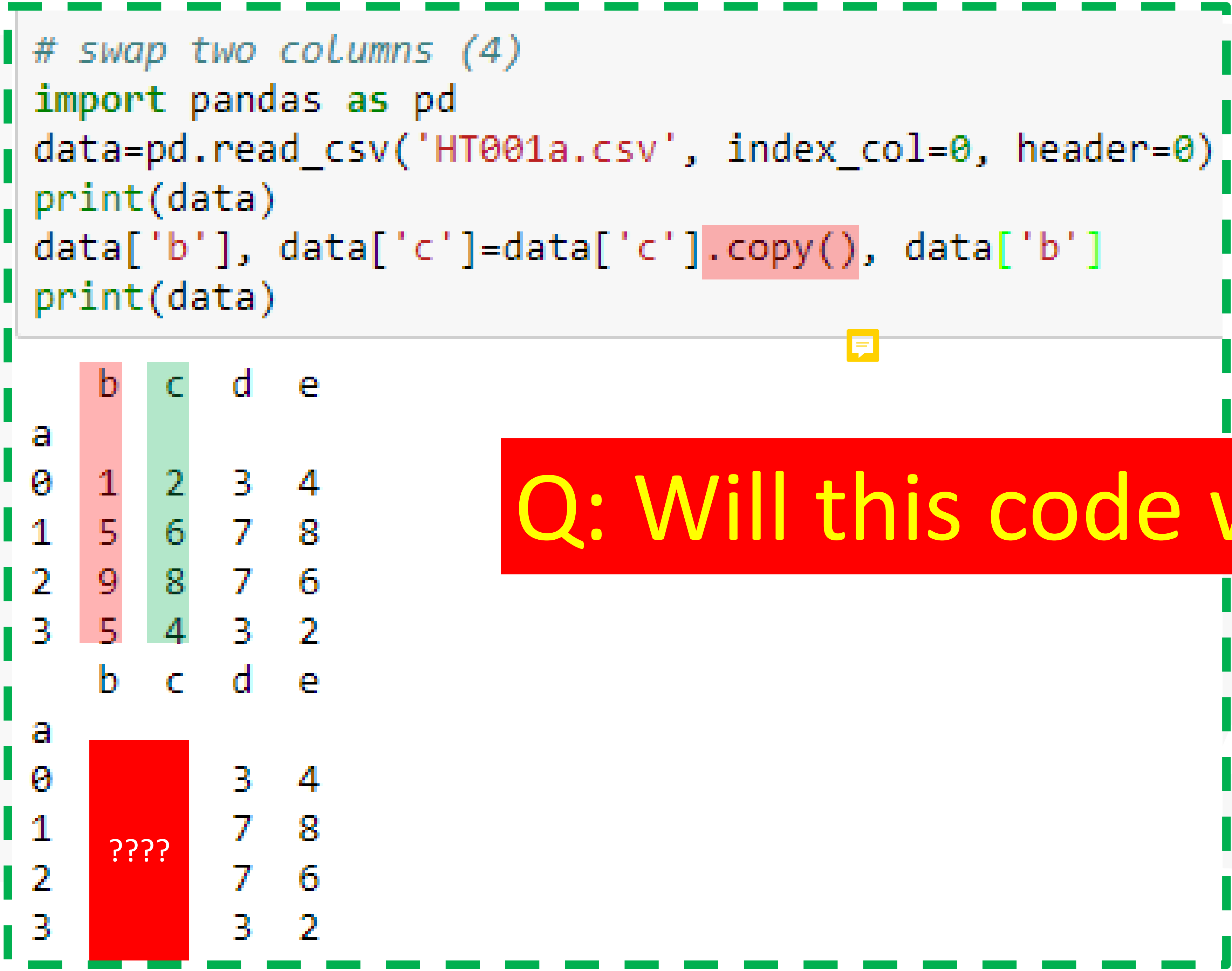

```
# swap two columns (4)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data['b'], data['c']=data['c'].copy(), data['b']
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0        3  4
1  ????  7  8
2        7  6
3        3  2
```

Q: Will this code work?

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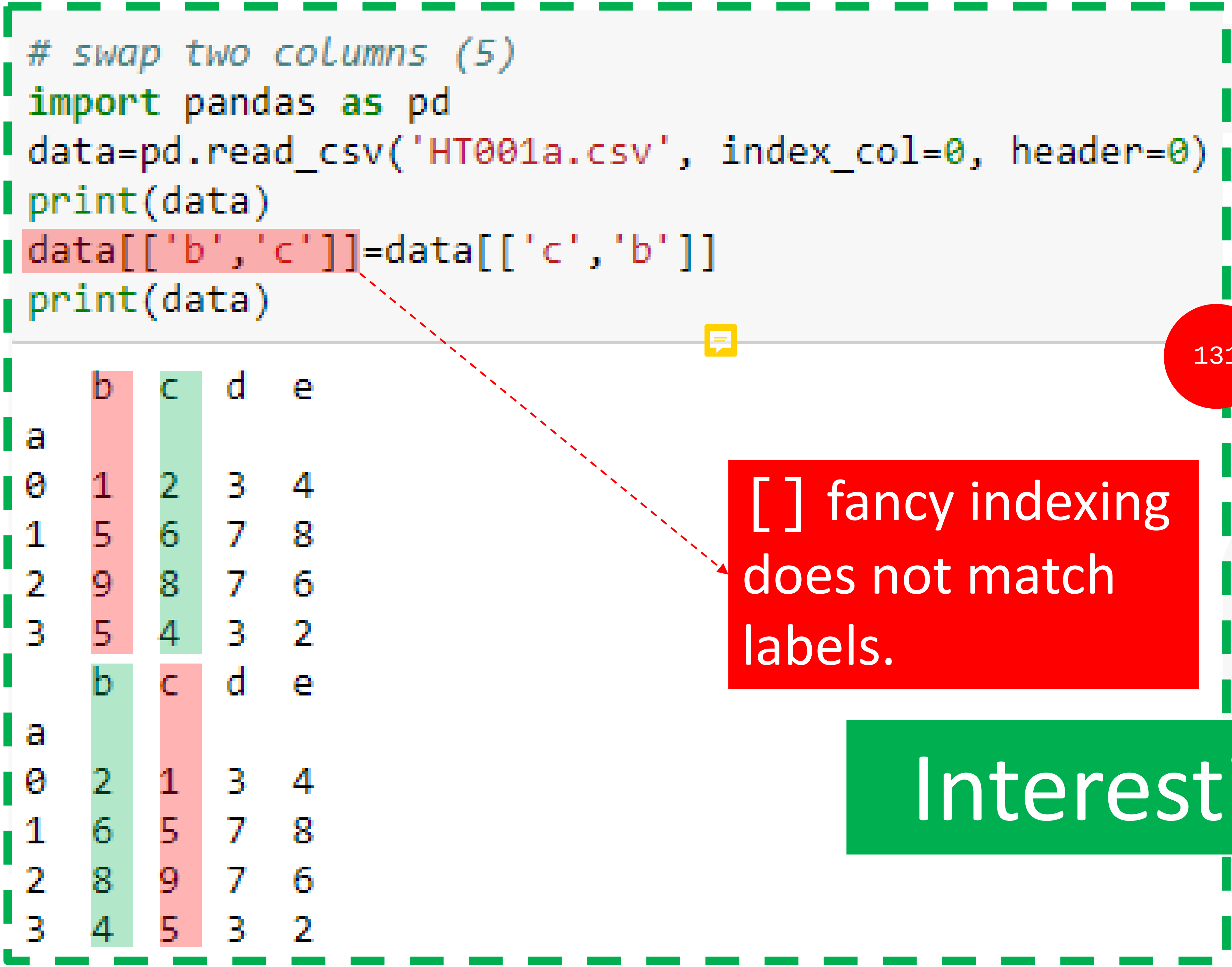

```
# swap two columns (5)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data[['b','c']]=data[['c','b']]
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  2  1  3  4
1  6  5  7  8
2  8  9  7  6
3  4  5  3  2
```

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[ ] fancy indexing does not match labels.

Interesting...

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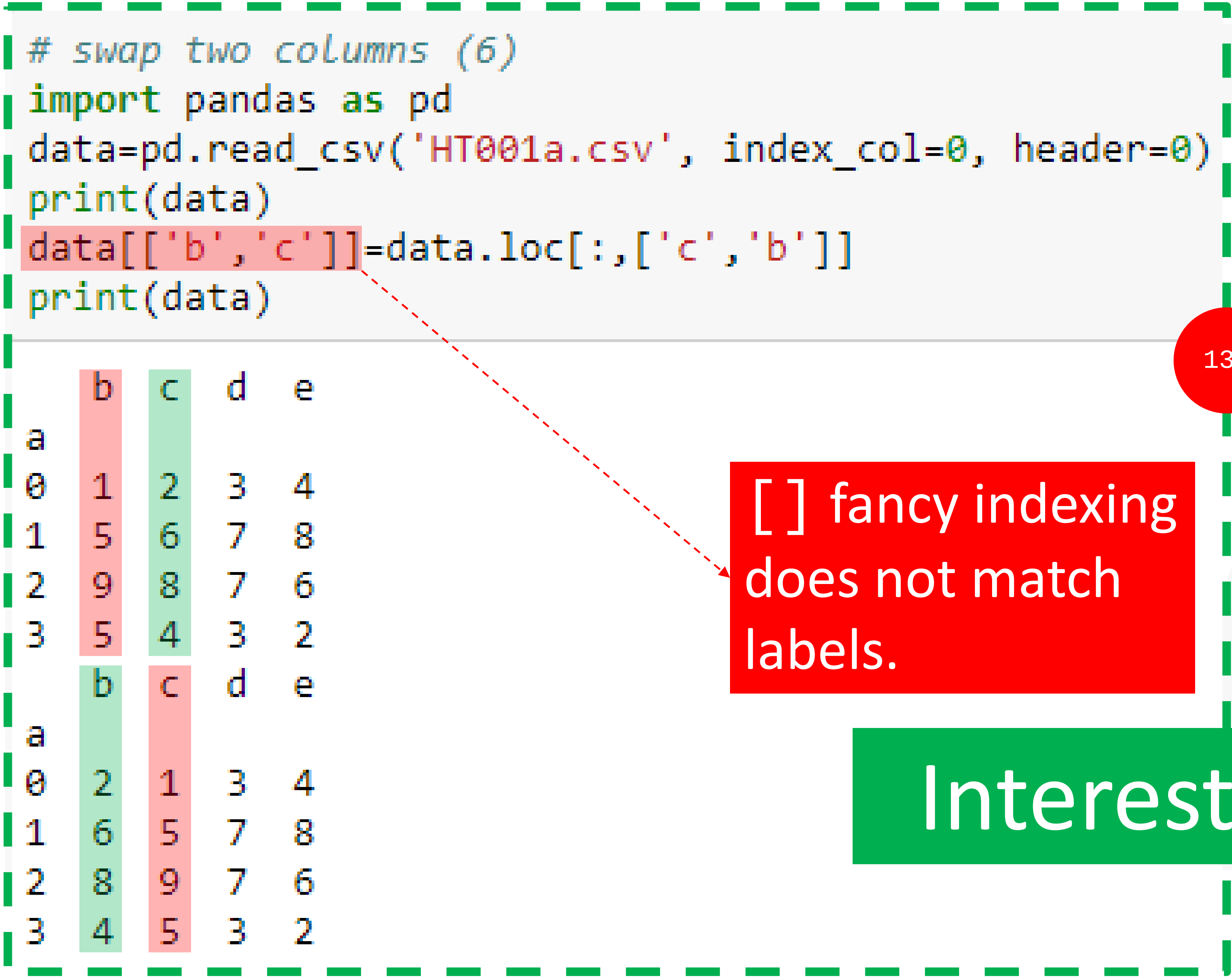

```
# swap two columns (6)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data[['b','c']]=data.loc[:,['c','b']]
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  2  1  3  4
1  6  5  7  8
2  8  9  7  6
3  4  5  3  2
```

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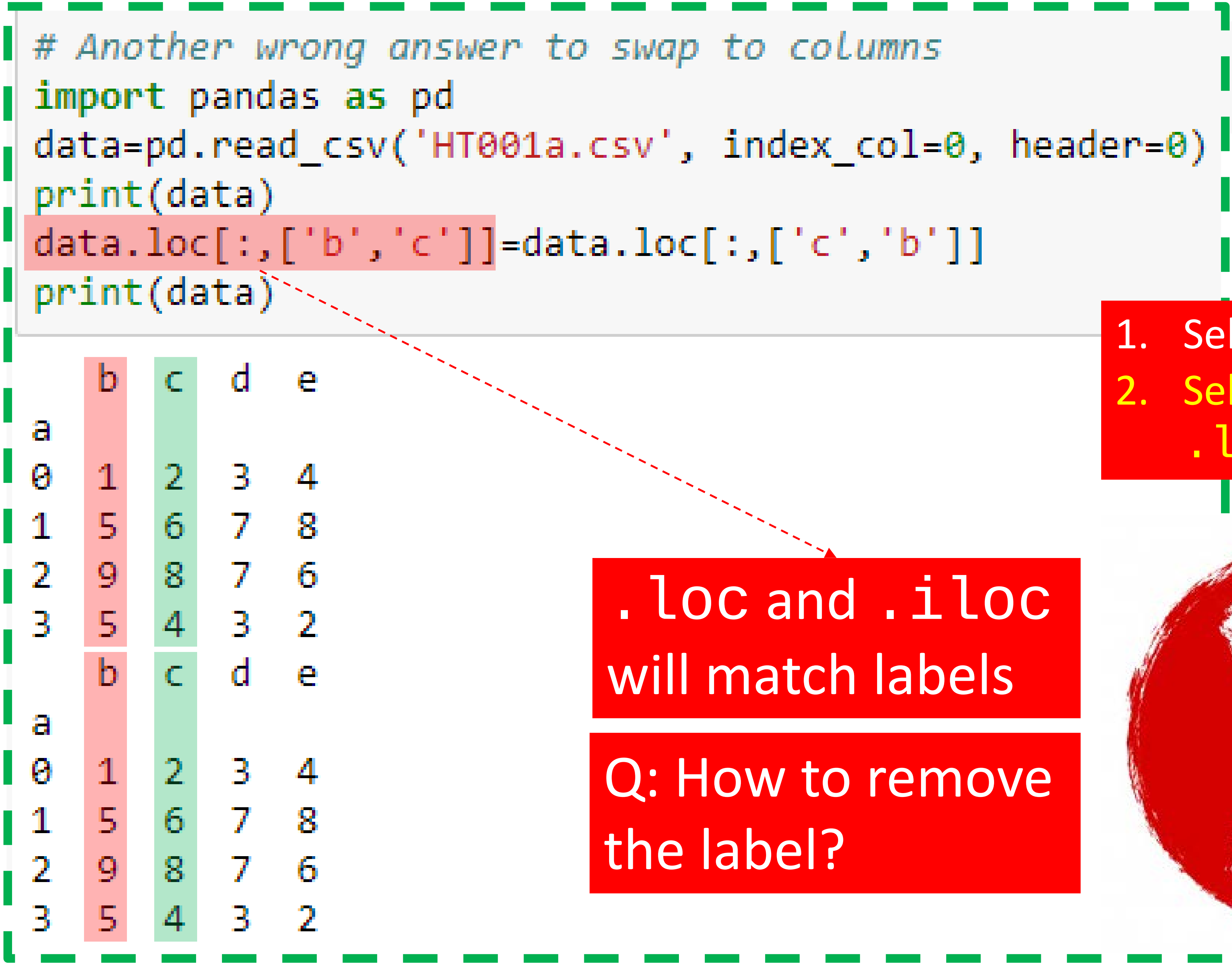
[ ] fancy indexing does not match labels.

✓

Interesting...



```
# Another wrong answer to swap to columns
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.loc[:,['b','c']]=data.loc[:,['c','b']]
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

1. Select data via [ ]
2. Select data via .loc or .iloc

.loc and .iloc will match labels

Q: How to remove the label?

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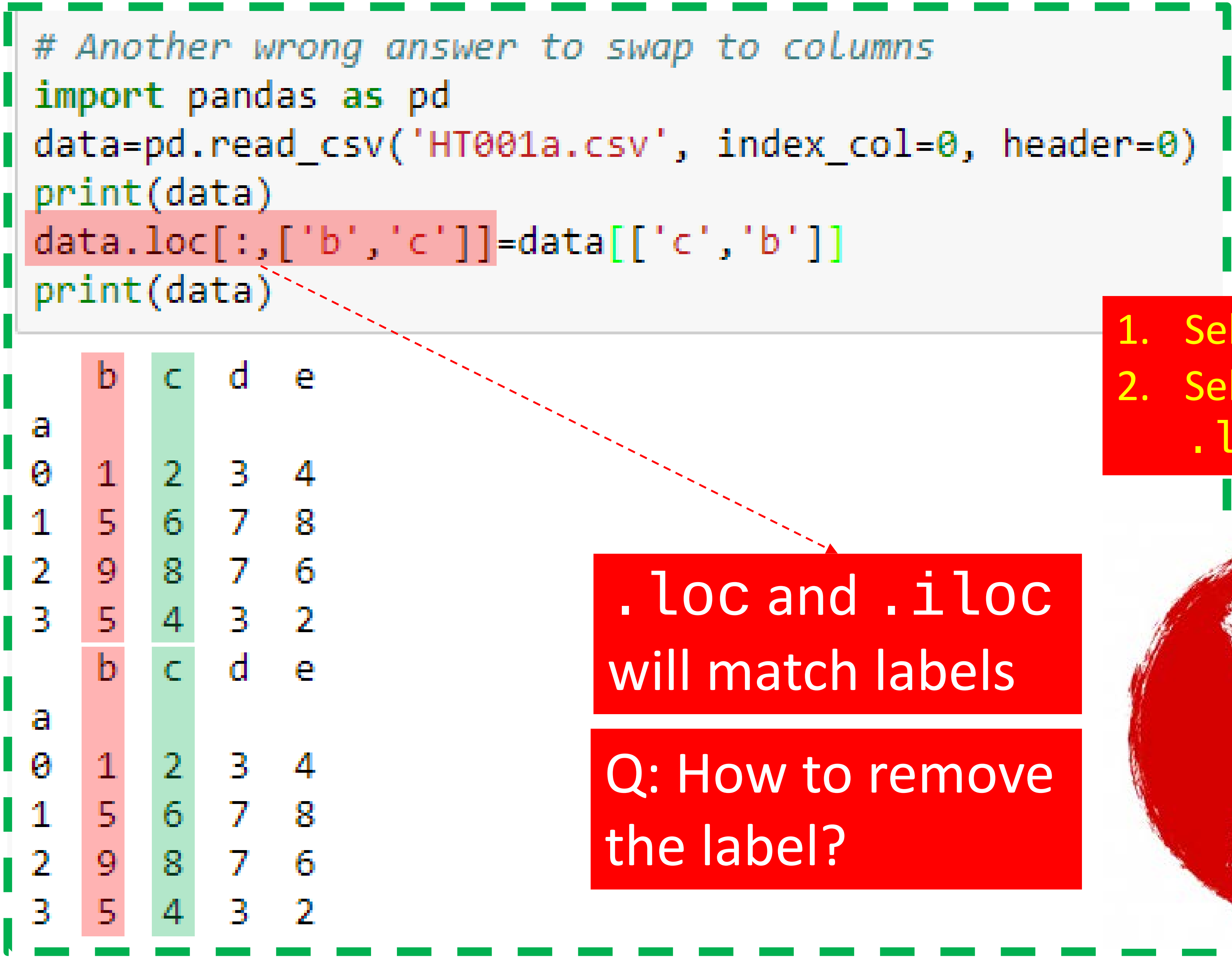

```
# Another wrong answer to swap to columns
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.loc[:,['b','c']]=data[['c','b']]
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

1. Select data via [ ]
2. Select data via .loc or .iloc

.loc and .iloc will match labels

Q: How to remove the label?

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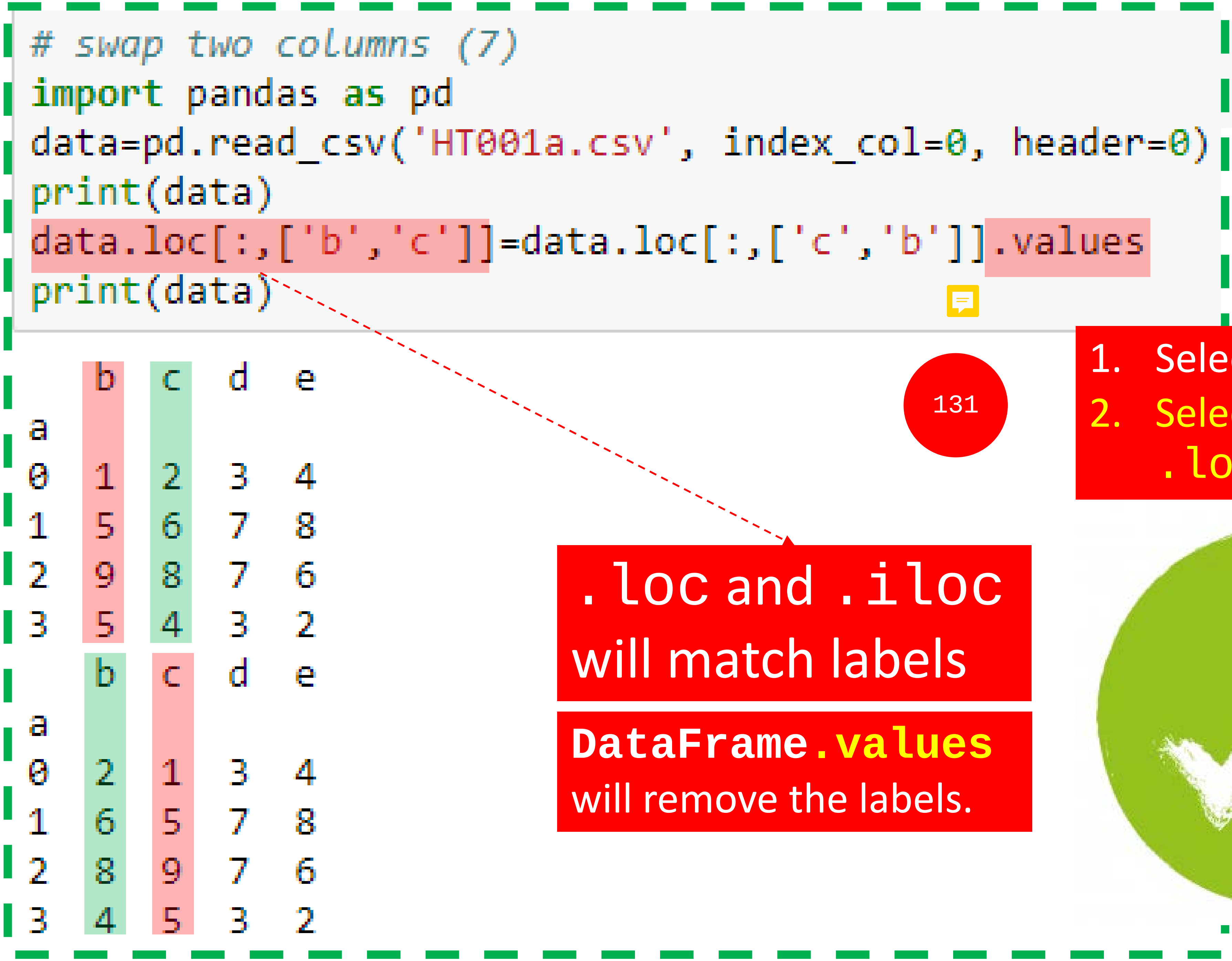

```
# swap two columns (7)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.loc[:,['b','c']]=data.loc[:,['c','b']].values
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  2  1  3  4
1  6  5  7  8
2  8  9  7  6
3  4  5  3  2
```

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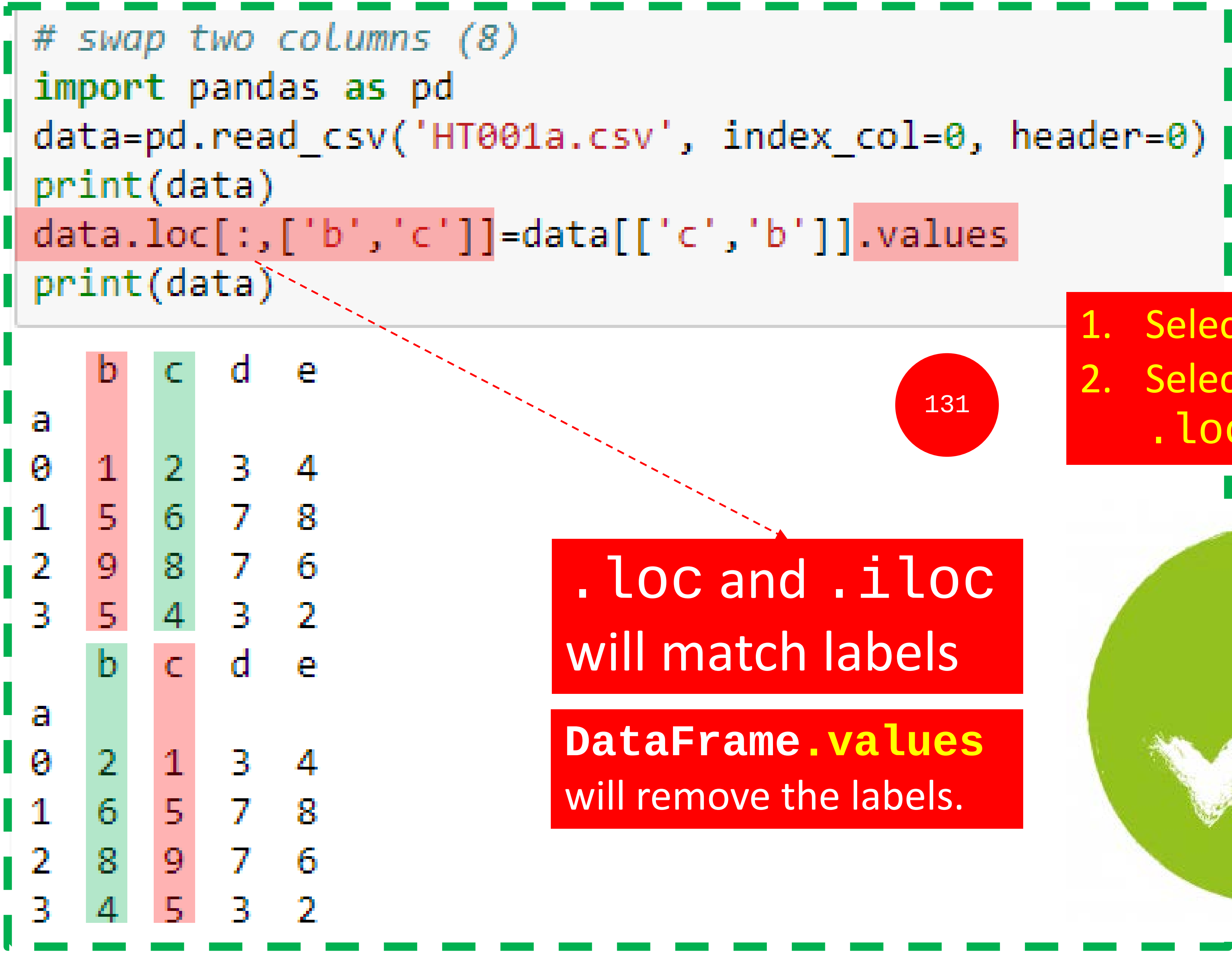
1. Select data via [ ]
2. Select data via `.loc` or `.iloc`

`.loc` and `.iloc` will match labels

`DataFrame.values` will remove the labels.



```
# swap two columns (8)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.loc[:,['b','c']]=data[['c','b']].values
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  2  1  3  4
1  6  5  7  8
2  8  9  7  6
3  4  5  3  2
```

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1. Select data via [ ]
2. Select data via `.loc` or `.iloc`

`.loc` and `.iloc` will match labels

`DataFrame.values` will remove the labels.

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Summary:

Use one command to swap two **columns** using column labels in `data`.

```
1. data['b'], data['c']=data['c'].copy(), data['b'].copy()
2. data['b'], data['c']=data['c'], data['b'].copy()
3. data[['b','c']]=data[['c','b']].copy()
4. data[['b','c']]=data.loc[:,['c','b']].copy()
5. data.loc[:,['b','c']]=data.loc[:,['c','b']].values.copy()
6. data.loc[:,['b','c']]=data[['c','b']].values.copy()
```

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Dr. Z: ⇨Better to use `.copy()`.

How about rows?

Use one command to swap two **rows** in data.

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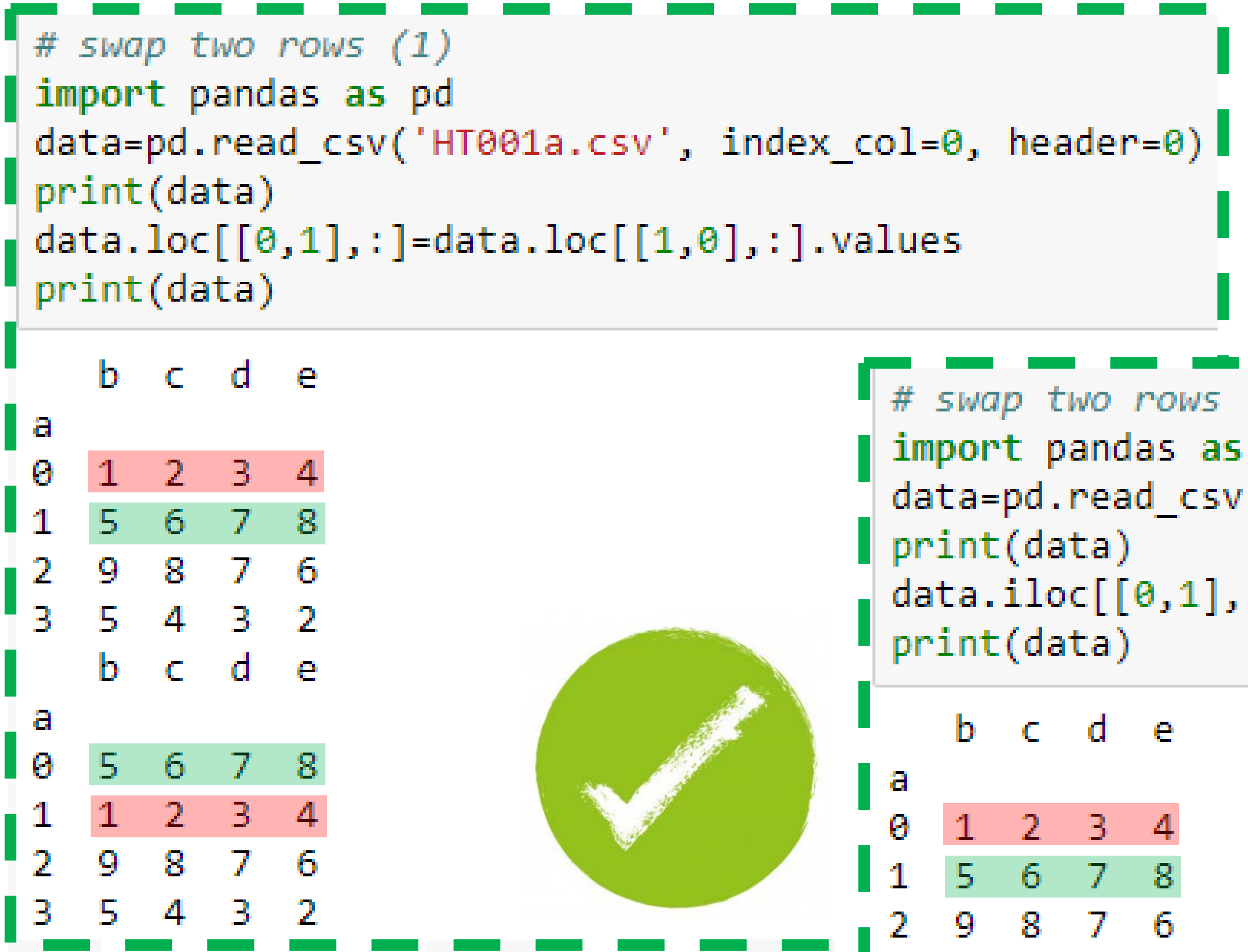
1. **Label-based indexing/slicing**

```
data.loc[[0,1],:]=data.loc[[1,0],:].values.copy()
```

2. **Position-based indexing/slicing**

```
data.iloc[[0,1],:]=data.iloc[[1,0],:].values.copy()
```

Dr. Z: ⇨Better to use **.copy()**.



```
# swap two rows (1)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.loc[[0,1],:]=data.loc[[1,0],:].values
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  5  6  7  8
1  1  2  3  4
2  9  8  7  6
3  5  4  3  2
```

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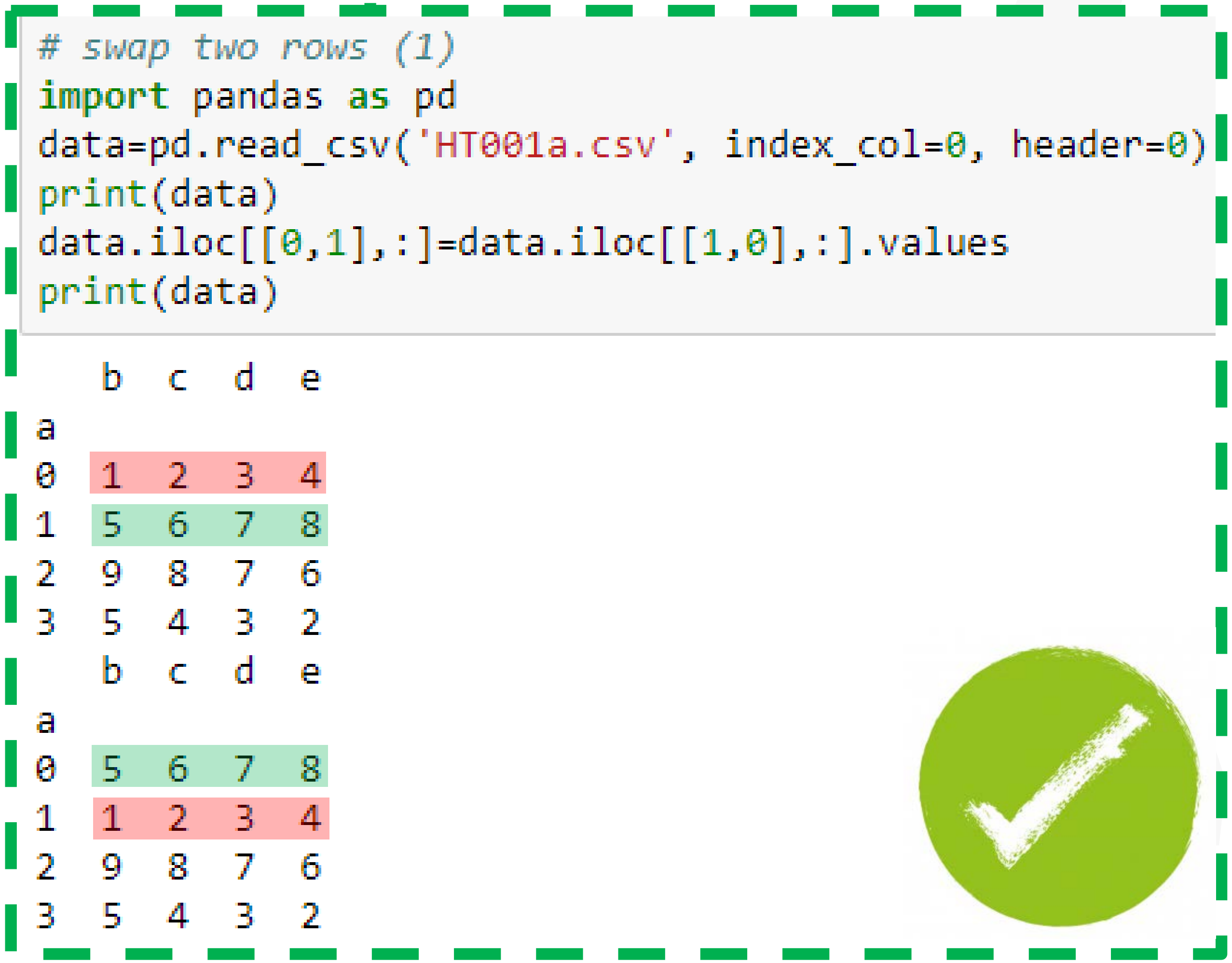

```
# swap two rows (1)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.iloc[[0,1],:]=data.iloc[[1,0],:].values
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  5  6  7  8
1  1  2  3  4
2  9  8  7  6
3  5  4  3  2
```

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HT007: Swap two rows/columns in **data**

✓ label-based indexing

Use one command

```
✓ data(:,{'b','c'})=data(:,{'c','b'})
✓ data{:,{'b','c'}}=data{:,{'c','b'}}
```

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```
× data(:,{'b','c'})=data{:,{'c','b'}}
```

Right hand side of an assignment into a table must be another table or a cell array.

```
× data{:,{'b','c'}}=data(:,{'c','b'})
```

The following error occurred converting from table to double:

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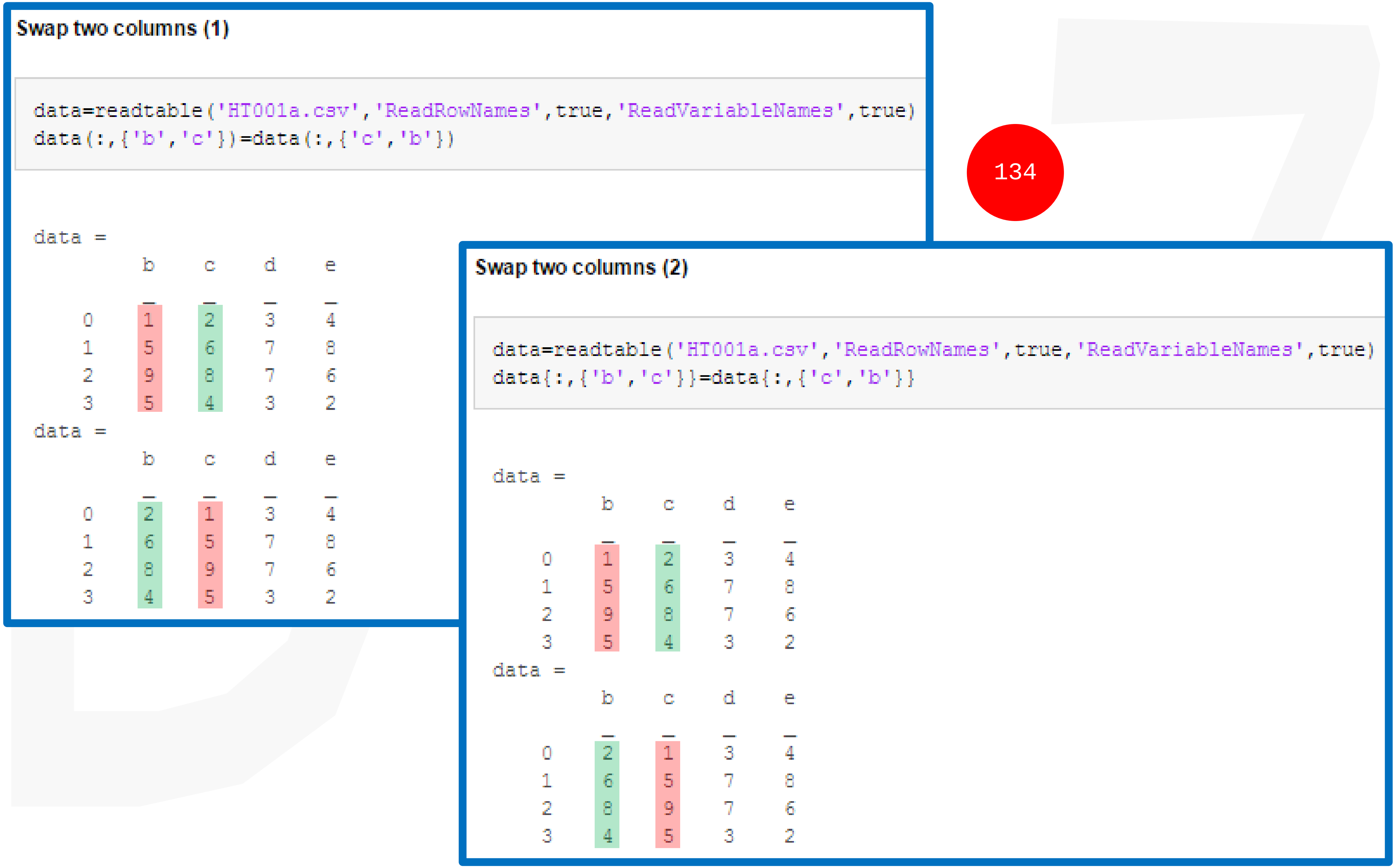

Swap two columns (1)

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data(:,{'b','c'})=data(:,{'c','b'})
```

```
data = 
          b    c    d    e
          _    _    _    _
    0     1    2    3    4
    1     5    6    7    8
    2     9    8    7    6
    3     5    4    3    2
data = 
          b    c    d    e
          _    _    _    _
    0     2    1    3    4
    1     6    5    7    8
    2     8    9    7    6
    3     4    5    3    2
```

Swap two columns (2)

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data{:,{'b','c'}}=data{:,{'c','b'}}
```

```
data = 
          b    c    d    e
          _    _    _    _
    0     1    2    3    4
    1     5    6    7    8
    2     9    8    7    6
    3     5    4    3    2
data = 
          b    c    d    e
          _    _    _    _
    0     2    1    3    4
    1     6    5    7    8
    2     8    9    7    6
    3     4    5    3    2
```

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How about rows?

✓ label-based indexing

Use one command

```
✓ data({'0','1'},:)=data({'1','0'},:)
✓ data{{'0','1'},:}=data{{'1','0'},:}
```

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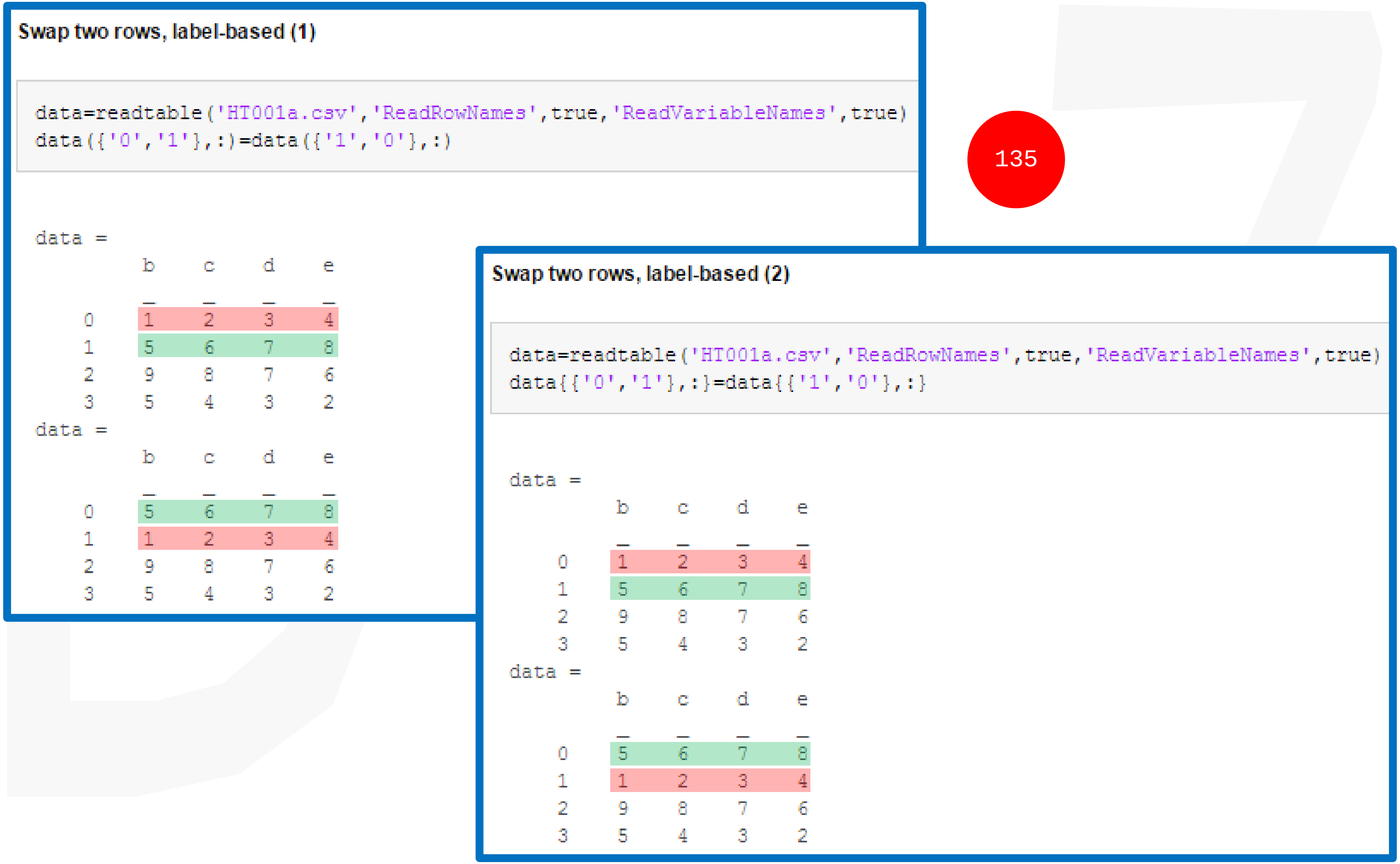

Swap two rows, label-based (1)

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data({'0','1'},:)=data({'1','0'},:)
```

```
data =
          b    c    d    e

          _    _    _    _
    0     1    2    3    4
    1     5    6    7    8
    2     9    8    7    6
    3     5    4    3    2
data =
          b    c    d    e

          _    _    _    _
    0     5    6    7    8
    1     1    2    3    4
    2     9    8    7    6
    3     5    4    3    2
```

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Swap two rows, label-based (2)

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
data{{'0','1'},:}=data{{'1','0'},:}
```

```
data =
          b    c    d    e

          _    _    _    _
    0     1    2    3    4
    1     5    6    7    8
    2     9    8    7    6
    3     5    4    3    2
data =
          b    c    d    e

          _    _    _    _
    0     5    6    7    8
    1     1    2    3    4
    2     9    8    7    6
    3     5    4    3    2
```

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How about using position-based indexing?

- Swap two columns

✓ `data(:,[1,2])=data(:,[2,1])`
✓ `data{:,[1,2]}=data{:,[2,1]}`

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- Swap two rows

✓ `data([1,2],:)=data([2,1],:)`
✓ `data{[1,2],:}=data{[2,1],:}`

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Use one command

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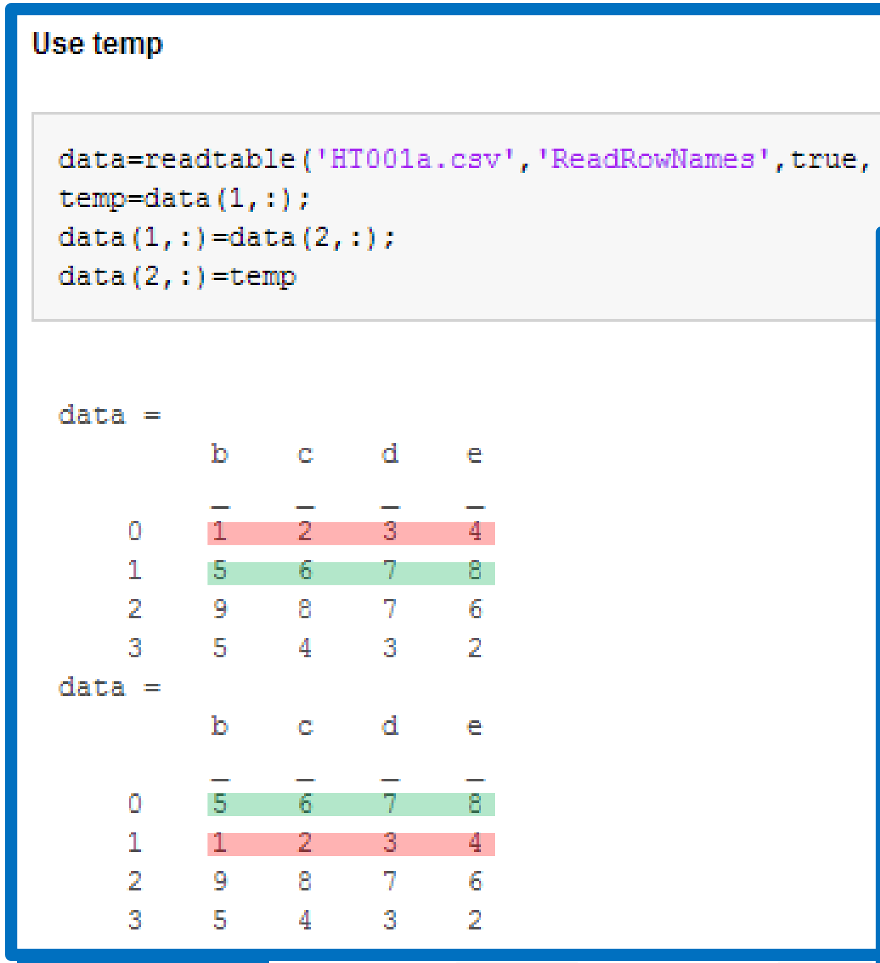

Use temp

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
temp=data(1,:);
data(1,:)=data(2,:);
data(2,:)=temp
```

```
data =
          b    c    d    e
          _    _    _    _
     0    1    2    3    4
     1    5    6    7    8
     2    9    8    7    6
     3    5    4    3    2
data =
          b    c    d    e
          _    _    _    _
     0    5    6    7    8
     1    1    2    3    4
     2    9    8    7    6
     3    5    4    3    2
```

✓ ( )
✓ {}

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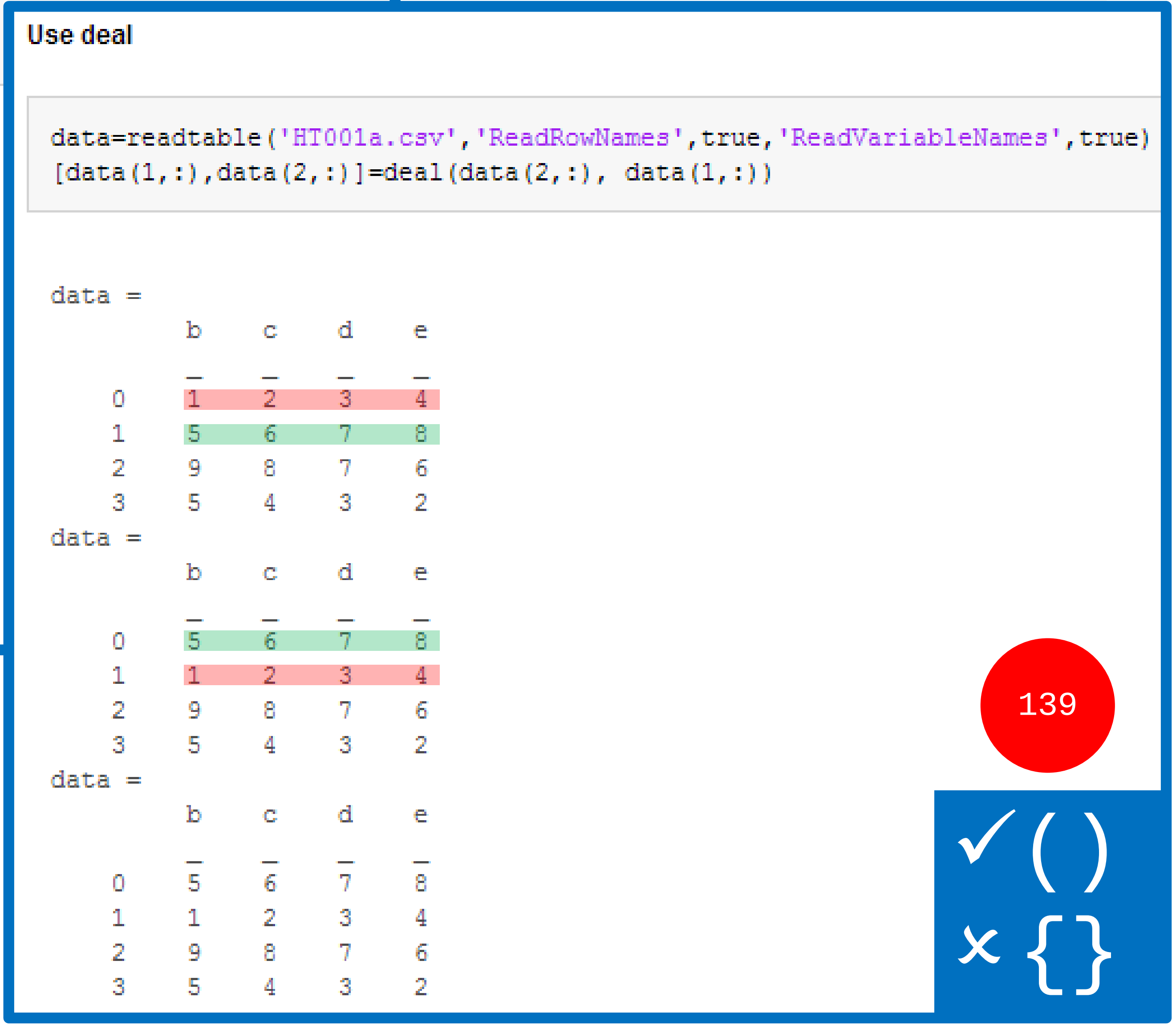

Use deal

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
[data(1,:),data(2,:)]=deal(data(2,:), data(1,:))
```

```
data =
          b    c    d    e
          _    _    _    _
     0    1    2    3    4
     1    5    6    7    8
     2    9    8    7    6
     3    5    4    3    2
data =
          b    c    d    e
          _    _    _    _
     0    5    6    7    8
     1    1    2    3    4
     2    9    8    7    6
     3    5    4    3    2
data =
          b    c    d    e
          _    _    _    _
     0    5    6    7    8
     1    1    2    3    4
     2    9    8    7    6
     3    5    4    3    2
```

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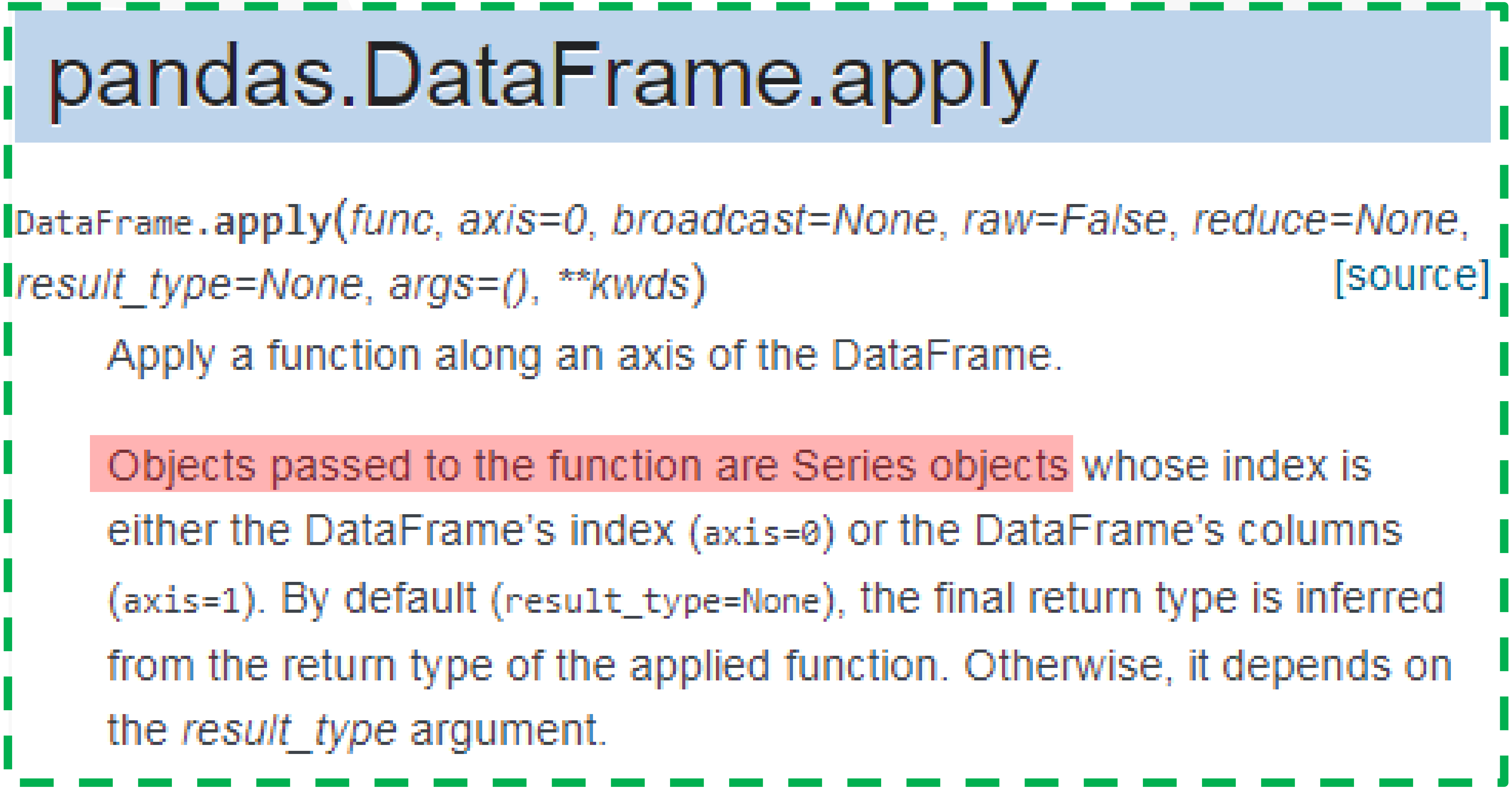
✓ ( )
× {}

HT008: Apply a function to each row/column of `data`



pandas.DataFrame.apply

`DataFrame.apply`(*func*, *axis=0*, *broadcast=None*, *raw=False*, *reduce=None*, *result_type=None*, *args=()*, ***kwds*) [source]

Apply a function along an axis of the DataFrame.

Objects passed to the function are Series objects whose index is either the DataFrame's index (`axis=0`) or the DataFrame's columns (`axis=1`). By default (`result_type=None`), the final return type is inferred from the return type of the applied function. Otherwise, it depends on the *result_type* argument.

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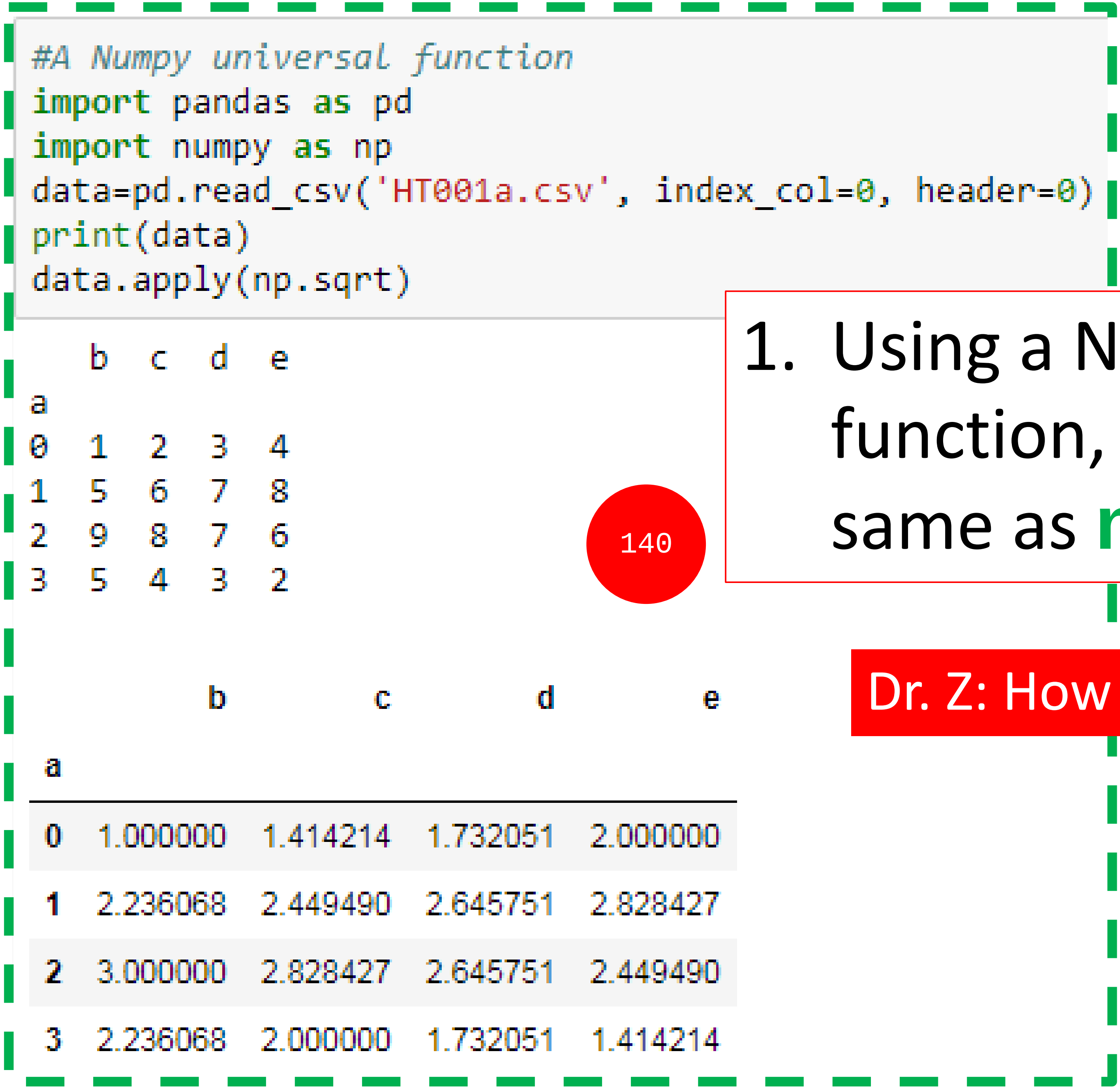

```
#A Numpy universal function
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.apply(np.sqrt)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

	b	c	d	e
a				
0	1.000000	1.414214	1.732051	2.000000
1	2.236068	2.449490	2.645751	2.828427
2	3.000000	2.828427	2.645751	2.449490
3	2.236068	2.000000	1.732051	1.414214

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1. Using a Numpy universal function, **fun**, (in the case same as **np.fun(data)**)

Dr. Z: How about math.sqrt?

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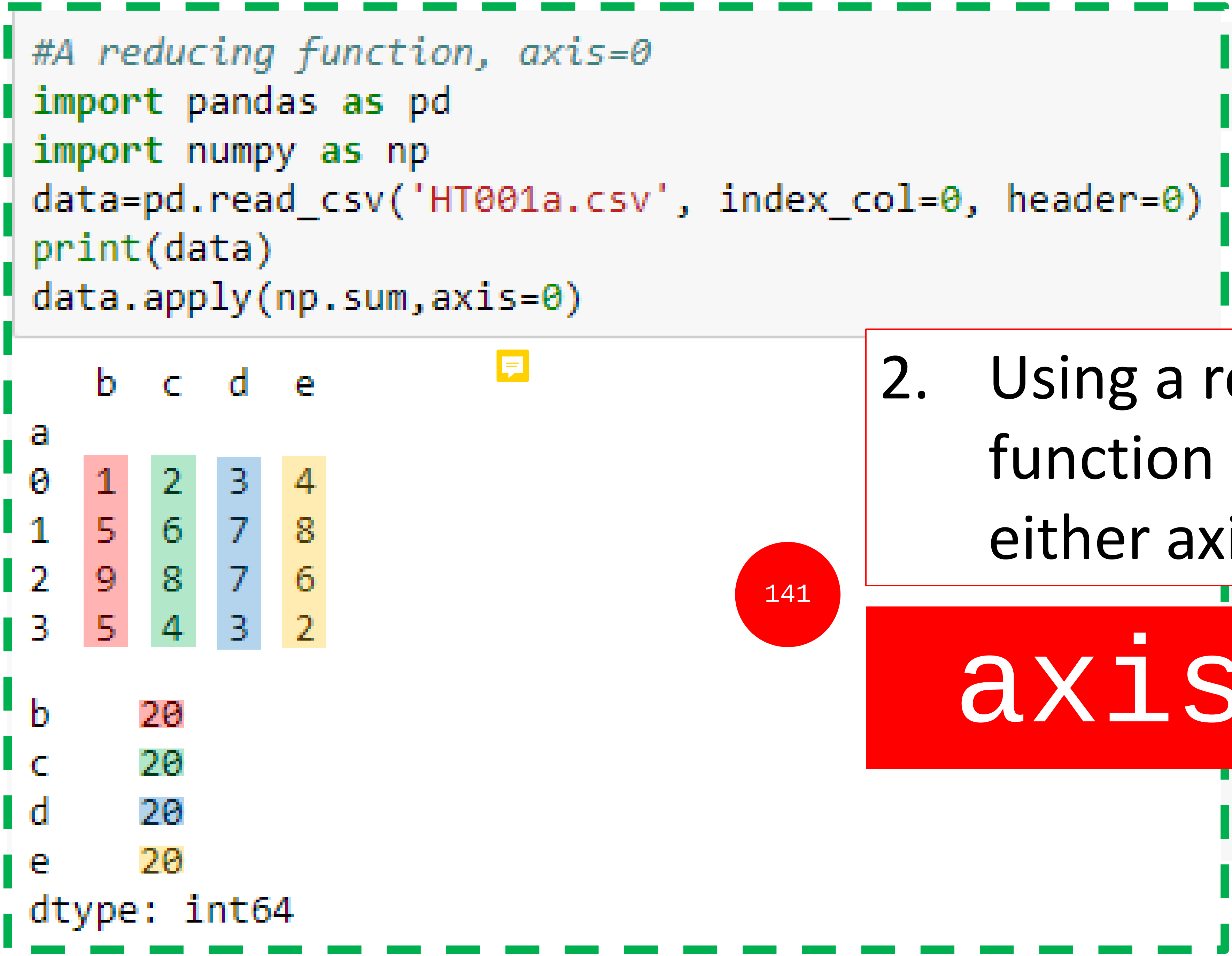

```
#A reducing function, axis=0
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.apply(np.sum,axis=0)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2

b    20
c    20
d    20
e    20
dtype: int64
```

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2. Using a reducing function on either axis

axis=0

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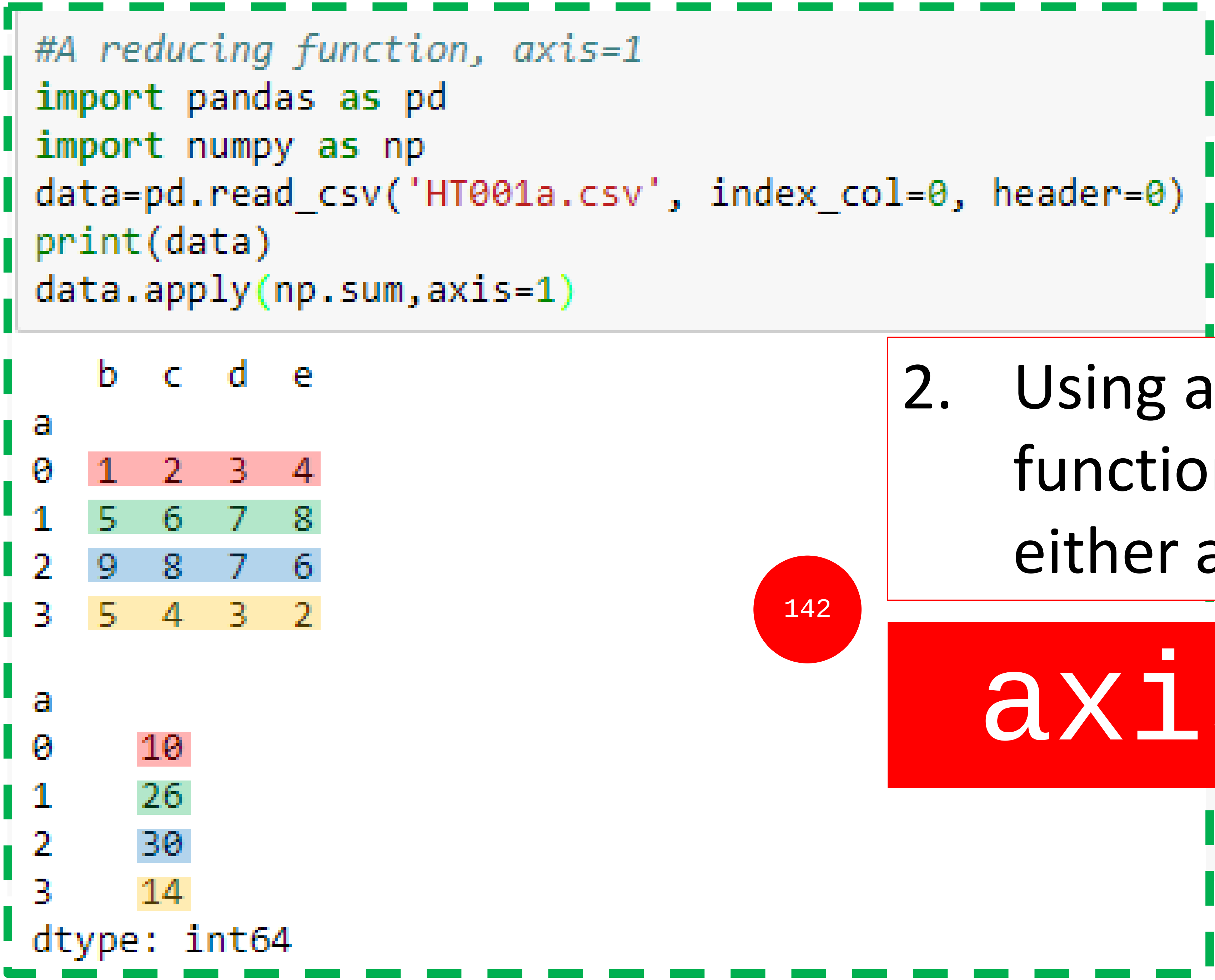

```
#A reducing function, axis=1
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.apply(np.sum,axis=1)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2

a
0    10
1    26
2    30
3    14
dtype: int64
```

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2. Using a reducing function on either axis

axis=1

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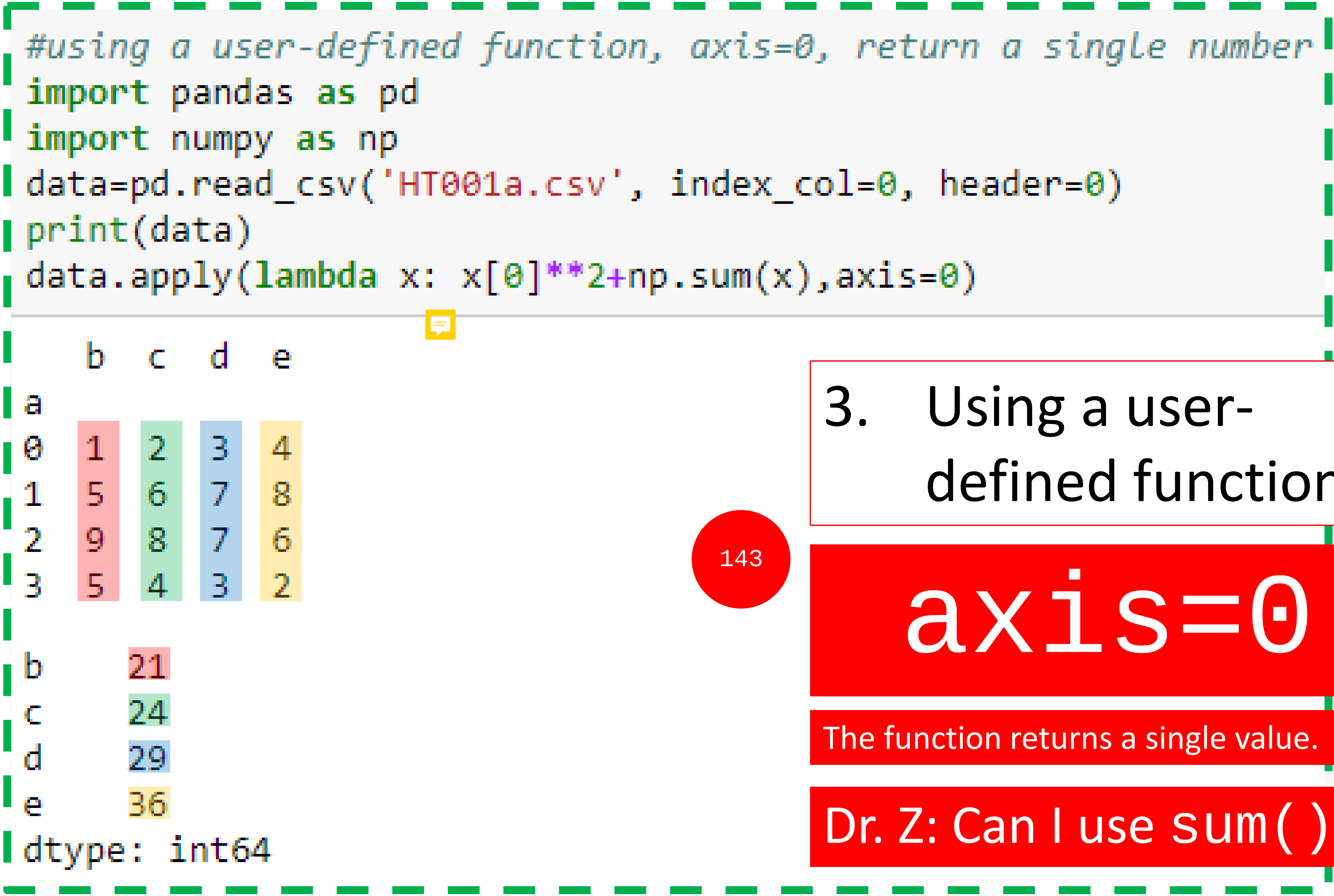

```
#using a user-defined function, axis=0, return a single number
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.apply(lambda x: x[0]**2+np.sum(x),axis=0)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2

b    21
c    24
d    29
e    36
dtype: int64
```

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3. Using a user-defined function

axis=0

The function returns a single value.

Dr. Z: Can I use sum( )?

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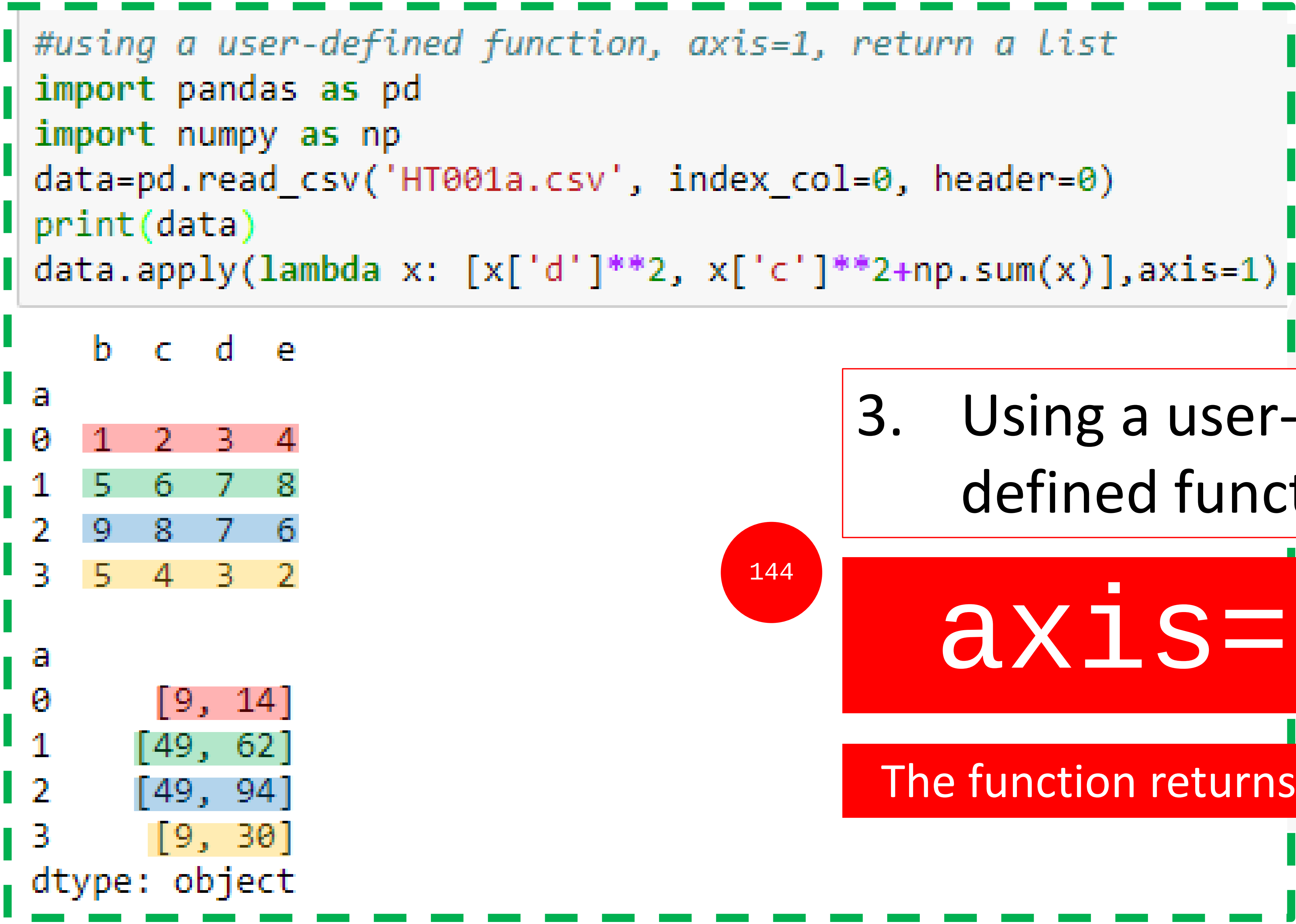

```
#using a user-defined function, axis=1, return a list
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.apply(lambda x: [x['d']**2, x['c']**2+np.sum(x)],axis=1)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2

a
0     [9, 14]
1    [49, 62]
2    [49, 94]
3     [9, 30]
dtype: object
```

3. Using a user-defined function

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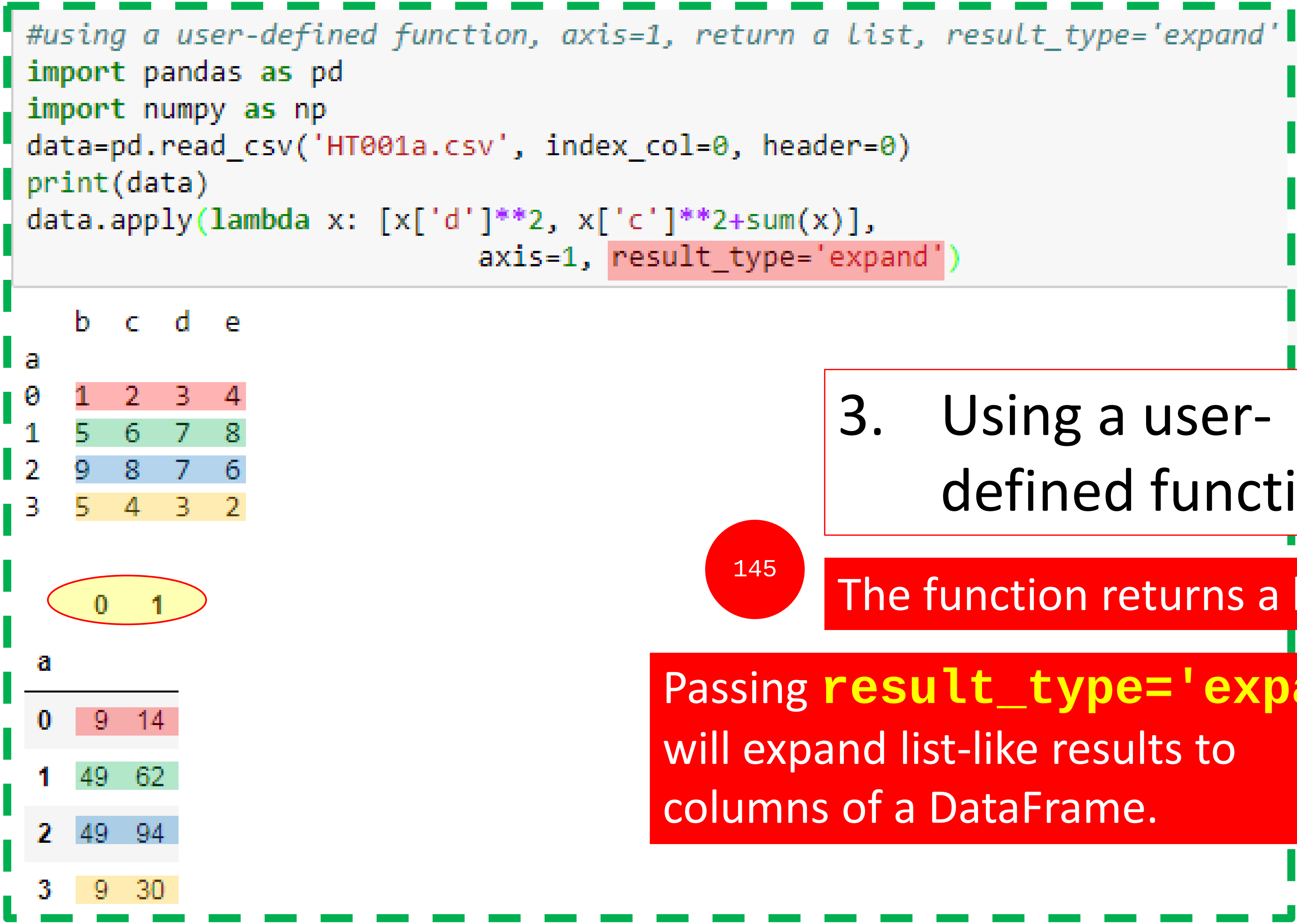
axis=1

The function returns a list.



```
#using a user-defined function, axis=1, return a list, result_type='expand'
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.apply(lambda x: [x['d']**2, x['c']**2+sum(x)],
                                axis=1, result_type='expand')
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

```
    0   1
a
0   9  14
1  49  62
2  49  94
3   9  30
```

3. Using a user-defined function

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The function returns a list.

Passing **result_type='expand'** will expand list-like results to columns of a DataFrame.

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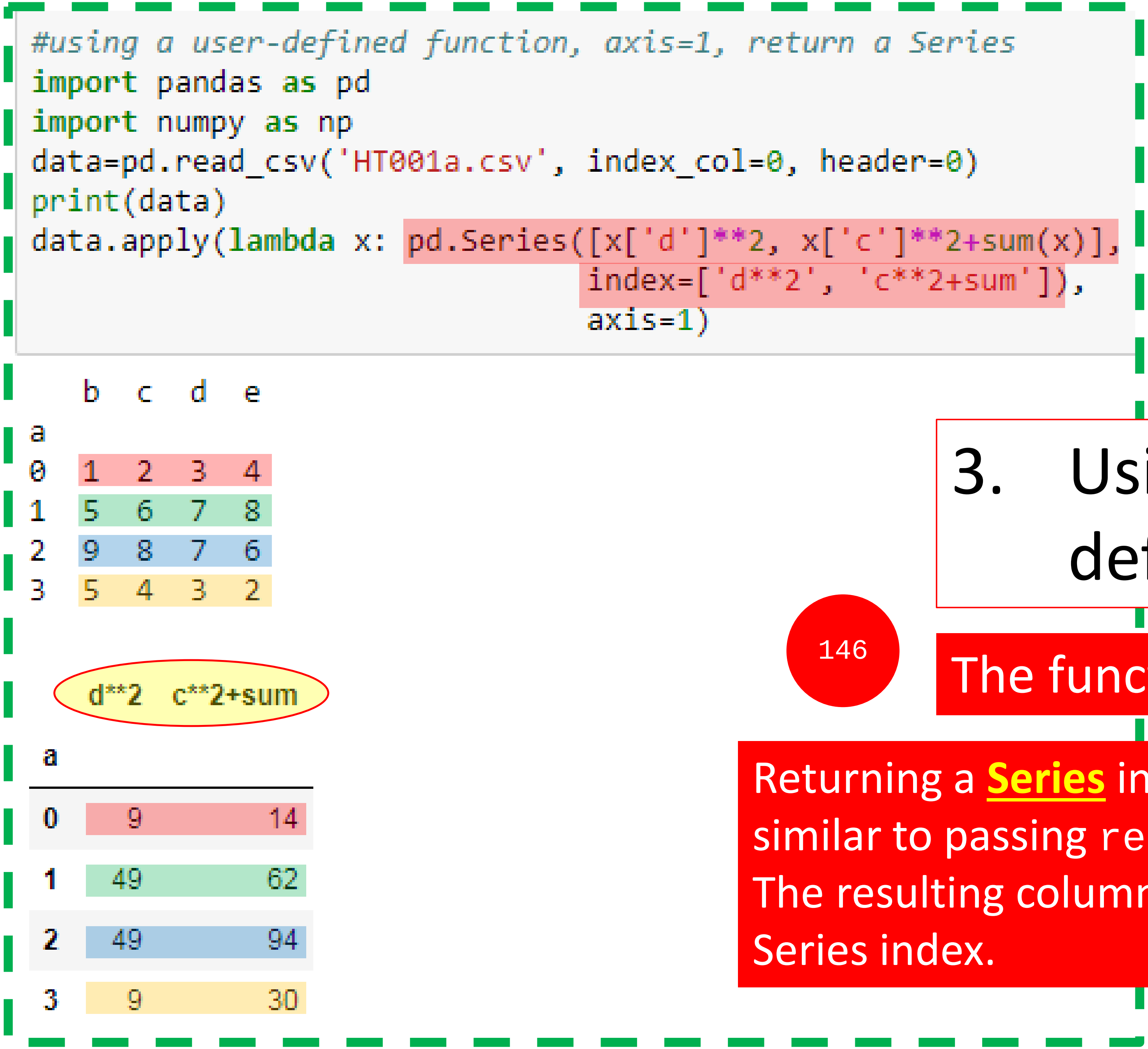

```
#using a user-defined function, axis=1, return a Series
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
data.apply(lambda x: pd.Series([x['d']**2, x['c']**2+sum(x)],
                               index=['d**2', 'c**2+sum']),
                               axis=1)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

```
   d**2  c**2+sum
a
0     9        14
1    49        62
2    49        94
3     9        30
```

3. Using a user-defined function

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The function returns a list.

Returning a **Series** inside the function is similar to passing `result_type='expand'`. The resulting column names will be the Series index.

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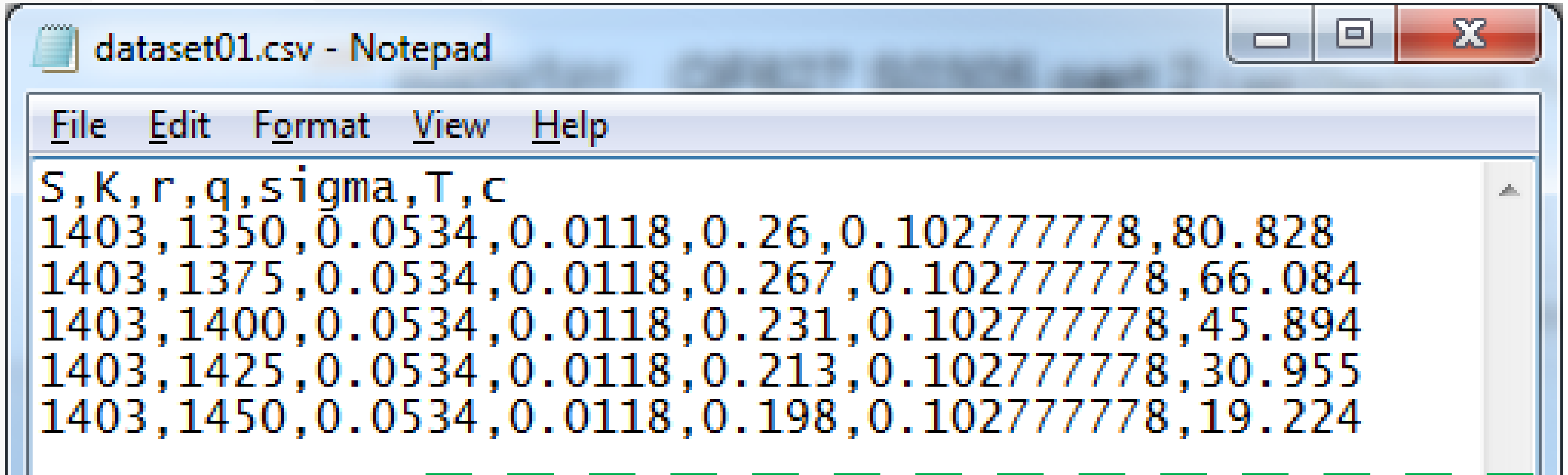
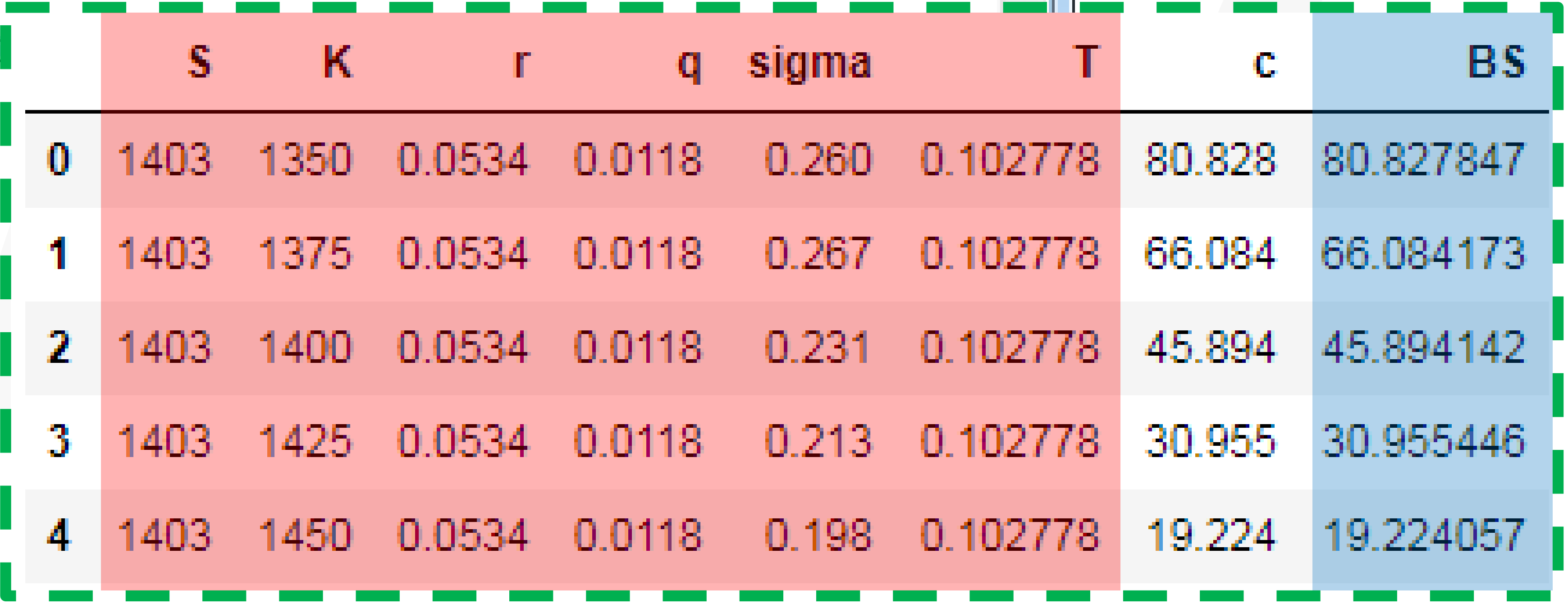
Homework Question:



```
S,K,r,q,sigma,T,c
1403,1350,0.0534,0.0118,0.26,0.102777778,80.828
1403,1375,0.0534,0.0118,0.267,0.102777778,66.084
1403,1400,0.0534,0.0118,0.231,0.102777778,45.894
1403,1425,0.0534,0.0118,0.213,0.102777778,30.955
1403,1450,0.0534,0.0118,0.198,0.102777778,19.224
```



	S	K	r	q	sigma	T	c	BS
0	1403	1350	0.0534	0.0118	0.260	0.102778	80.828	80.827847
1	1403	1375	0.0534	0.0118	0.267	0.102778	66.084	66.084173
2	1403	1400	0.0534	0.0118	0.231	0.102778	45.894	45.894142
3	1403	1425	0.0534	0.0118	0.213	0.102778	30.955	30.955446
4	1403	1450	0.0534	0.0118	0.198	0.102778	19.224	19.224057

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1. **Use one command** with the Pandas library function **`pandas.read_csv`** to load data from the CSV file, `dataset01.csv`, using the first row as column names. Name the data as **`data`**.
2. Define a function, **`option_BS`**, which computes and returns the European call option price using the following formula:

$$c = S \cdot e^{-q \cdot T} \cdot \Phi(d_1) - K \cdot e^{-r \cdot T} \cdot \Phi(d_2)$$

where

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r - q + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \text{ and } d_2 = d_1 - \sigma\sqrt{T}$$

3. **Use one command** with the Pandas library function **`pandas.DataFrame.apply`** to compute the European call option price for each row of **`data`** and add the results to **`data`** as a new column, and name this column as **BS**.

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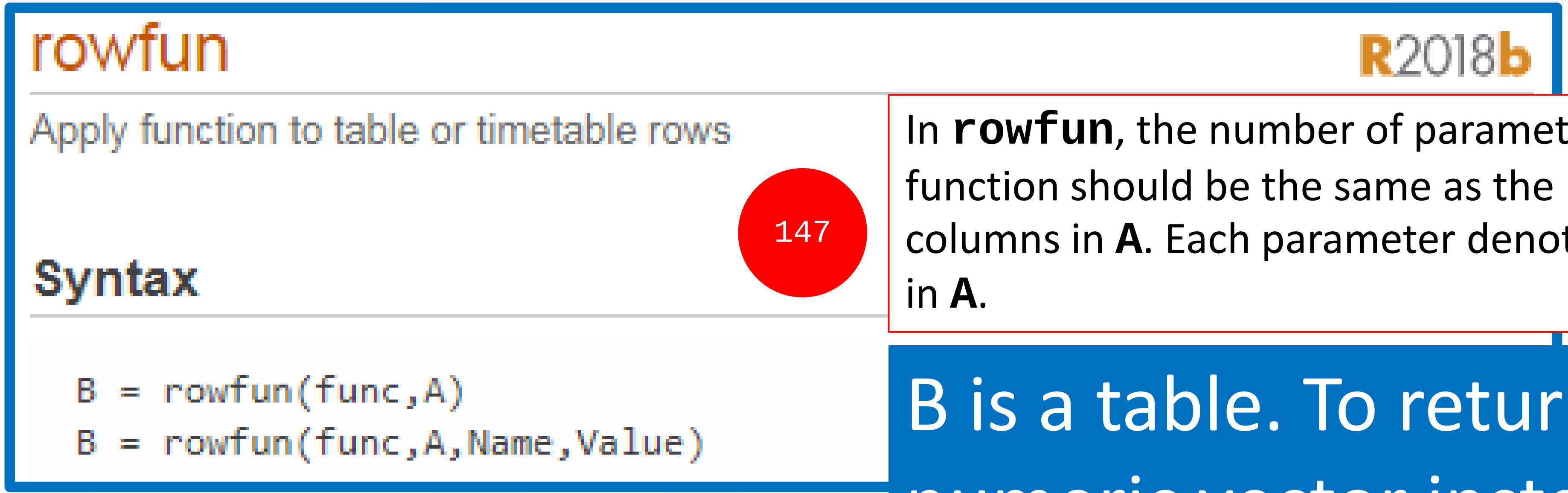
HT008: Apply a function to each row/column of **`data`**



rowfun

R2018b

Apply function to table or timetable rows

Syntax

```
B = rowfun(func,A)
B = rowfun(func,A,Name,Value)
```

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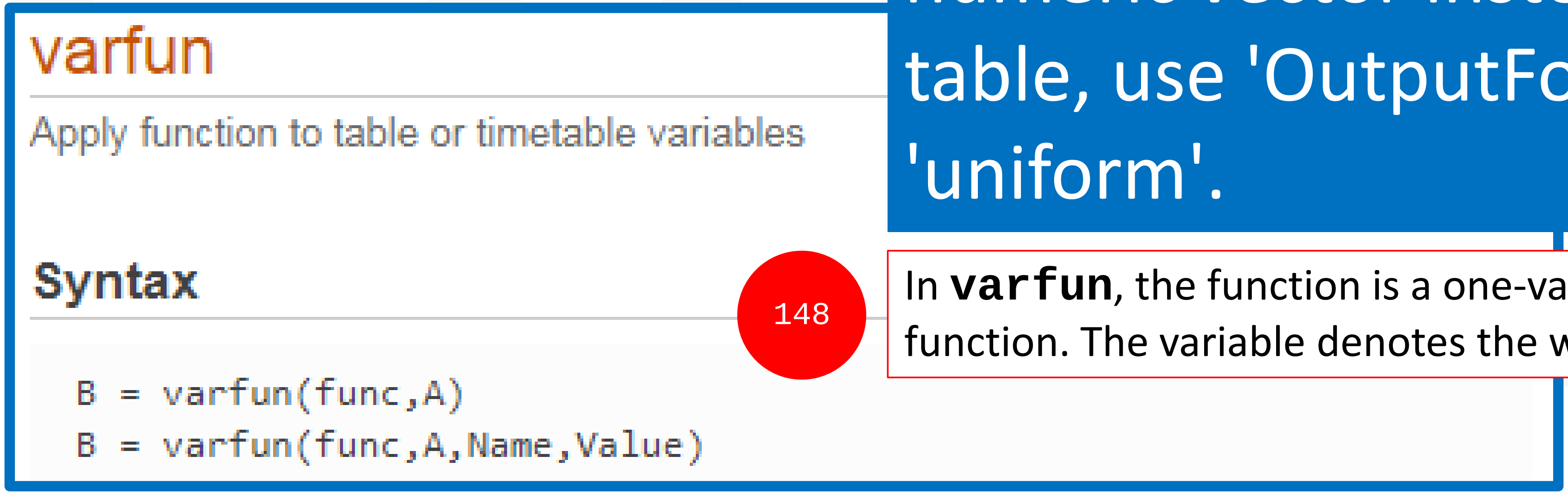
In **`rowfun`**, the number of parameters in the function should be the same as the number of columns in **A**. Each parameter denotes a column in **A**.

B is a table. To return a numeric vector instead of a table, use 'OutputFormat', 'uniform'.



varfun

Apply function to table or timetable variables

Syntax

```
B = varfun(func,A)
B = varfun(func,A,Name,Value)
```

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In **`varfun`**, the function is a one-variable function. The variable denotes the whole column.

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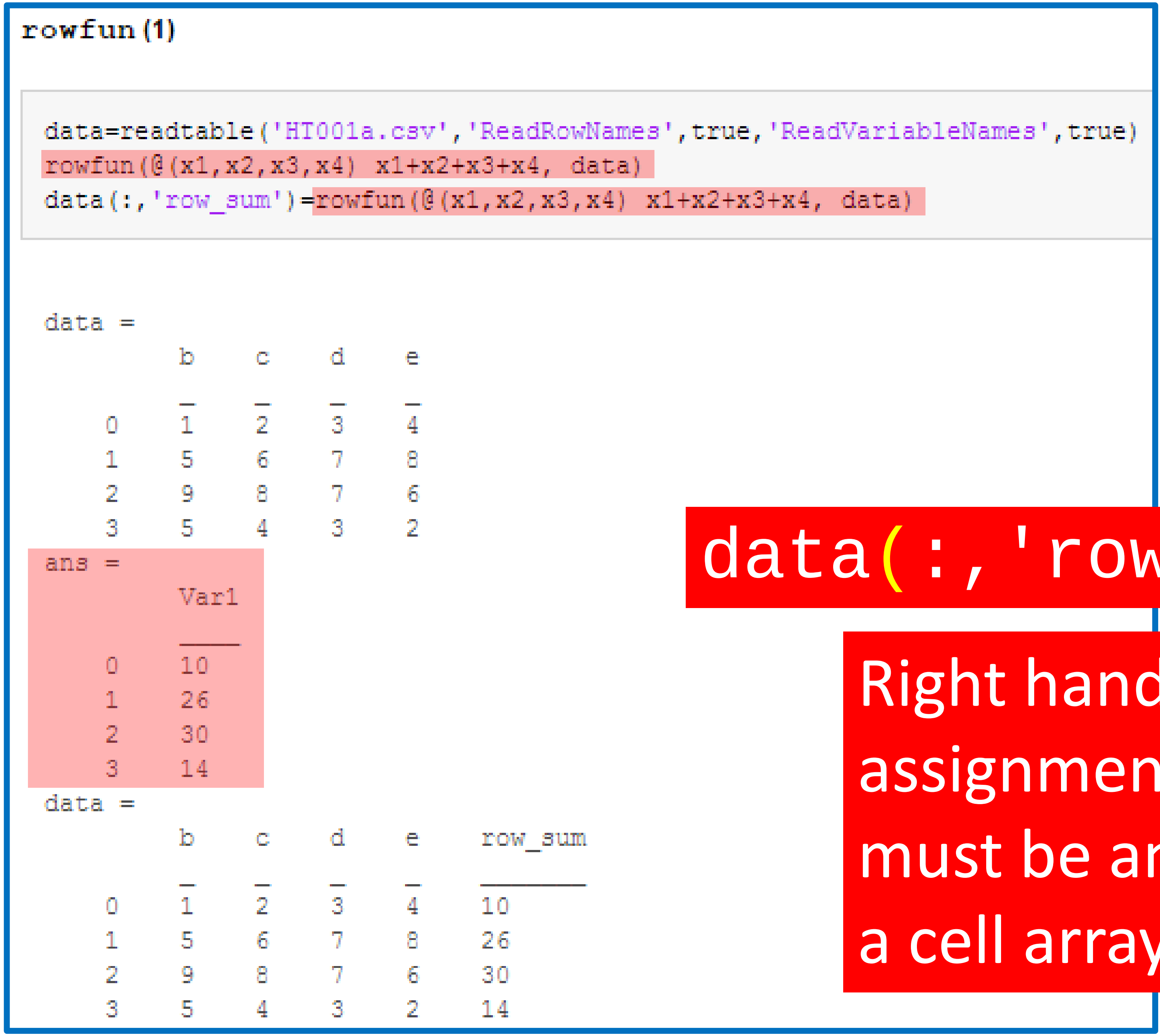

rowfun (1)

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
rowfun(@(x1,x2,x3,x4) x1+x2+x3+x4, data)
data(:,'row_sum')=rowfun(@(x1,x2,x3,x4) x1+x2+x3+x4, data)
```

```
data =
             b    c    d    e

             _    _    _    _
        0    1    2    3    4
        1    5    6    7    8
        2    9    8    7    6
        3    5    4    3    2
ans =
             Var1

             ____
        0    10
        1    26
        2    30
        3    14
data =
             b    c    d    e    row_sum

             _    _    _    _    _______
        0    1    2    3    4    10
        1    5    6    7    8    26
        2    9    8    7    6    30
        3    5    4    3    2    14
```

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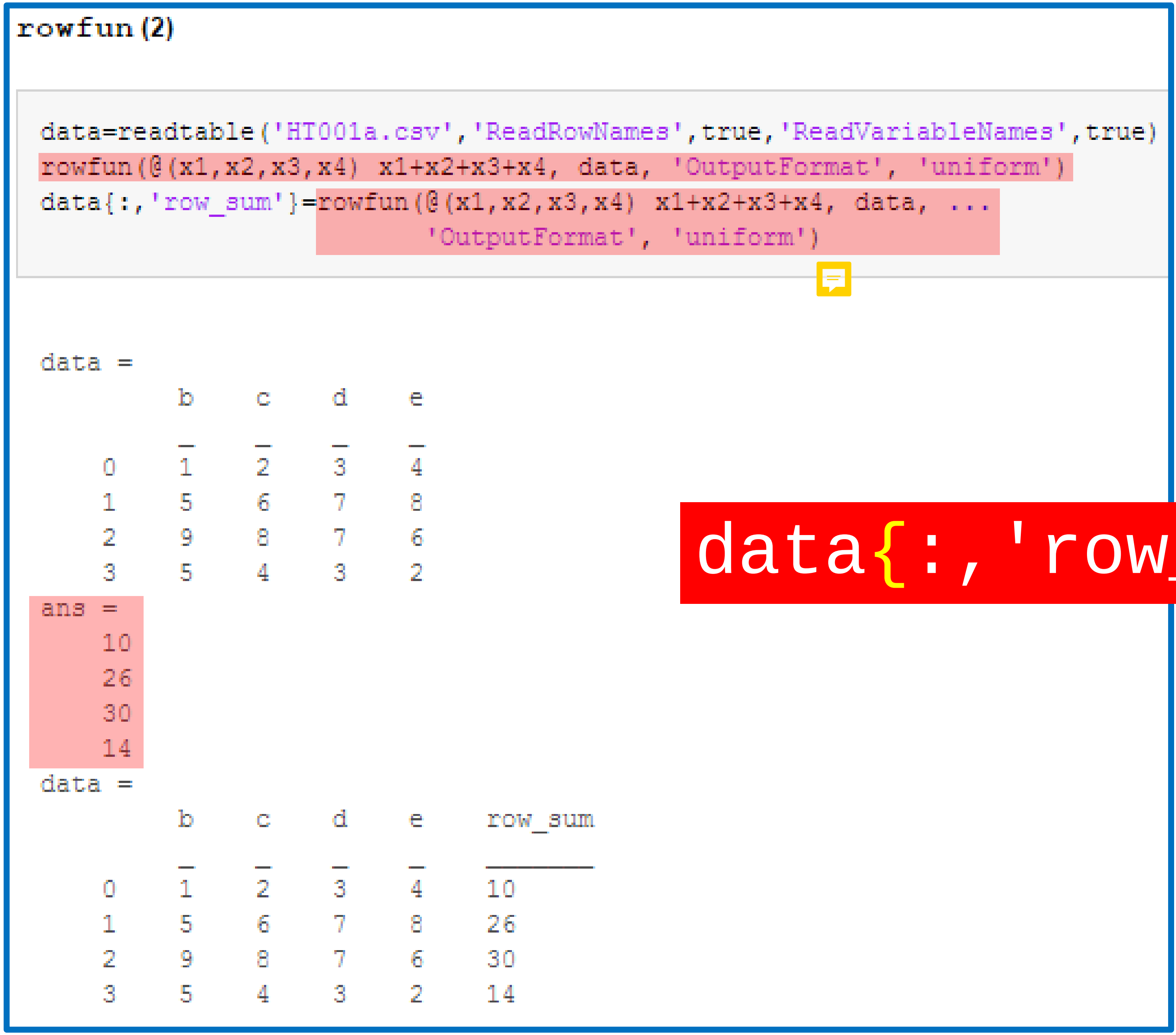
`data(:,'row_sum')=`

Right hand side of an assignment into a table must be another table or a cell array.



rowfun (2)

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
rowfun(@(x1,x2,x3,x4) x1+x2+x3+x4, data, 'OutputFormat', 'uniform')
data{:,'row_sum'}=rowfun(@(x1,x2,x3,x4) x1+x2+x3+x4, data, ...
                  'OutputFormat', 'uniform')
```

```
data =
         b    c    d    e

         _    _    _    _
    0    1    2    3    4
    1    5    6    7    8
    2    9    8    7    6
    3    5    4    3    2
ans =
   10
   26
   30
   14
data =
         b    c    d    e    row_sum

         _    _    _    _    _______
    0    1    2    3    4    10
    1    5    6    7    8    26
    2    9    8    7    6    30
    3    5    4    3    2    14
```

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data{:,'row_sum'}=

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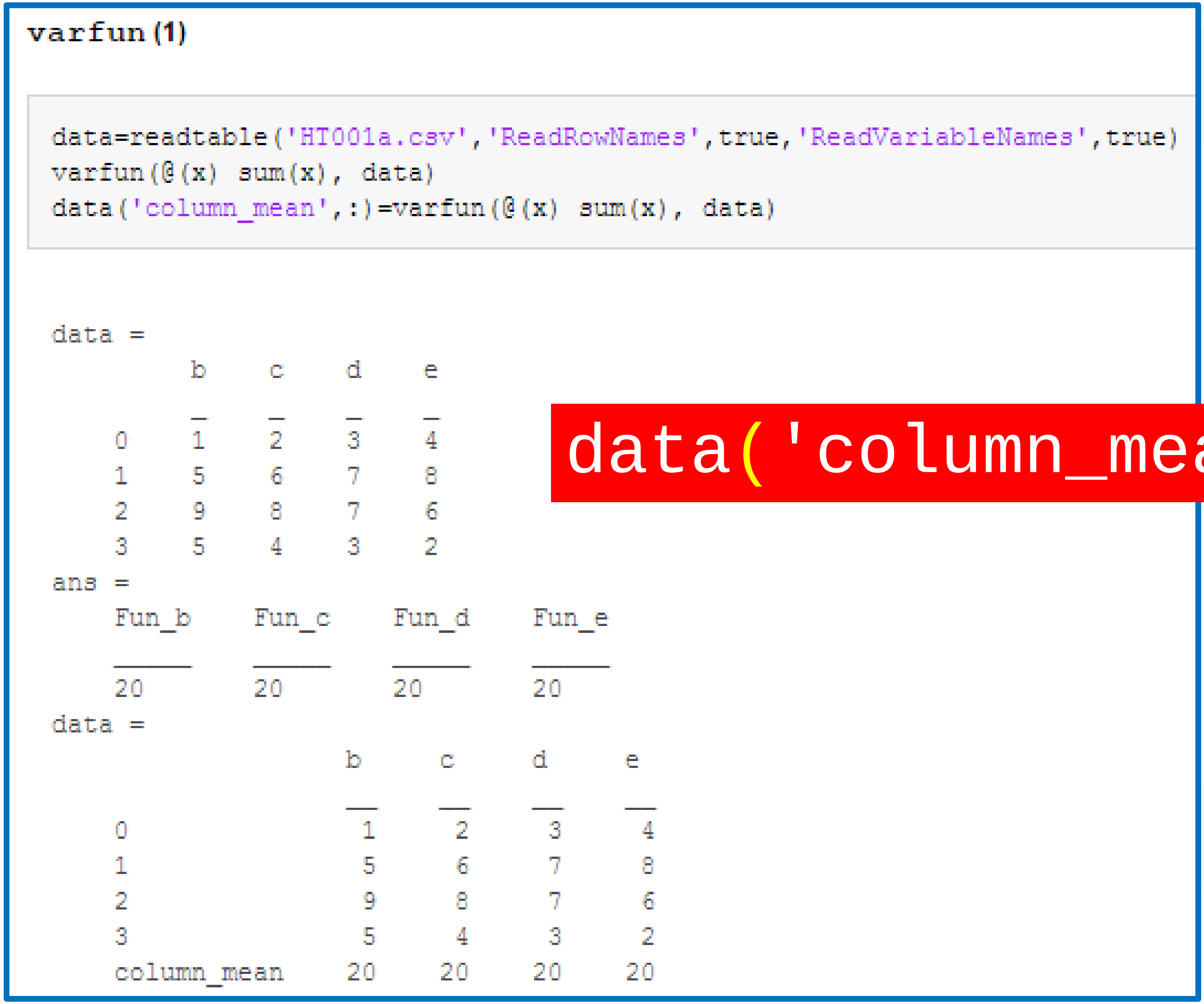

varfun (1)

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
varfun(@(x) sum(x), data)
data('column_mean',:)=varfun(@(x) sum(x), data)
```

```
data =
              b    c    d    e

              _    _    _    _
    0         1    2    3    4
    1         5    6    7    8
    2         9    8    7    6
    3         5    4    3    2
ans =
    Fun_b    Fun_c    Fun_d    Fun_e

    _____    _____    _____    _____
    20       20       20       20
data =
                   b     c     d     e

                   __    __    __    __
    0               1     2     3     4
    1               5     6     7     8
    2               9     8     7     6
    3               5     4     3     2
    column_mean    20    20    20    20
```

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data('column_mean',:)=

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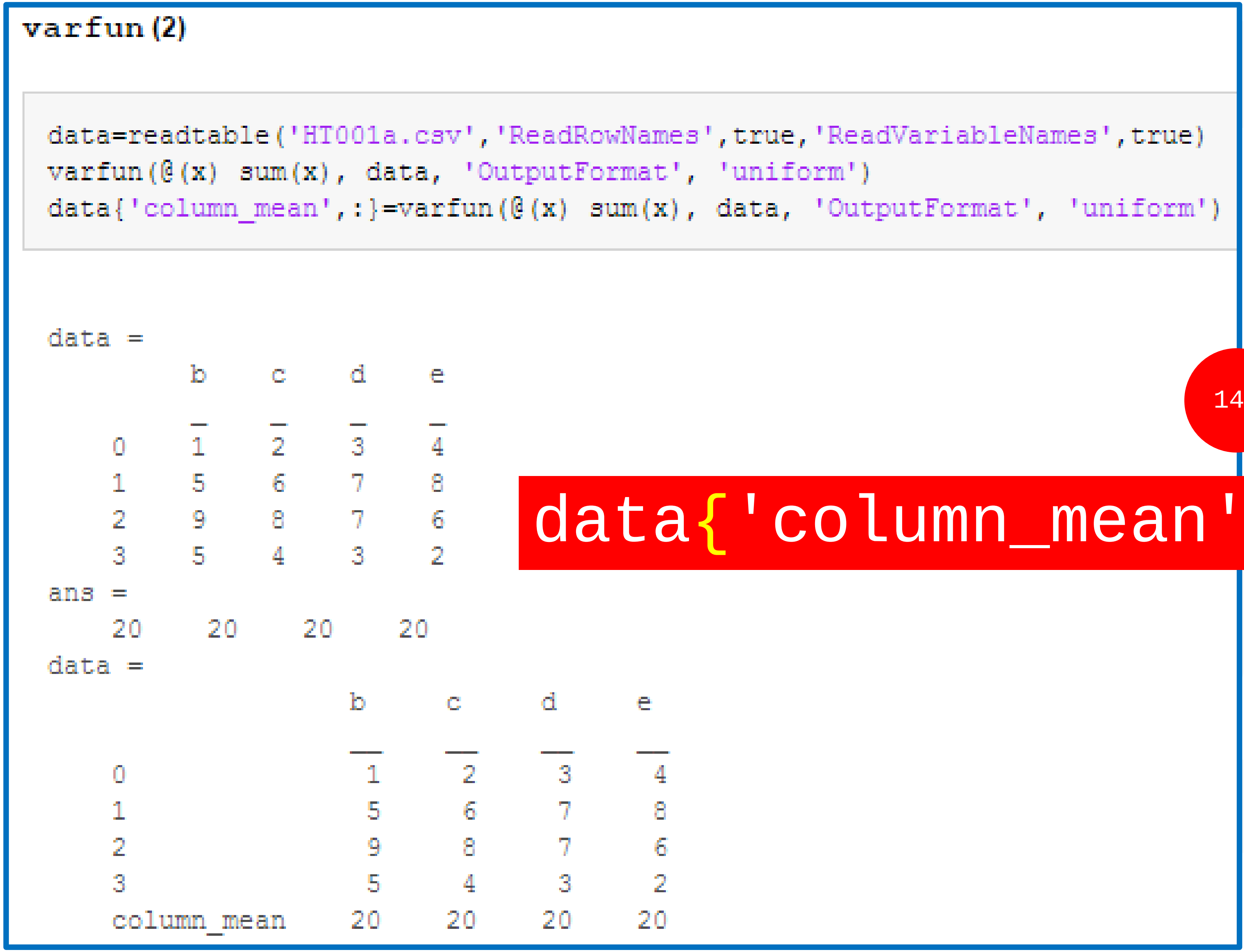

varfun(2)

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
varfun(@(x) sum(x), data, 'OutputFormat', 'uniform')
data{'column_mean',:}=varfun(@(x) sum(x), data, 'OutputFormat', 'uniform')
```

```
data =
            b    c    d    e
            _    _    _    _
    0       1    2    3    4
    1       5    6    7    8
    2       9    8    7    6
    3       5    4    3    2
ans =
    20     20     20     20
data =
                    b      c      d      e
                   ___    ___    ___    ___
    0               1      2      3      4
    1               5      6      7      8
    2               9      8      7      6
    3               5      4      3      2
    column_mean    20     20     20     20
```

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data{'column_mean',:}=

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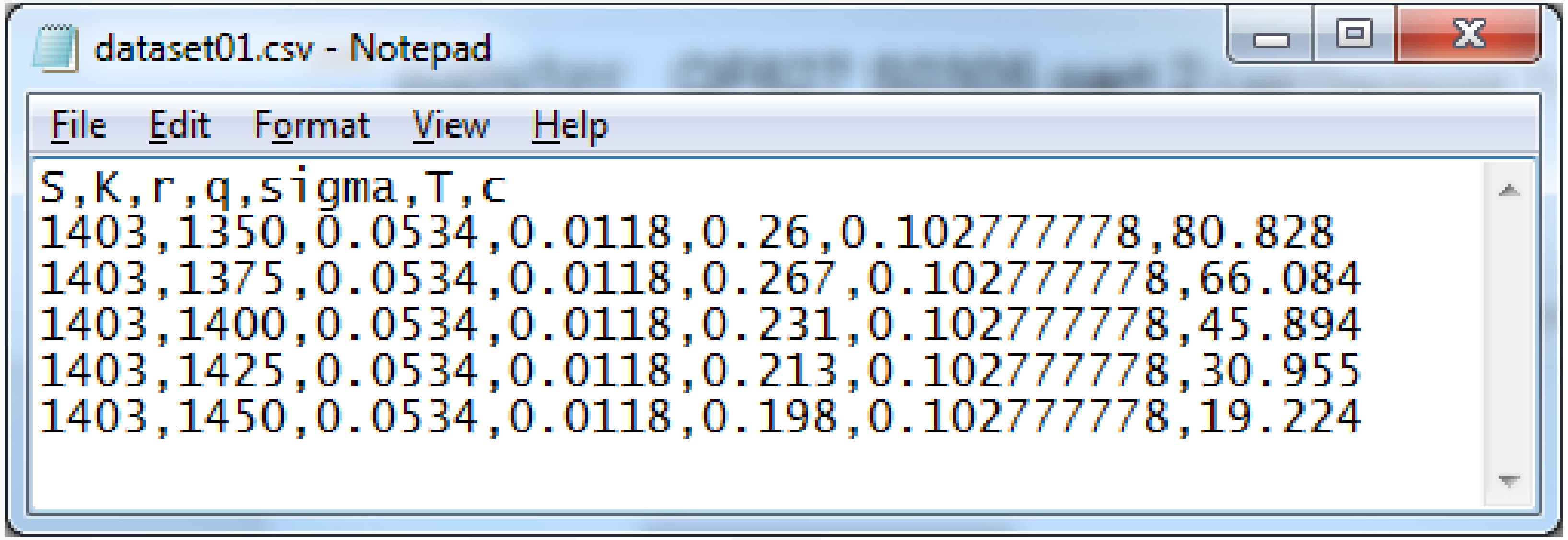
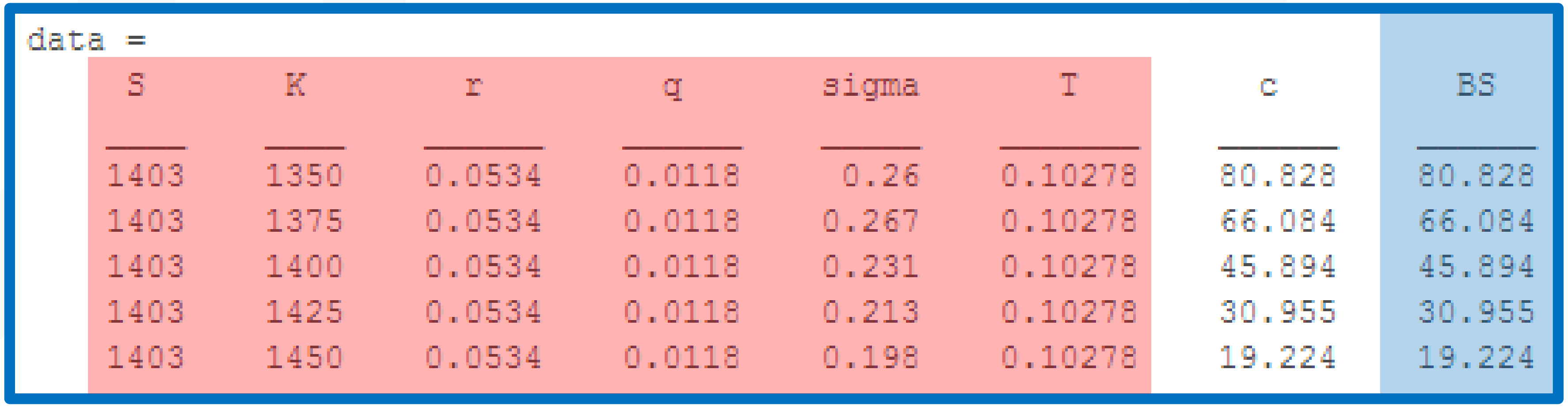
Homework Question:



```
S,K,r,q,sigma,T,c
1403,1350,0.0534,0.0118,0.26,0.102777778,80.828
1403,1375,0.0534,0.0118,0.267,0.102777778,66.084
1403,1400,0.0534,0.0118,0.231,0.102777778,45.894
1403,1425,0.0534,0.0118,0.213,0.102777778,30.955
1403,1450,0.0534,0.0118,0.198,0.102777778,19.224
```



```
data =
     S       K        r         q       sigma       T           c         BS
    ____    ____    ______    ______    _____    _______    ______    ______
    1403    1350    0.0534    0.0118     0.26    0.10278    80.828    80.828
    1403    1375    0.0534    0.0118    0.267    0.10278    66.084    66.084
    1403    1400    0.0534    0.0118    0.231    0.10278    45.894    45.894
    1403    1425    0.0534    0.0118    0.213    0.10278    30.955    30.955
    1403    1450    0.0534    0.0118    0.198    0.10278    19.224    19.224
```

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1. Load data from the CSV file, `dataset01.csv`, using the first row as column names. Name the data as **`data`**.
2. Define a function, **`option_BS`**, which computes and returns the European call option price using the following formula:

$$c = S \cdot e^{-q \cdot T} \cdot \Phi(d_1) - K \cdot e^{-r \cdot T} \cdot \Phi(d_2)$$

where

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r - q + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \text{ and } d_2 = d_1 - \sigma\sqrt{T}$$

3. **Use one command** to compute the European call option price for each row of **`data`** and add the results to **`data`** as a new column, and name this column as **BS**.

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HT009: Basic operations on two rows/columns of **`data`**

1. row(s) *op* row(s) (with the same label)
2. row(s) *op* row(s) (with different labels)
3. column(s) *op* column(s) (with the same label)
4. column(s) *op* column(s) (with different labels)
5. row(s) *op* column(s) (??? What operation???)

op: +, -, *, /, ** (or ^)

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HT009: Basic operations on two rows/columns of **data**

- ✓ A row/column of a DataFrame can be a DataFrame, a Series, a Numpy 2D array or a Numpy 1D array.
- ✓ Rows/Columns of a DataFrame can be a DataFrame or a Numpy 2D array.

	DataFrame	Series	Numpy 2D array	Numpy 1D array
DataFrame	element-wise, aligned by labels	broadcasting, align DataFrame's column labels and Series' labels	element-wise, size must agree	use array as a row, broadcasting, element-wise, **size** must agree
Series	▨	element-wise, aligned by labels	N.A.	element-wise, size must agree
Numpy 2D array	▨	▨	broadcasting, element-wise, size must agree	broadcasting
Numpy 1D array	▨	▨	▨	element-wise, size must agree

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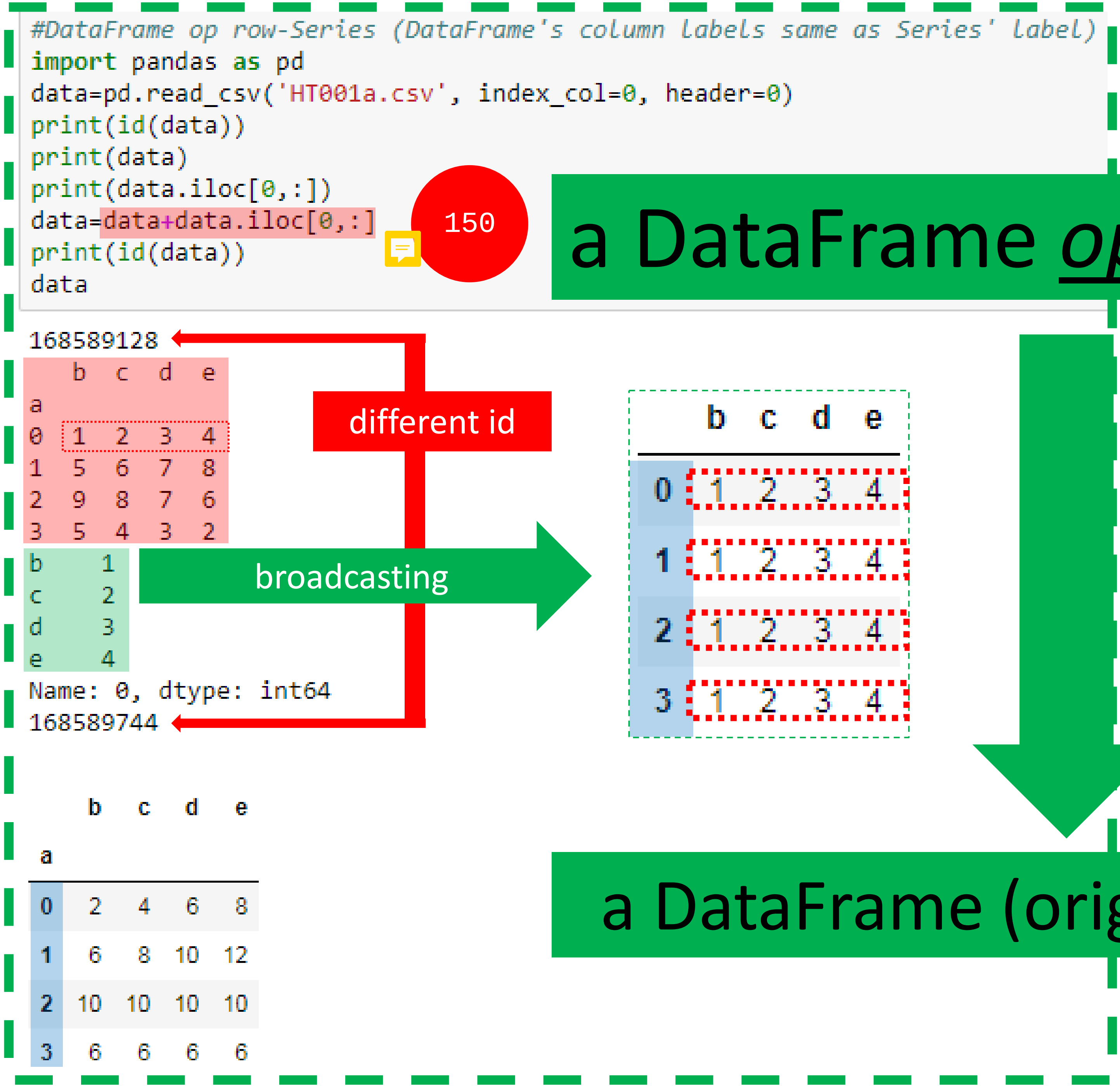

```
#DataFrame op row-Series (DataFrame's column labels same as Series' label)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(id(data))
print(data)
print(data.iloc[0,:])
data=data+data.iloc[0,:]
print(id(data))
data
```

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```
168589128
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
b    1
c    2
d    3
e    4
Name: 0, dtype: int64
168589744
```

different id

broadcasting

	b	c	d	e
0	1	2	3	4
1	1	2	3	4
2	1	2	3	4
3	1	2	3	4

	b	c	d	e
a				
0	2	4	6	8
1	6	8	10	12
2	10	10	10	10
3	6	6	6	6

data=

a DataFrame *op* a row-Series

(row)

(N,)⇨(1,N)

Use one command to add the first row to every row in **data**.

a DataFrame (original row labels)

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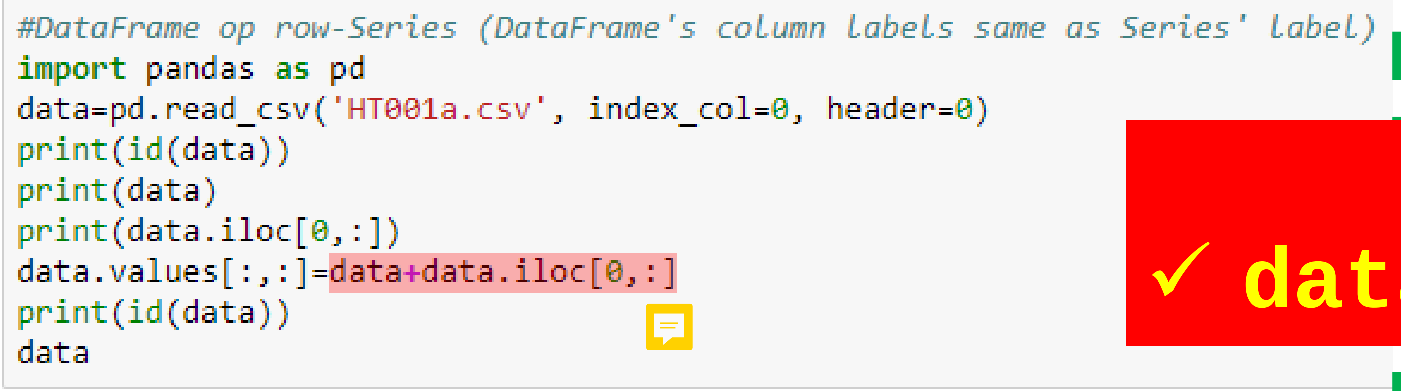
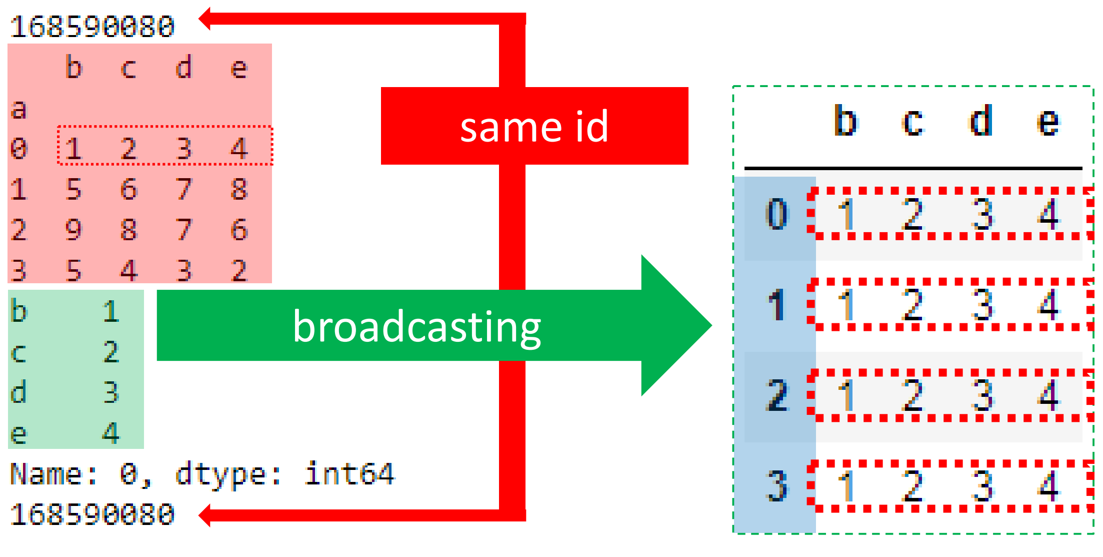


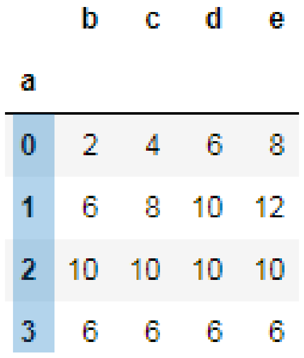
```
#DataFrame op row-Series (DataFrame's column labels same as Series' label)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(id(data))
print(data)
print(data.iloc[0,:])
data.values[:,:]=data+data.iloc[0,:]
print(id(data))
data
```

× data.values=
✓ data.values[:,:]=



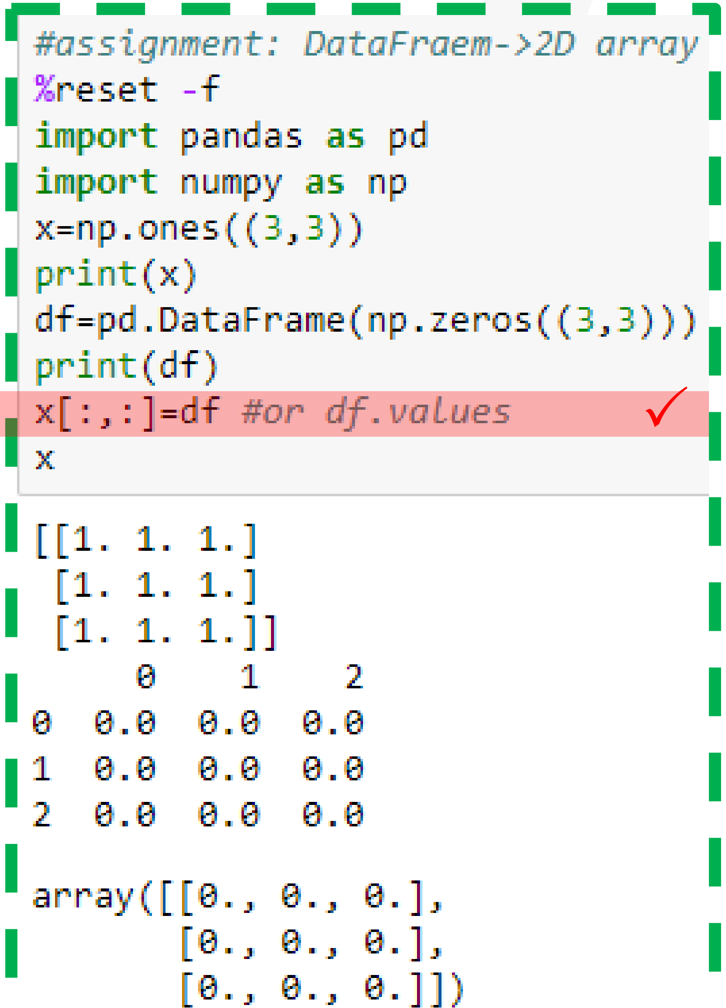
```
168590080
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
b    1
c    2
d    3
e    4
Name: 0, dtype: int64
168590080
```

	b	c	d	e
0	1	2	3	4
1	1	2	3	4
2	1	2	3	4
3	1	2	3	4



	b	c	d	e
a				
0	2	4	6	8
1	6	8	10	12
2	10	10	10	10
3	6	6	6	6

Use one command to add the first row to every row in **data**.



```
#assignment: DataFraem->2D array
%reset -f
import pandas as pd
import numpy as np
x=np.ones((3,3))
print(x)
df=pd.DataFrame(np.zeros((3,3)))
print(df)
x[:,:]=df #or df.values ✓
x
```

```
[[1. 1. 1.]
 [1. 1. 1.]
 [1. 1. 1.]]
     0    1    2
0  0.0  0.0  0.0
1  0.0  0.0  0.0
2  0.0  0.0  0.0

array([[0., 0., 0.],
       [0., 0., 0.],
       [0., 0., 0.]])
```

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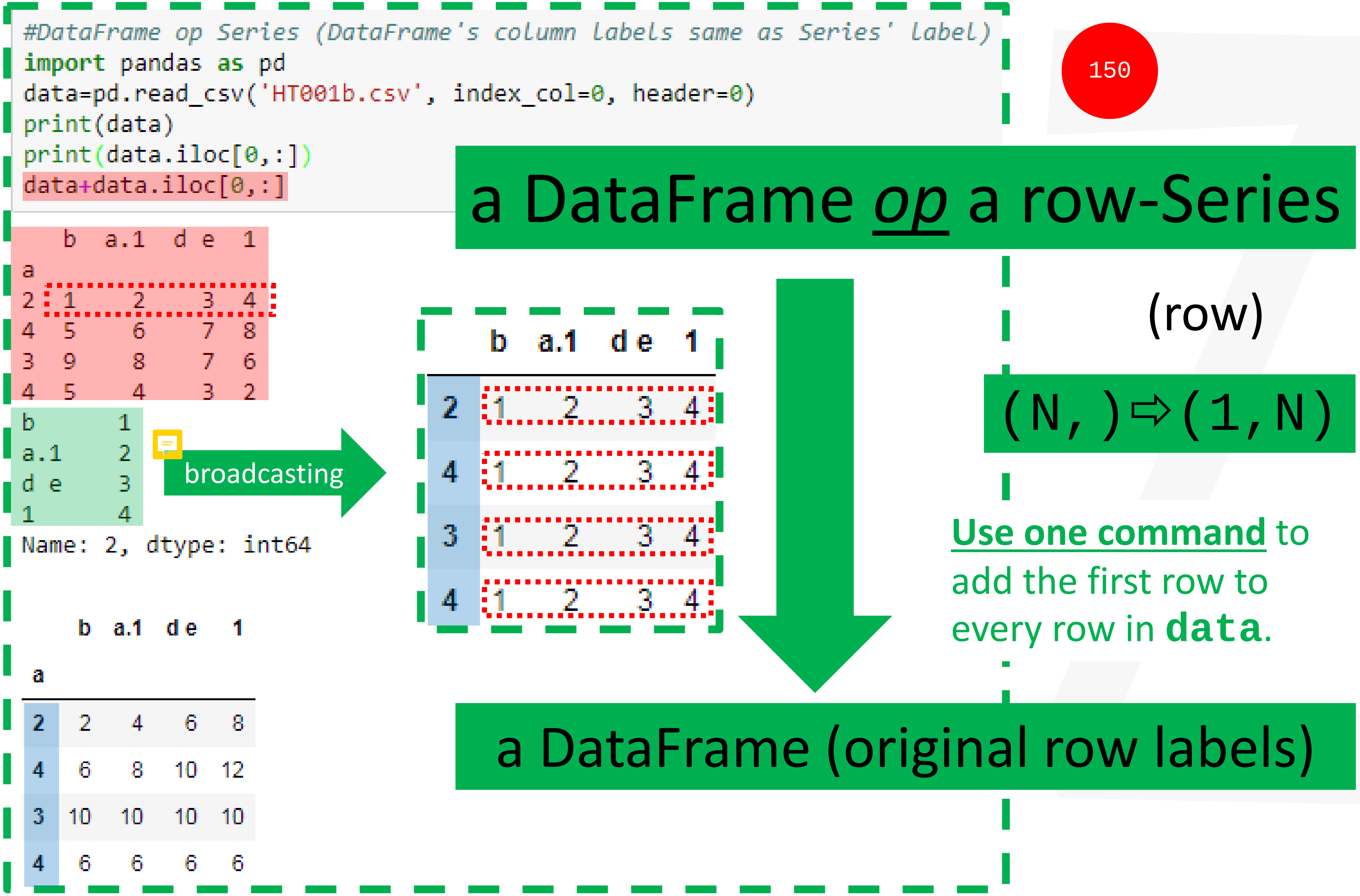

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```
#DataFrame op Series (DataFrame's column labels same as Series' label)
import pandas as pd
data=pd.read_csv('HT001b.csv', index_col=0, header=0)
print(data)
print(data.iloc[0,:])
data+data.iloc[0,:]
```

```
   b  a.1  d e  1
a
2  1    2    3  4
4  5    6    7  8
3  9    8    7  6
4  5    4    3  2
b      1
a.1    2
d e    3
1      4
Name: 2, dtype: int64
```

a	b	a.1	d e	1
2	2	4	6	8
4	6	8	10	12
3	10	10	10	10
4	6	6	6	6

broadcasting

	b	a.1	d e	1
2	1	2	3	4
4	1	2	3	4
3	1	2	3	4
4	1	2	3	4

a DataFrame *op* a row-Series

(row)

(N,)⇨(1,N)

a DataFrame (original row labels)

Use one command to add the first row to every row in **data**.

a DataFrame *op* 1D array

(or list)

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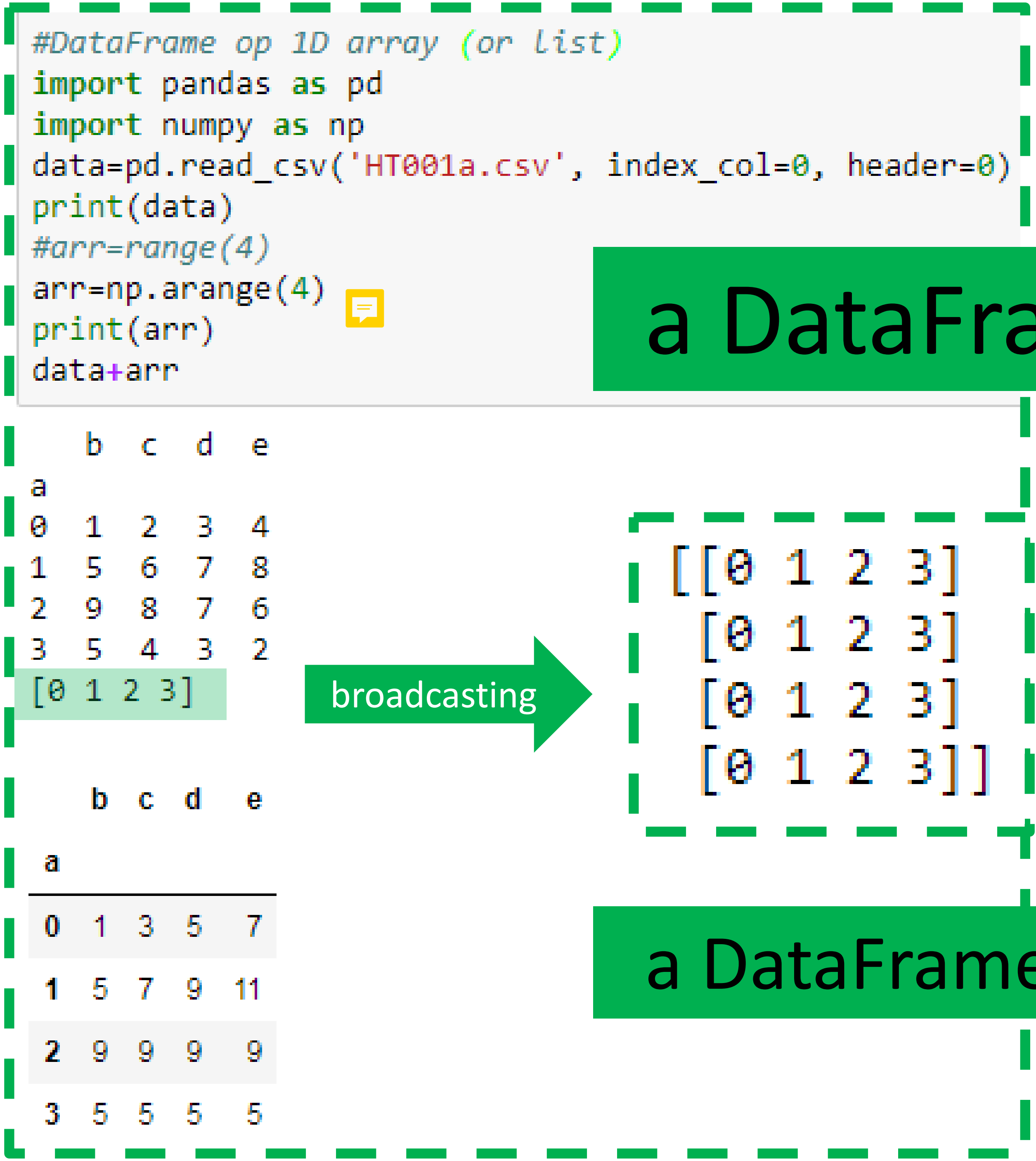

```
#DataFrame op 1D array (or list)
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
#arr=range(4)
arr=np.arange(4)
print(arr)
data+arr
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
[0 1 2 3]
```

broadcasting

```
[[0 1 2 3]
 [0 1 2 3]
 [0 1 2 3]
 [0 1 2 3]]
```

	b	c	d	e
a				
0	1	3	5	7
1	5	7	9	11
2	9	9	9	9
3	5	5	5	5

a DataFrame (original row labels)

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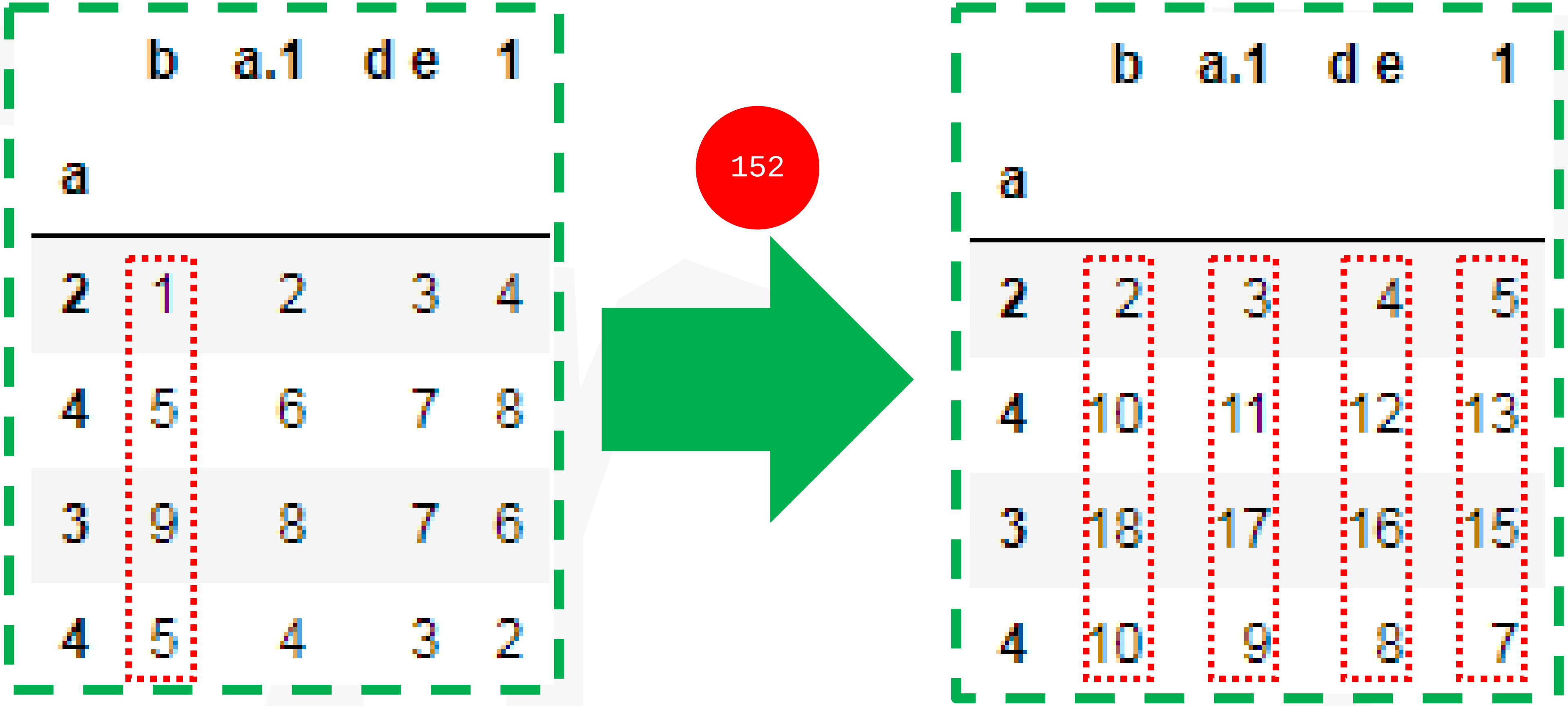


a	b	a.1	d e	1
2	1	2	3	4
4	5	6	7	8
3	9	8	7	6
4	5	4	3	2

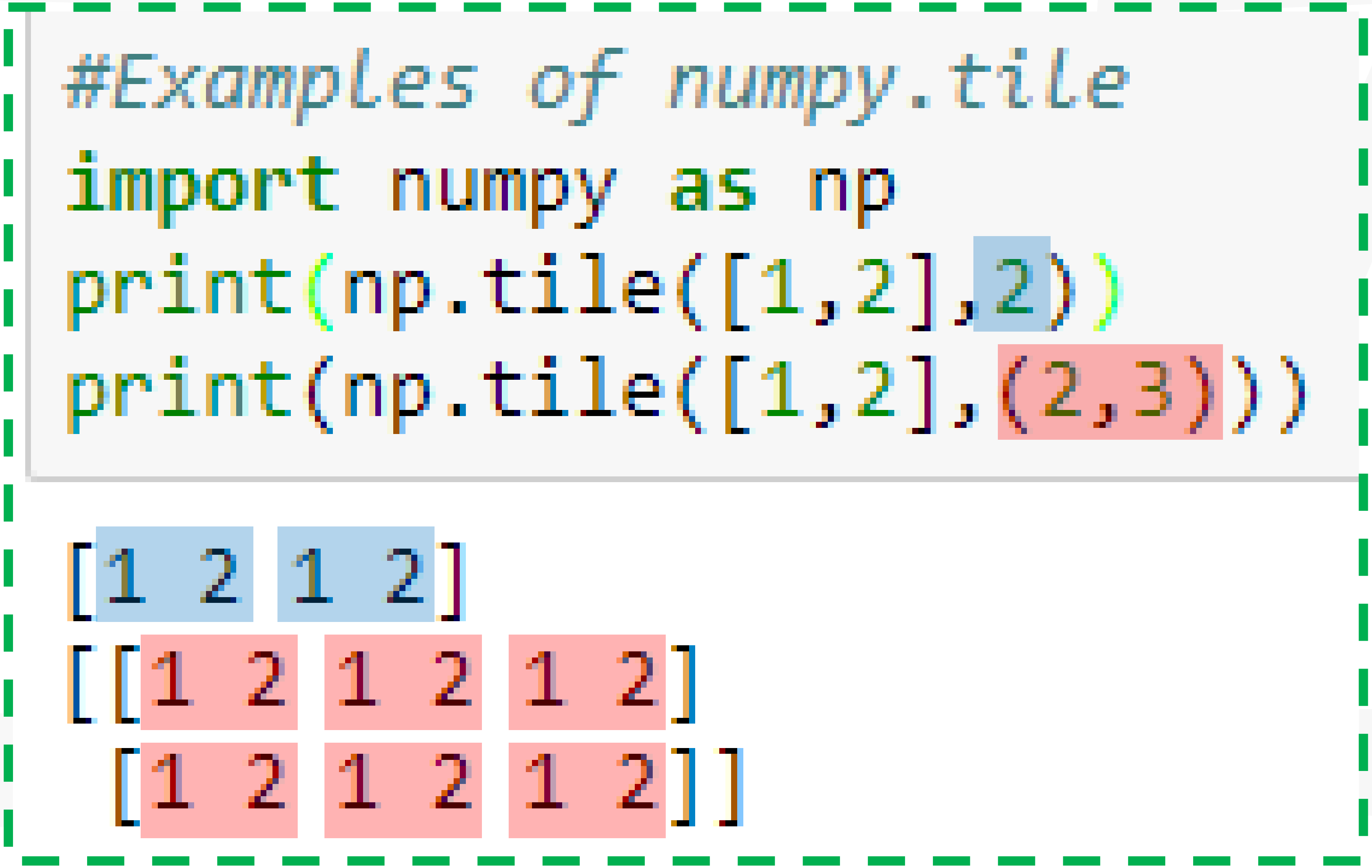
a	b	a.1	d e	1
2	2	3	4	5
4	10	11	12	13
3	18	17	16	15
4	10	9	8	7

Use one command to add the first column to every column in **data**.

numpy.tile

```
×  data+data.iloc[:,0]
?  data+data.iloc[:,0].values
×  data+data.iloc[:,0].values.reshape(4,1)
✓  data+np.tile(data.iloc[:,0].values.reshape(4,1),4)
✓  data+np.tile(data.iloc[:,[0]].values,4)
✓  data.apply(lambda x: x+data.iloc[:,0].values, axis=0)
```

https://docs.scipy.org/doc/numpy-1.15.0/reference/generated/numpy.tile.html



```
#Examples of numpy.tile
import numpy as np
print(np.tile([1,2],2))
print(np.tile([1,2],(2,3)))
```

```
[1 2 1 2]
[[1 2 1 2 1 2]
 [1 2 1 2 1 2]]
```

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Numpy Array Arithmetic Operations

$1 \le M_1 < M_2; 1 \le N_1 < N_2$

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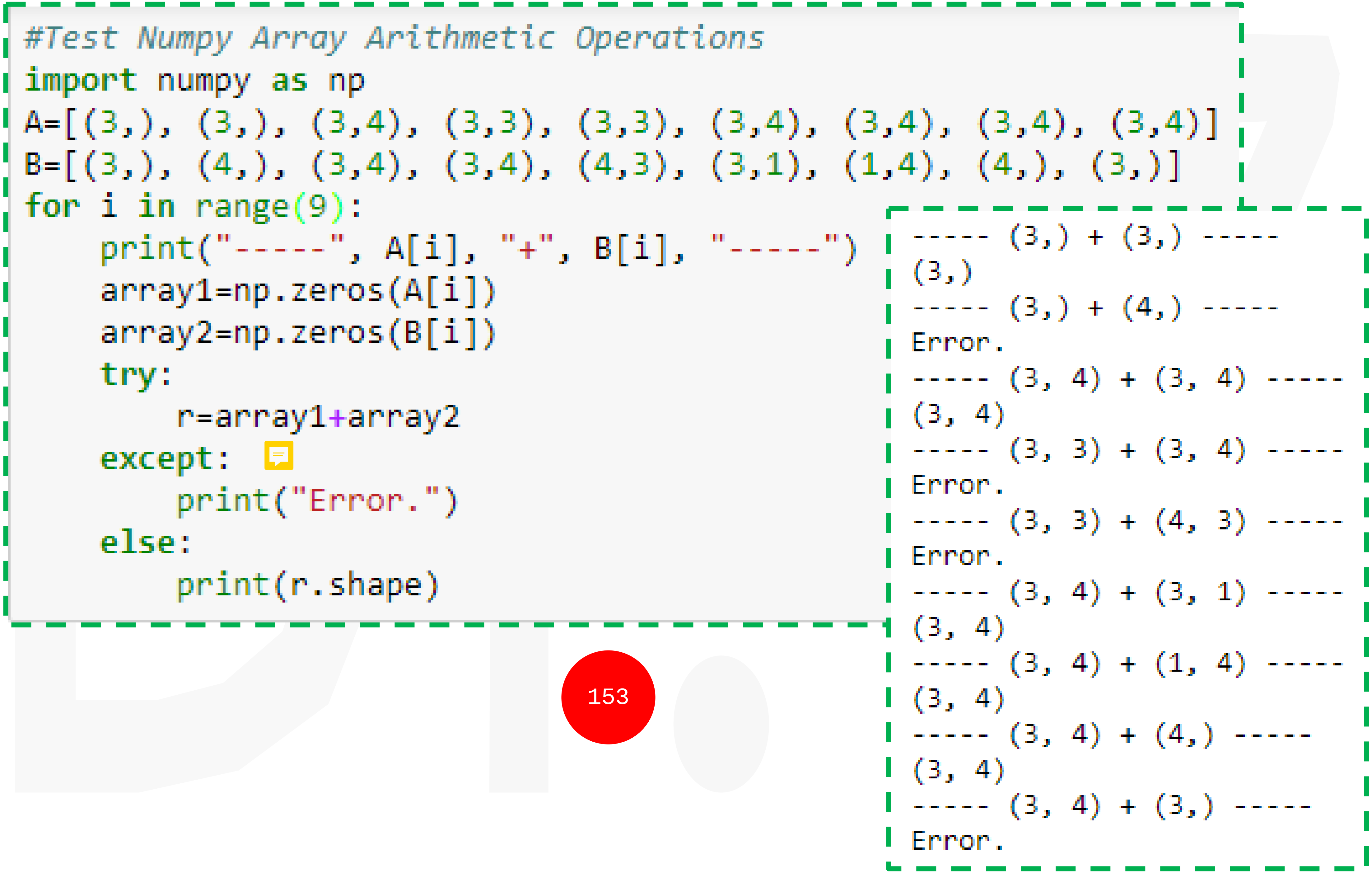
- ✓ $(M_1,)$ 1D array *op* $(M_1,)$ 1D array ⇨ $(M_1,)$ 1D array
- × $(M_1,)$ 1D array *op* $(M_2,)$ 1D array
- ✓ (M_1, N_1) 2D array *op* (M_1, N_1) 2D array ⇨ (M_1, N_1) 2D array
- × (M_1, N_1) 2D array *op* (M_1, N_2) 2D array
- × (M_1, N_1) 2D array *op* (M_2, N_1) 2D array
- ✓ $(M_1, 1)$ 2D array *op* $(1, N_1)$ 2D array ⇨ (M_1, N_1) 2D array
- ✓ (M_1, N_1) 2D array *op* $(M_1, 1)$ 2D array ⇨ (M_1, N_1) 2D array
- ✓ (M_1, N_1) 2D array *op* $(1, N_1)$ 2D array ⇨ (M_1, N_1) 2D array
- ✓ (M_1, N_1) 2D array *op* $(N_1,)$ 1D array ⇨ (M_1, N_1) 2D array
- × (M_1, N_2) 2D array *op* $(M_1,)$ 1D array



```
#Test Numpy Array Arithmetic Operations
import numpy as np
A=[(3,), (3,), (3,4), (3,3), (3,3), (3,4), (3,4), (3,4), (3,4)]
B=[(3,), (4,), (3,4), (3,4), (4,3), (3,1), (1,4), (4,), (3,)]
for i in range(9):
    print("-----", A[i], "+", B[i], "-----")
    array1=np.zeros(A[i])
    array2=np.zeros(B[i])
    try:
        r=array1+array2
    except:
        print("Error.")
    else:
        print(r.shape)
```

```
----- (3,) + (3,) -----
(3,)
----- (3,) + (4,) -----
Error.
----- (3, 4) + (3, 4) -----
(3, 4)
----- (3, 3) + (3, 4) -----
Error.
----- (3, 3) + (4, 3) -----
Error.
----- (3, 4) + (3, 1) -----
(3, 4)
----- (3, 4) + (1, 4) -----
(3, 4)
----- (3, 4) + (4,) -----
(3, 4)
----- (3, 4) + (3,) -----
Error.
```

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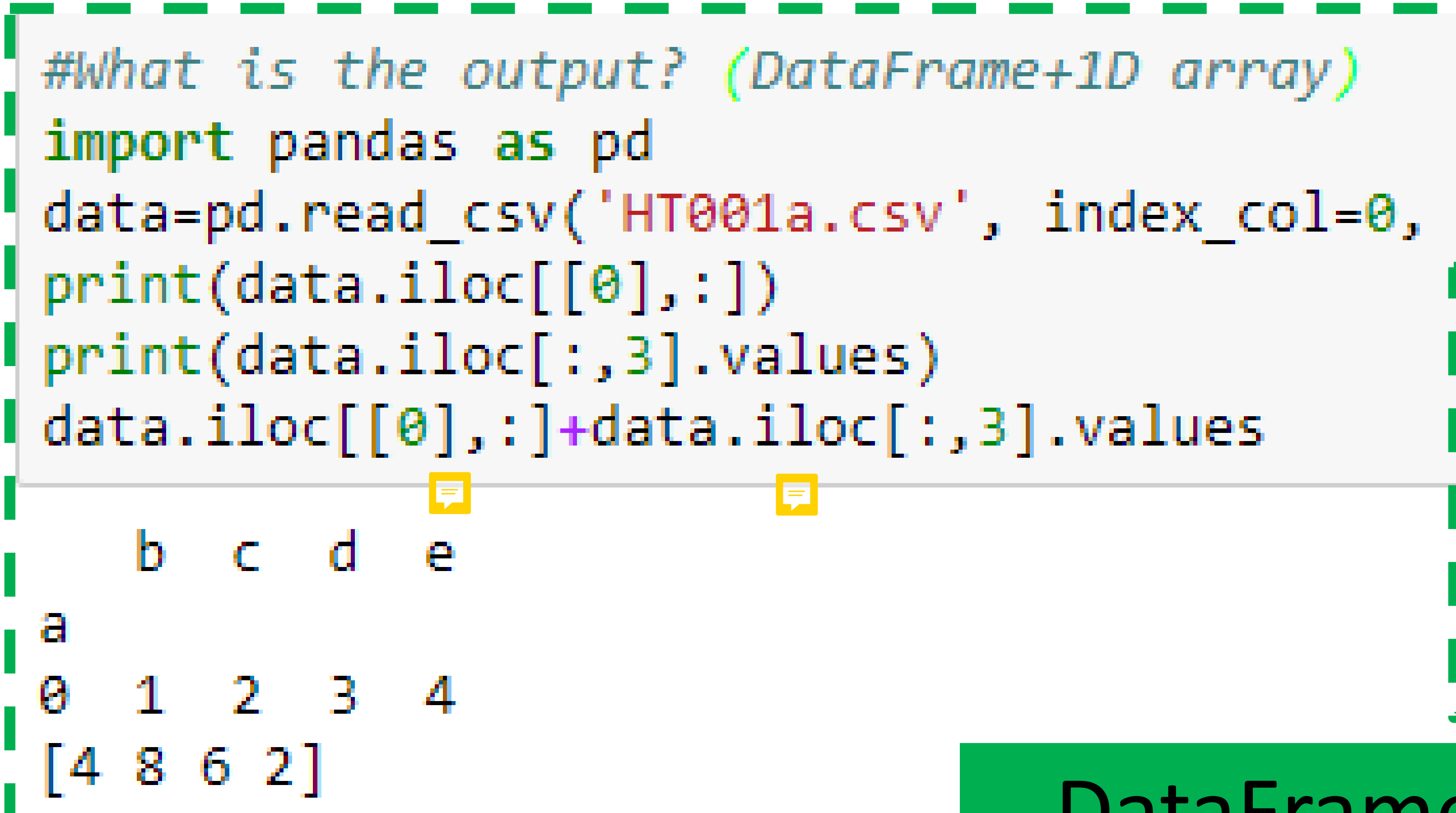
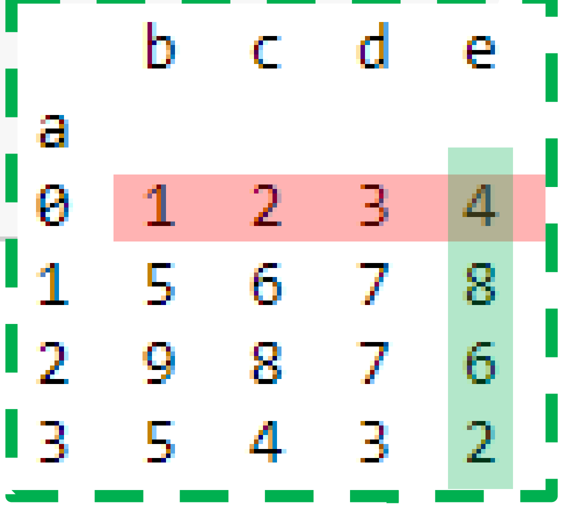


```
#What is the output? (DataFrame+1D array)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data.iloc[[0],:])
print(data.iloc[:,3].values)
data.iloc[[0],:]+data.iloc[:,3].values
```

```
   b  c  d  e
a
0  1  2  3  4
[4 8 6 2]
```



```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

DataFrame+1D array

What is the output?

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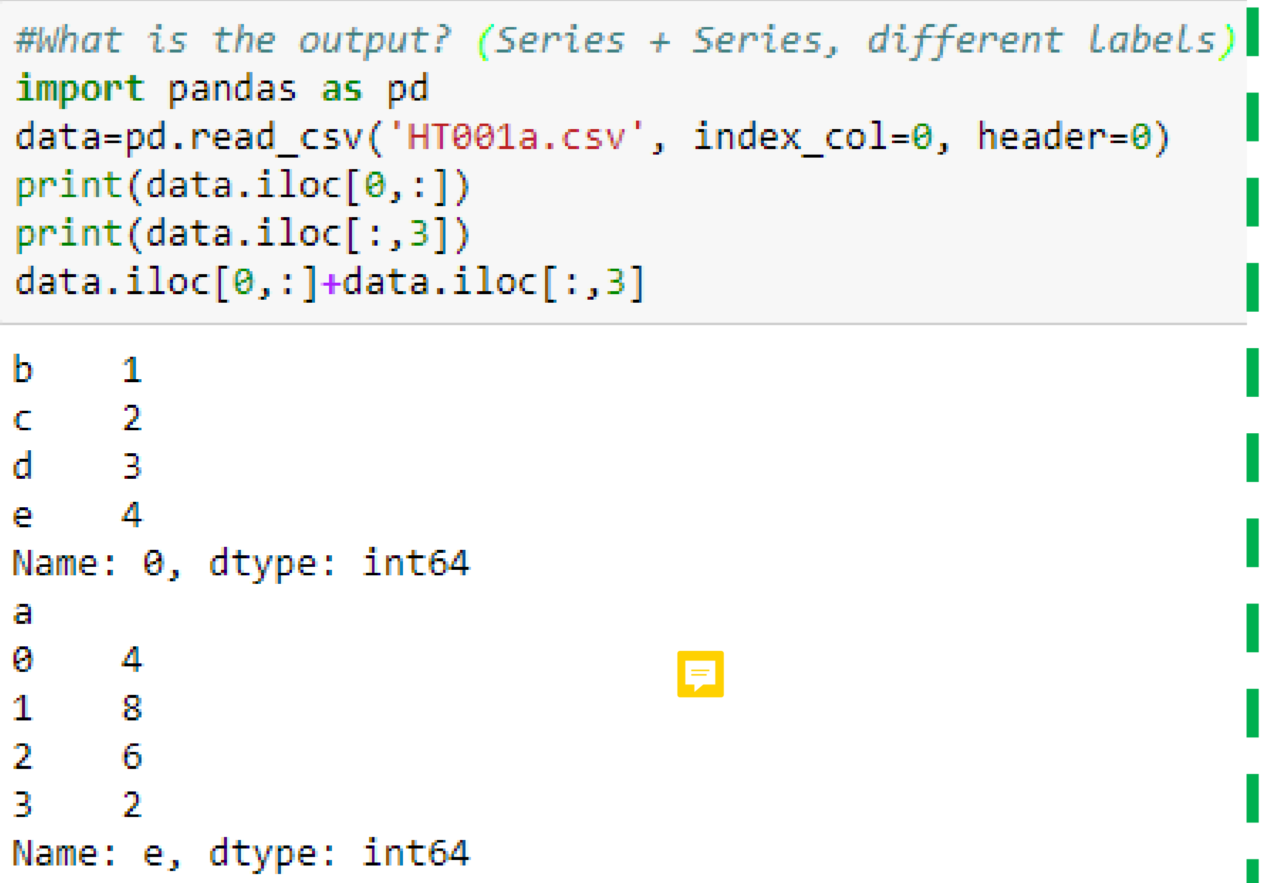
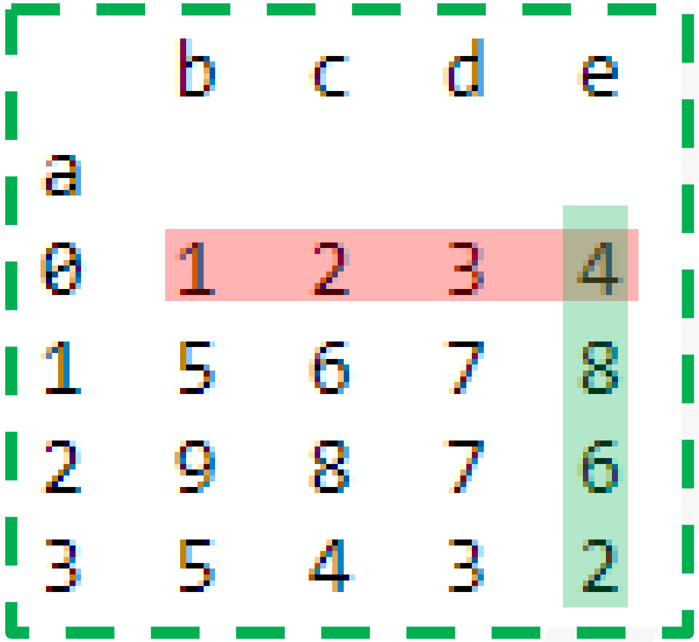


```
#What is the output? (Series + Series, different labels)
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data.iloc[0,:])
print(data.iloc[:,3])
data.iloc[0,:]+data.iloc[:,3]
```

```
b    1
c    2
d    3
e    4
Name: 0, dtype: int64
a
0    4
1    8
2    6
3    2
Name: e, dtype: int64
```

What is the output?



	b	c	d	e
a				
0	1	2	3	4
1	5	6	7	8
2	9	8	7	6
3	5	4	3	2

Series+Series

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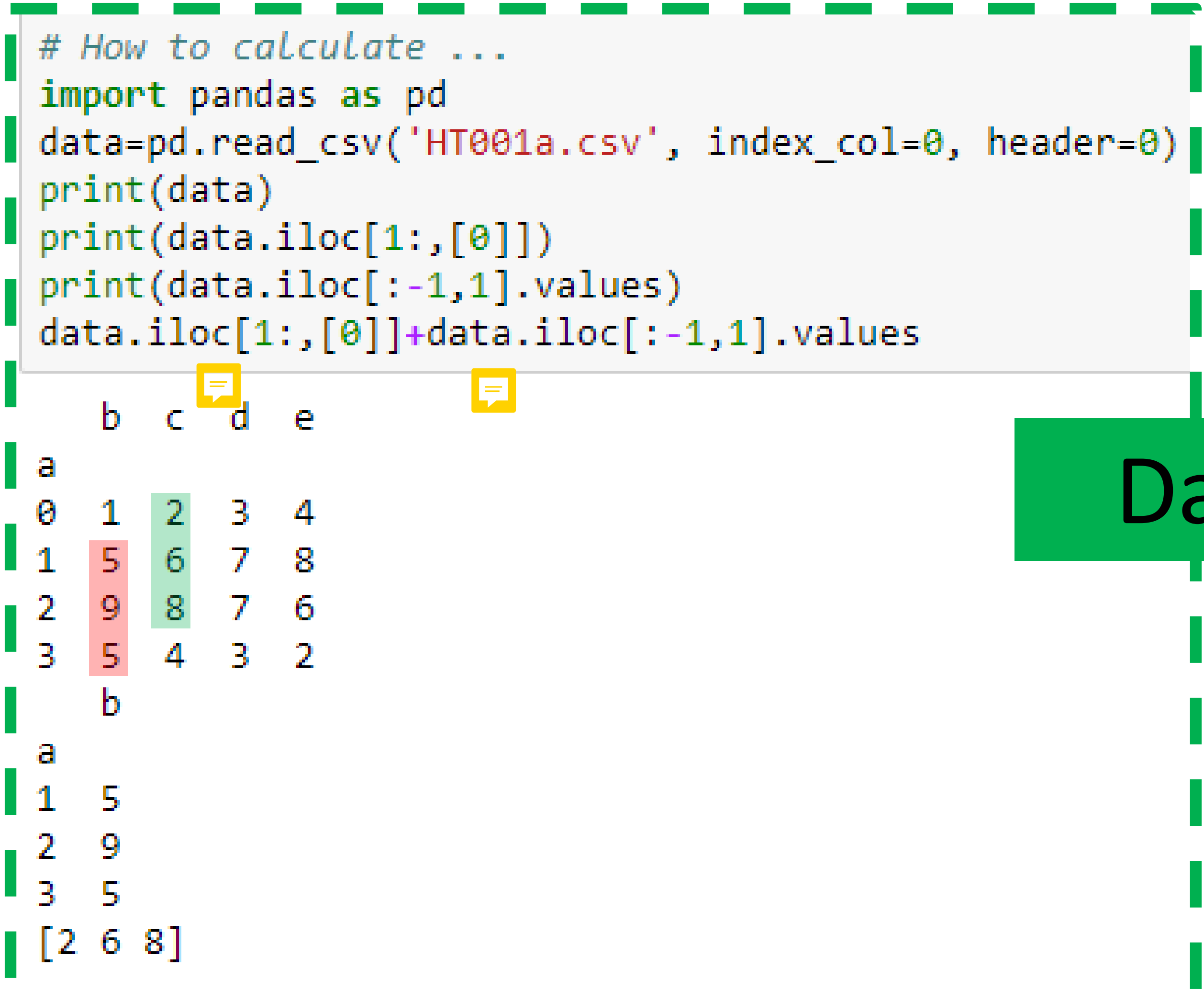
DataFrame+1D array



```python
# How to calculate ...
import pandas as pd
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
print(data.iloc[1:,[0]])
print(data.iloc[:-1,1].values)
data.iloc[1:,[0]]+data.iloc[:-1,1].values
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b
a
1  5
2  9
3  5
[2 6 8]
```

What is the output?

calculate ⇨ use array (label free)

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Matrix Multiplication using Numpy 1D/2D arrays

(M, N) 2D array
or
(N,) 1D array used
as (1,N) 2D array

@

(N, P) 2D array
or
(N,) 1D array used
as (N,1) 2D array

A	B	A @ B
(M, N)	(N, P)	(M, P)
(M, N)	(N, 1)	(M, 1)
(M, N)	(N,)	(M,)
(1, N)	(N, P)	(1, P)
(N,)	(N, P)	(P,)
(1, N)	(N, 1)	(1, 1)
(N,)	(N,)	()

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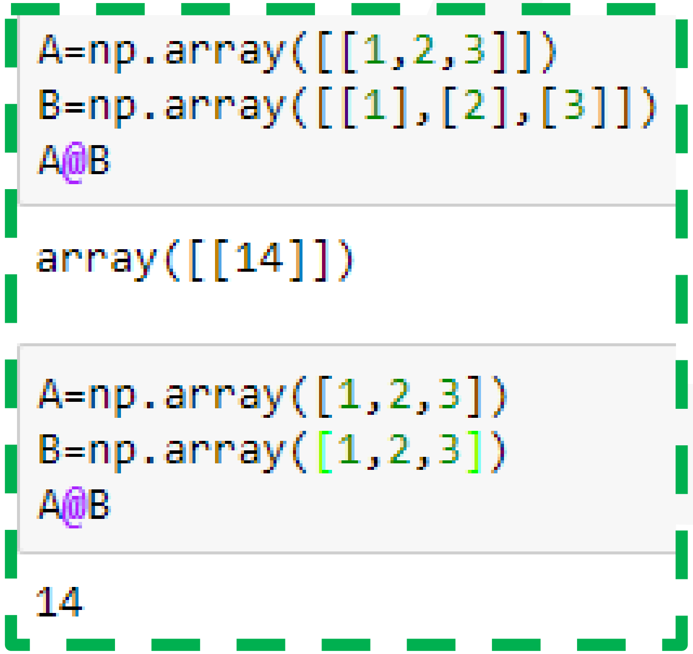

```
A=np.array([[1,2,3]])
B=np.array([[1],[2],[3]])
A@B
```

```
array([[14]])
```

```
A=np.array([1,2,3])
B=np.array([1,2,3])
A@B
```

```
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```

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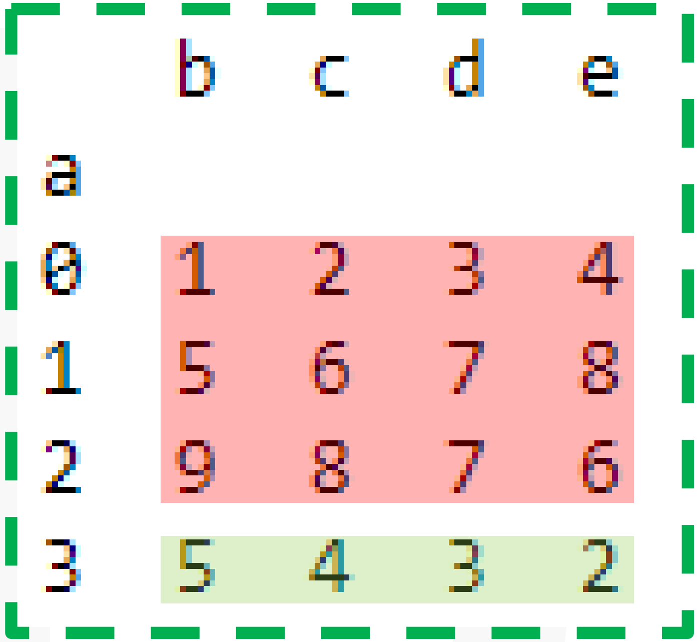

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

$$\begin{pmatrix}1&2&3&4\\5&6&7&8\\9&8&7&6\end{pmatrix} \times \begin{pmatrix}5\\4\\3\\2\end{pmatrix}$$

(3,4) (4,1)

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Use one command to compute the matrix multiplication, using the first 3 rows in **data** as the first matrix, and using the last row (without finding the number of rows) as the second 1-column matrix.

```
✓ data.values[:3] @ data.values[-1]
✓ data.values[:3] @ data.values[-1:].T
✓ data.values[:3] @ data.values[[-1]].T
```

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HT009: Basic operations on two rows/columns of `data`

✓ MATLAB tables do not support arithmetic operations.

HAHAHA....
HAHAHA....

✓ Using the dot syntax (⇨1-column 2D array) or **{}**-indexing, we obtain MATLAB arrays.

- ✓ 1D arrays are row matrices (or 1-row 2D arrays).
- ✓ Matrix dimensions must agree or one is a scalar.
- ✓ Manual broadcasting

Wow~~~

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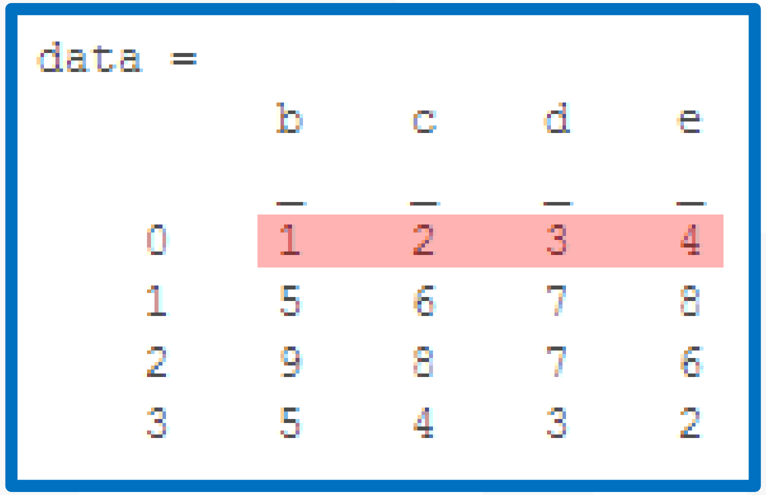


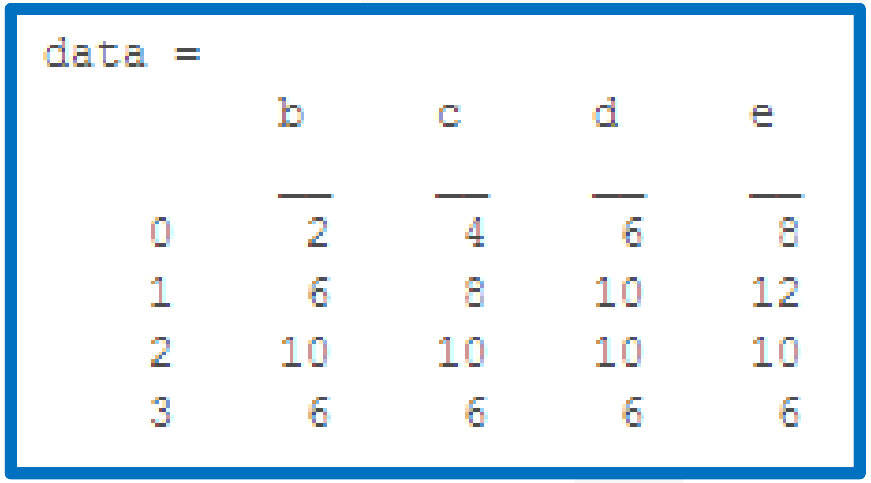
```
data =

         b    c    d    e
         _    _    _    _

    0    1    2    3    4
    1    5    6    7    8
    2    9    8    7    6
    3    5    4    3    2
```

1. Add the first row to every row.
2. “help repmat”
3. “help size”

Use one command



```
data =

          b     c     d     e
         __    __    __    __

    0     2     4     6     8
    1     6     8    10    12
    2    10    10    10    10
    3     6     6     6     6
```

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```
data{:,:}=data{:,:}+repmat(data{1,:},size(data,1),1)
```

numpy.tile(A, (M, N)) ⇔ **repmat(A, M, N)**

or **repmat(A, [M, N])**

https://www.mathworks.com/help/matlab/ref/repmat.html

https://www.mathworks.com/help/matlab/ref/size.html

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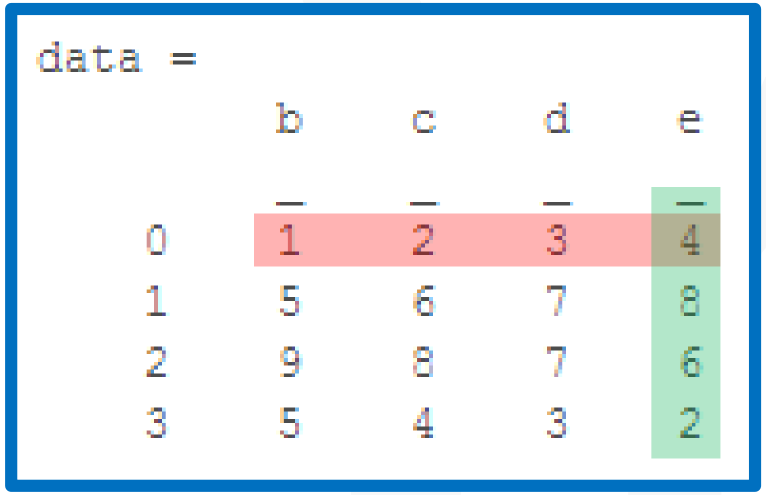
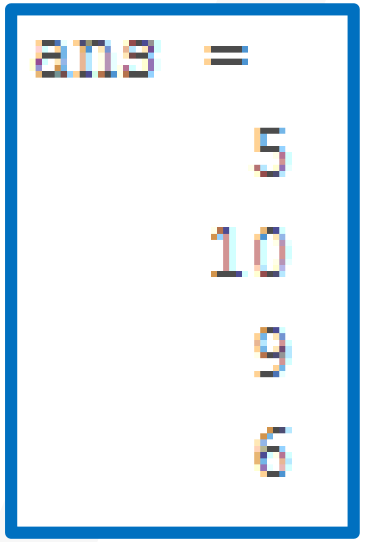


```
data =
            b    c    d    e
            _    _    _    _
      0     1    2    3    4
      1     5    6    7    8
      2     9    8    7    6
      3     5    4    3    2
```

- ✓ Use one command to add the first row and last column (without using the size of **`data`**) of **`data`** elementwise and return the result in a column array.
- ✓ “help transpose”
- ✓ “help end”



```
ans =
      5
     10
      9
      6
```

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```
transpose(data{1,:})+data{:,end}
```

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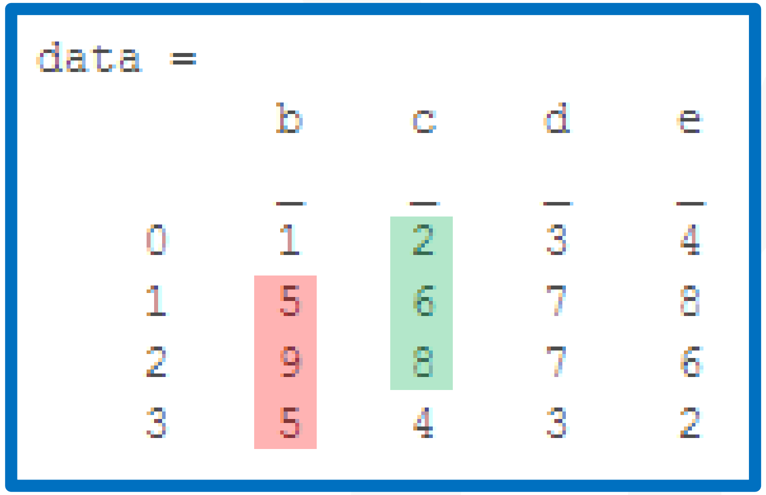
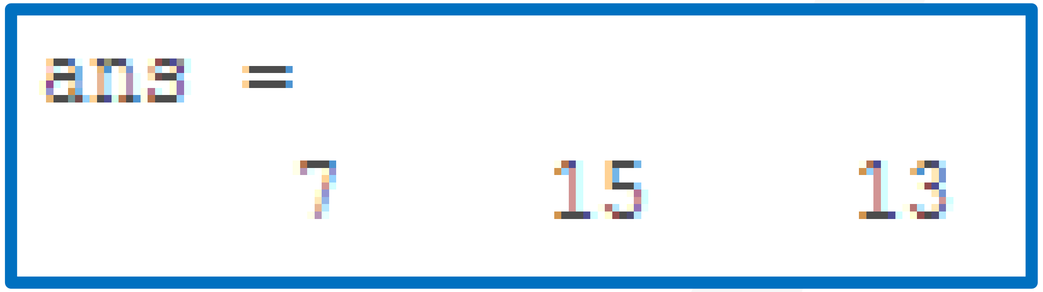
- ✓ Use one command to add elements in the first column from the second row to the last row (without using the size of **`data`**) and elements in the second column from the first row to the second to the last row (without finding the size of **`data`**) element wise and return the result in a row array.



```
data =
          b    c    d    e
          _    _    _    _
     0    1    2    3    4
     1    5    6    7    8
     2    9    8    7    6
     3    5    4    3    2
```



```
ans =

     7     15     13
```

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`transpose(data{2:end,1}+data{1:end-1,2})`

MATLAB Operators

X*Y	: matrix multiplication
X.*Y	: element-wise multiplication
X^y	: matrix power
X.^Y	: element-wise power
X/Y	: matrix right division
X./Y	: element-wise divide

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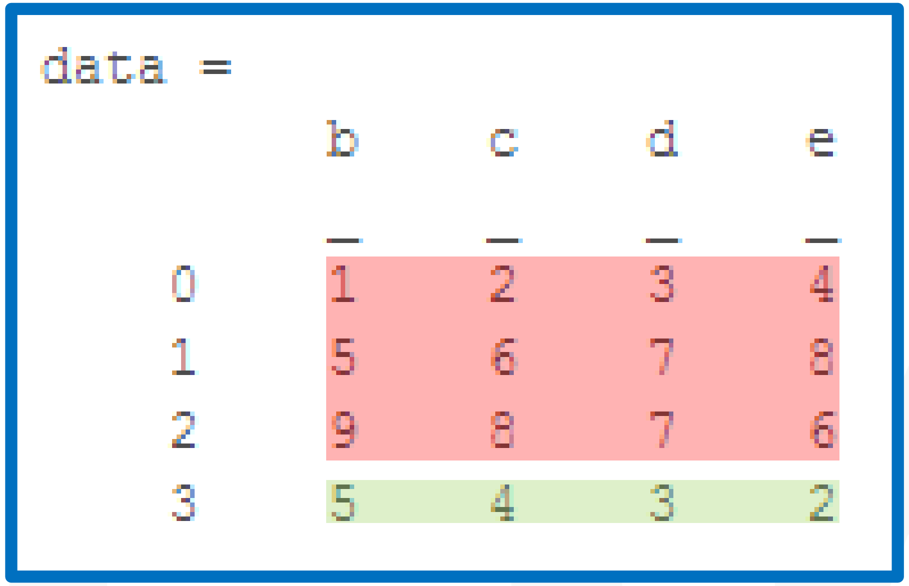

```
data =

          b    c    d    e

          _    _    _    _
    0     1    2    3    4
    1     5    6    7    8
    2     9    8    7    6
    3     5    4    3    2
```

$$\underset{(3,4)}{\begin{pmatrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \\ 9 & 8 & 7 & 6 \end{pmatrix}} \times \underset{(4,1)}{\begin{pmatrix} 5 \\ 4 \\ 3 \\ 2 \end{pmatrix}}$$

Use one command to compute the matrix multiplication, using the first 3 rows in **`data`** as the first matrix, and using the last row (without using the size of **`data`**) as the second 1-column matrix.

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```
data{1:3, :}*transpose(data{end,:})
```

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Slide
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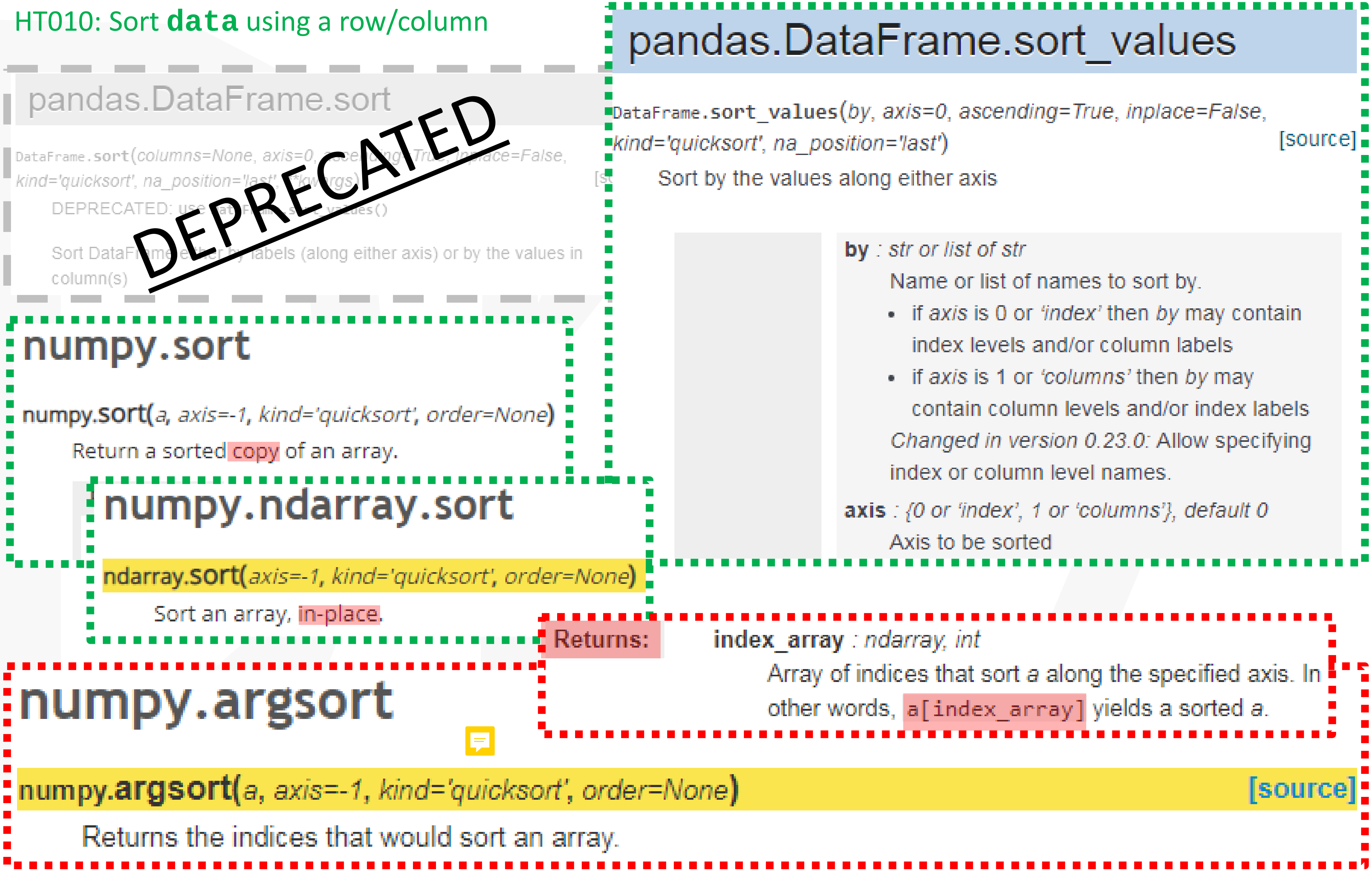
HT010: Sort **data** using a row/column



pandas.DataFrame.sort

DataFrame.sort(*columns=None, axis=0, ascending=True, inplace=False, kind='quicksort', na_position='last', **kwargs*) [source]

DEPRECATED: use DataFrame.sort_values()

Sort DataFrame either by labels (along either axis) or by the values in column(s)

DEPRECATED

pandas.DataFrame.sort_values

DataFrame.**sort_values**(*by, axis=0, ascending=True, inplace=False, kind='quicksort', na_position='last'*) [source]

Sort by the values along either axis

by : *str or list of str*

Name or list of names to sort by.

- if *axis* is 0 or *'index'* then *by* may contain index levels and/or column labels
- if *axis* is 1 or *'columns'* then *by* may contain column levels and/or index labels

Changed in version 0.23.0: Allow specifying index or column level names.

axis : *{0 or 'index', 1 or 'columns'}, default 0*

Axis to be sorted

numpy.sort

numpy.sort(*a, axis=-1, kind='quicksort', order=None*)

Return a sorted copy of an array.

numpy.ndarray.sort

ndarray.sort(*axis=-1, kind='quicksort', order=None*)

Sort an array, in-place.

numpy.argsort

numpy.argsort(*a, axis=-1, kind='quicksort', order=None*) [source]

Returns the indices that would sort an array.

Returns: **index_array** : *ndarray, int*

Array of indices that sort *a* along the specified axis. In other words, `a[index_array]` yields a sorted *a*.

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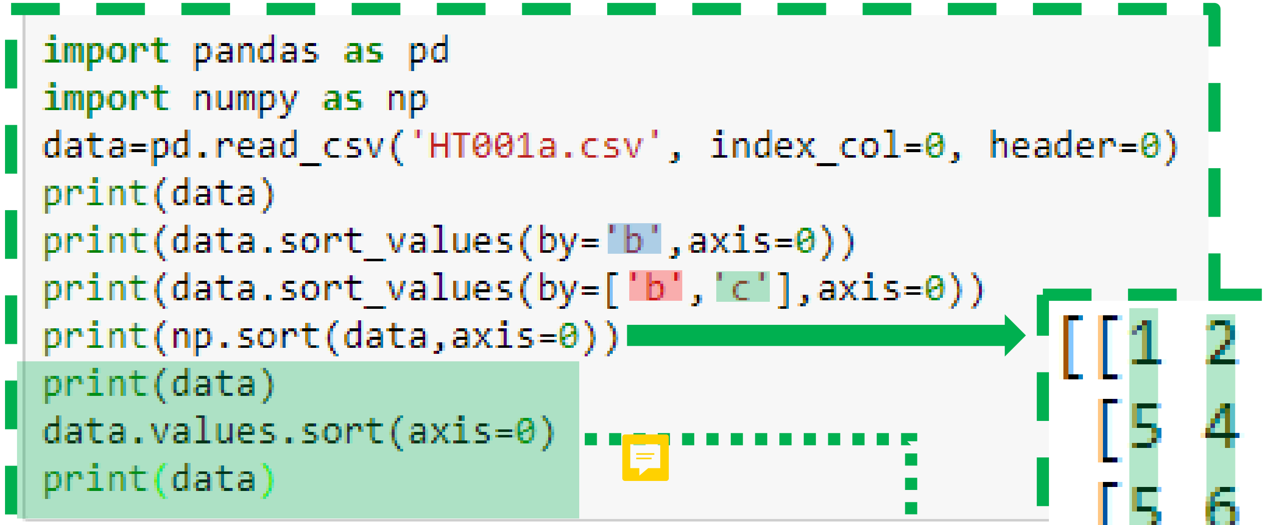
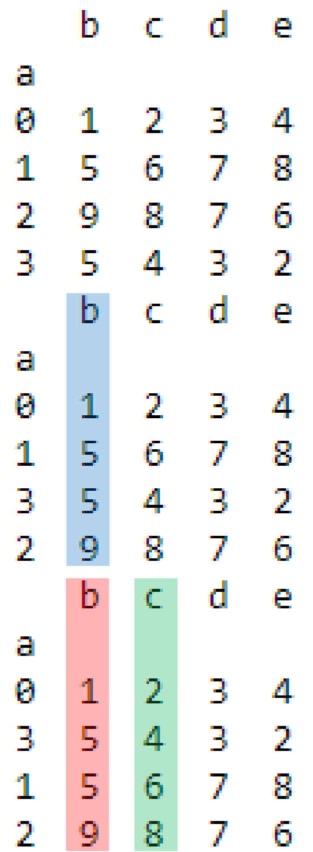
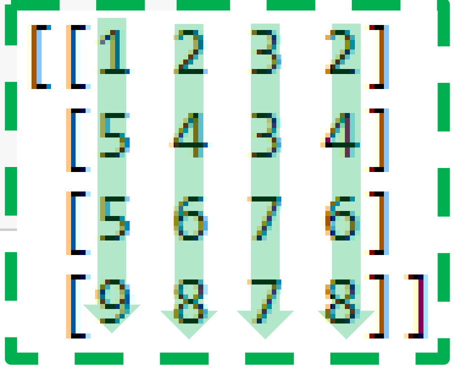


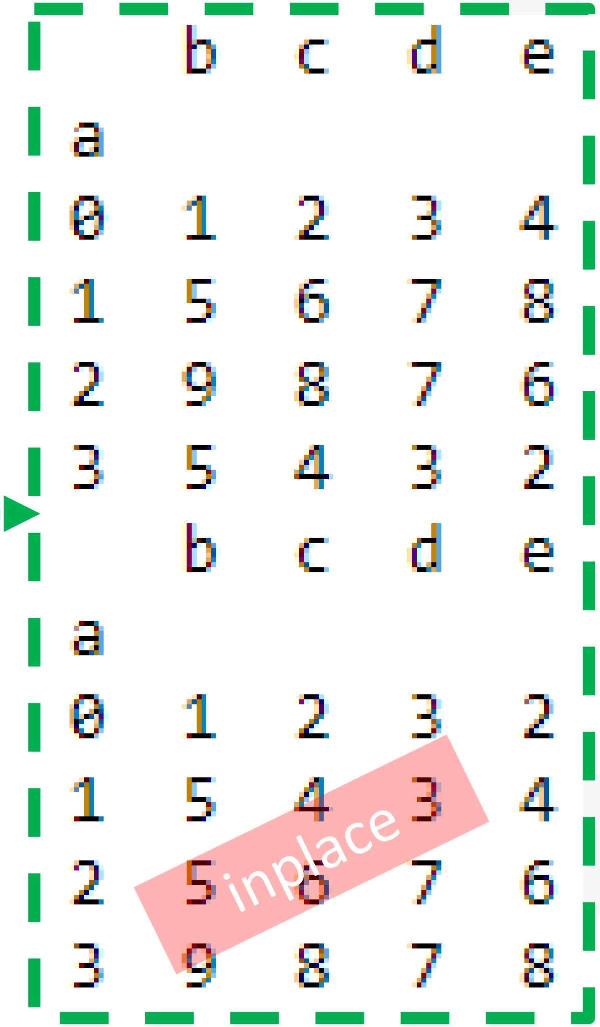
```
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
print(data.sort_values(by='b',axis=0))
print(data.sort_values(by=['b','c'],axis=0))
print(np.sort(data,axis=0))
print(data)
data.values.sort(axis=0)
print(data)
```



```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
3  5  4  3  2
2  9  8  7  6
   b  c  d  e
a
0  1  2  3  4
3  5  4  3  2
1  5  6  7  8
2  9  8  7  6
```



```
[[1 2 3 2]
 [5 4 3 4]
 [5 6 7 6]
 [9 8 7 8]]
```



```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
   b  c  d  e
a
0  1  2  3  2
1  5  4  3  4
2  5  6  7  6
3  9  8  7  8
```

- ❑ **np.sort** sort **every** row/colum.
- ❑ **np.ndarray.sort** sort, **inplace**, **every** row/colum.

pandas.DataFrame.sort_values:
Sort **data** using rows/columns.

Use one command to sort rows in ascending order using the 3rd column?

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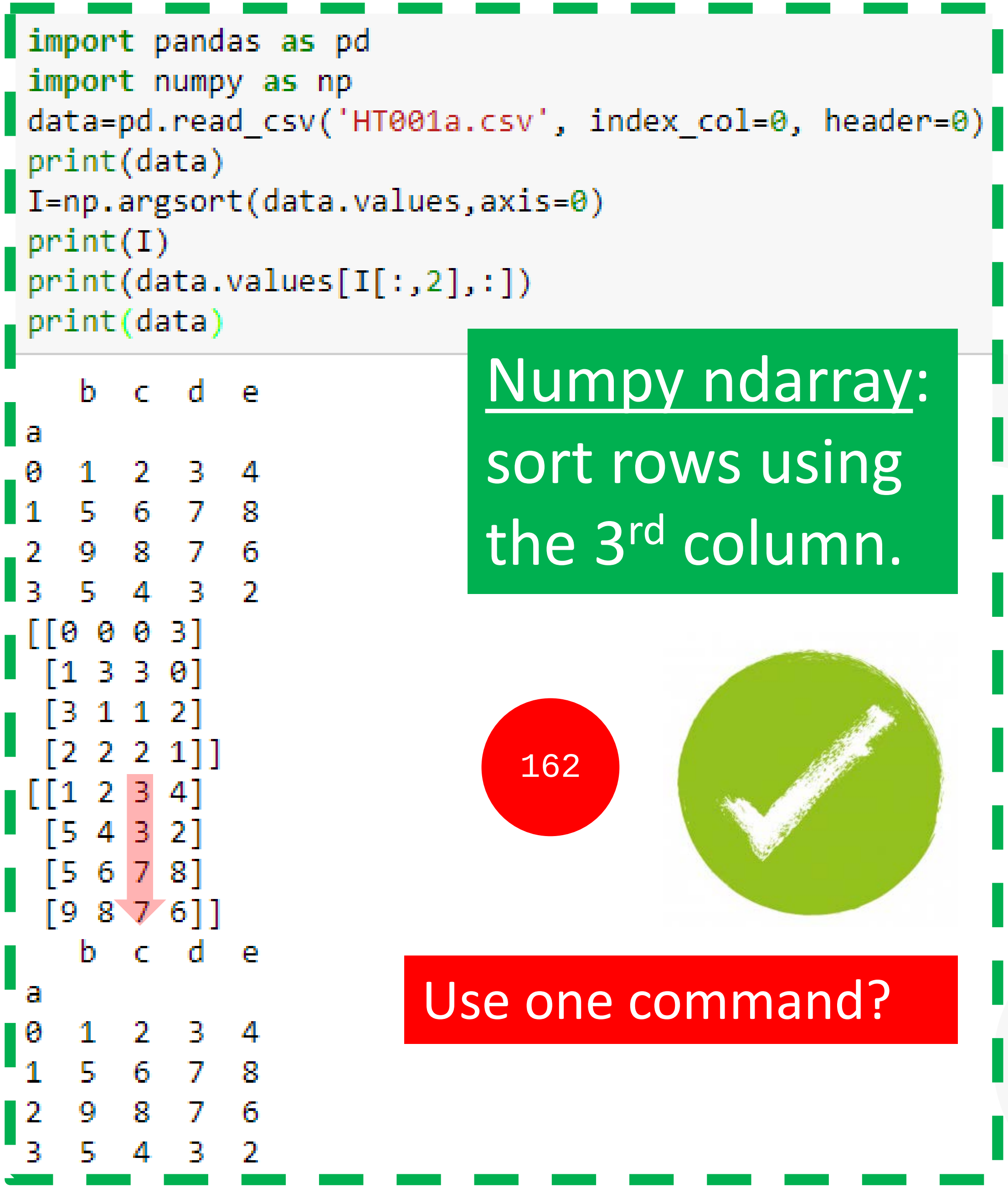

```
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
I=np.argsort(data.values,axis=0)
print(I)
print(data.values[I[:,2],:])
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
[[0 0 0 3]
 [1 3 3 0]
 [3 1 1 2]
 [2 2 2 1]]
[[1 2 3 4]
 [5 4 3 2]
 [5 6 7 8]
 [9 8 7 6]]
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

Numpy ndarray: sort rows using the 3rd column.

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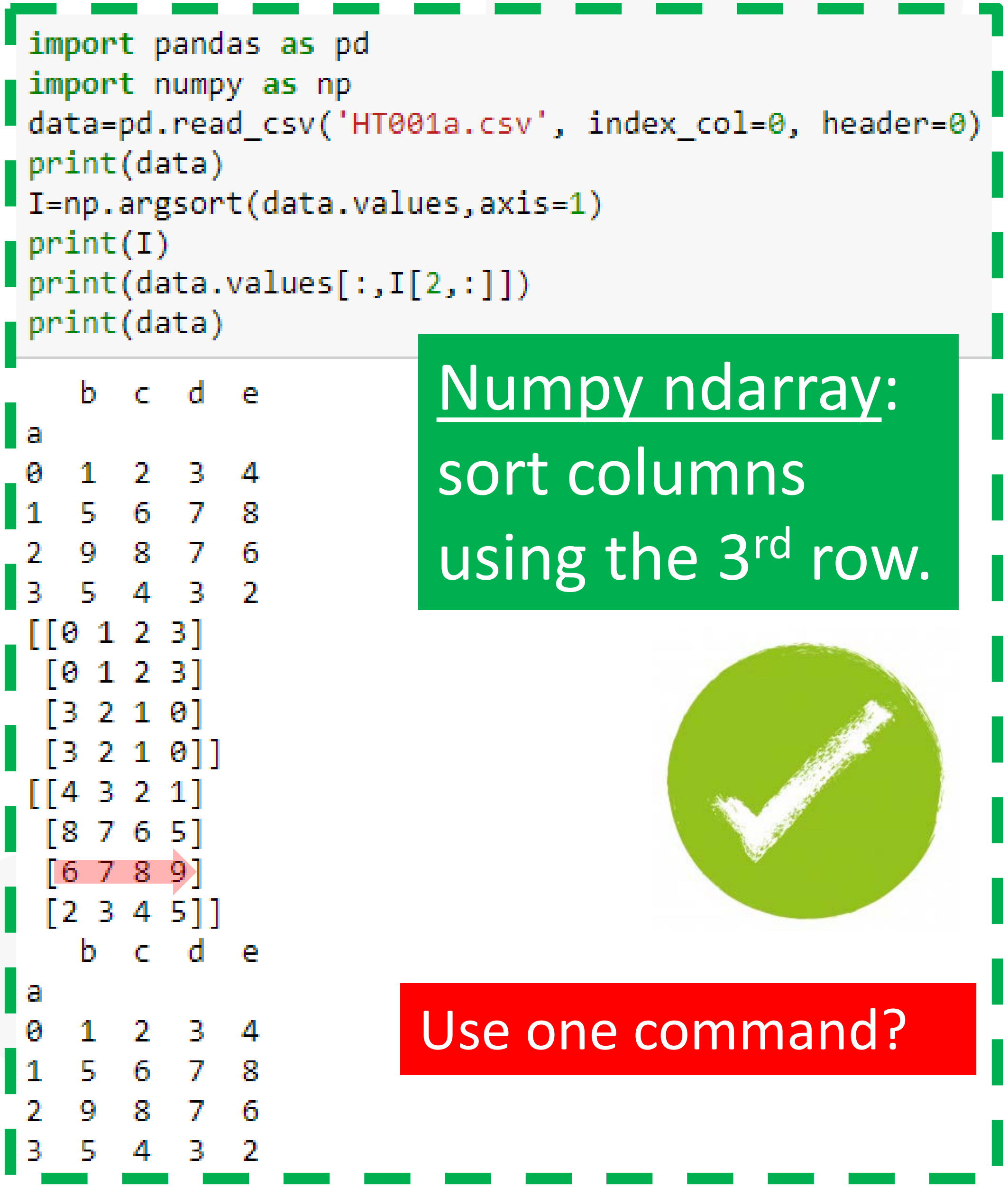
Use one command?



```
import pandas as pd
import numpy as np
data=pd.read_csv('HT001a.csv', index_col=0, header=0)
print(data)
I=np.argsort(data.values,axis=1)
print(I)
print(data.values[:,I[2,:]])
print(data)
```

```
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
[[0 1 2 3]
 [0 1 2 3]
 [3 2 1 0]
 [3 2 1 0]]
[[4 3 2 1]
 [8 7 6 5]
 [6 7 8 9]
 [2 3 4 5]]
   b  c  d  e
a
0  1  2  3  4
1  5  6  7  8
2  9  8  7  6
3  5  4  3  2
```

Numpy ndarray: sort columns using the 3rd row.

Use one command?

HT010: Sort `data` using a row/column

✓ `sort` (total row/column sort)

✓ `sortrows` (sort rows)

`sort` and `sortrows` are functions on matrices. `sort` does not work on table, `sortrows` works on table.

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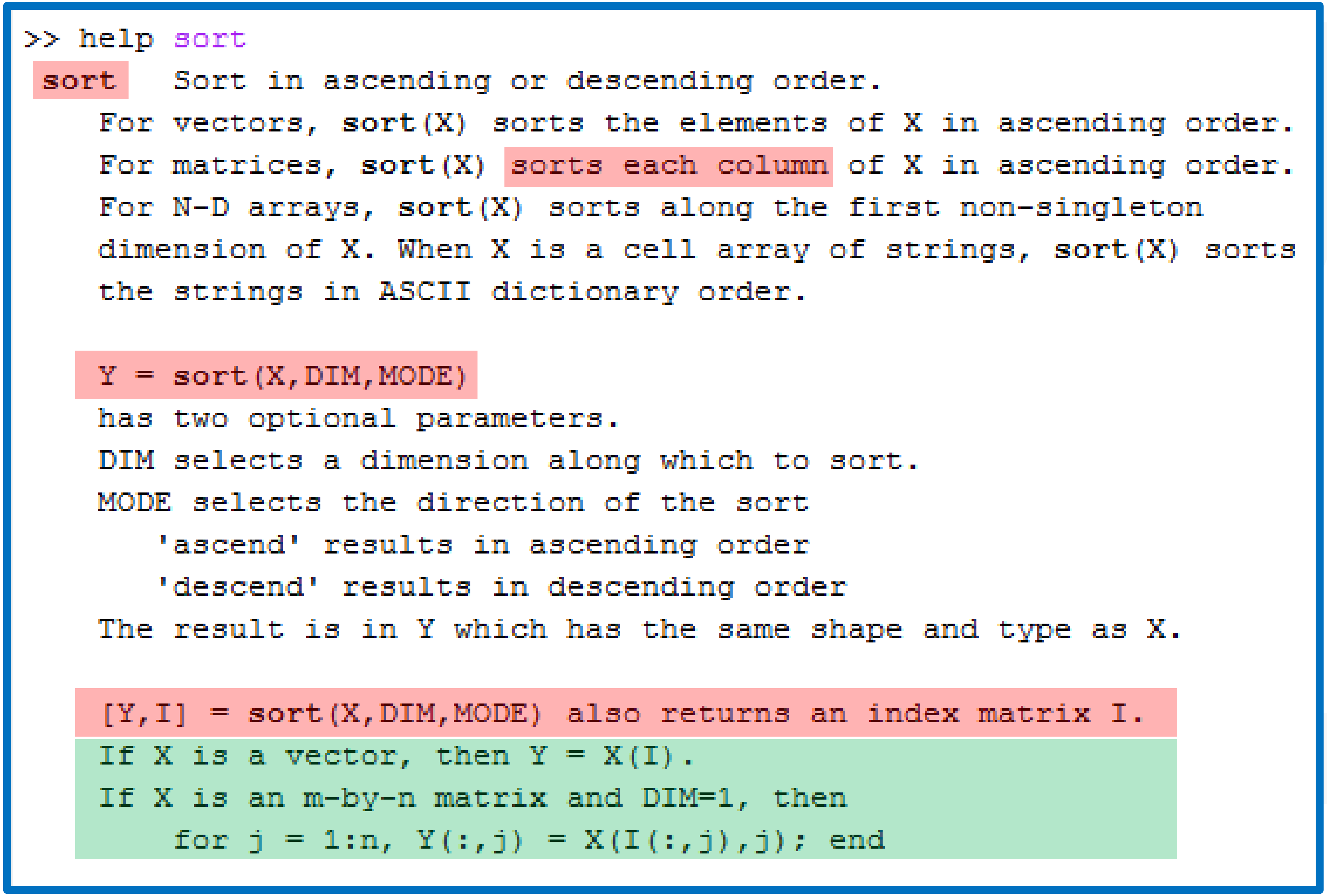
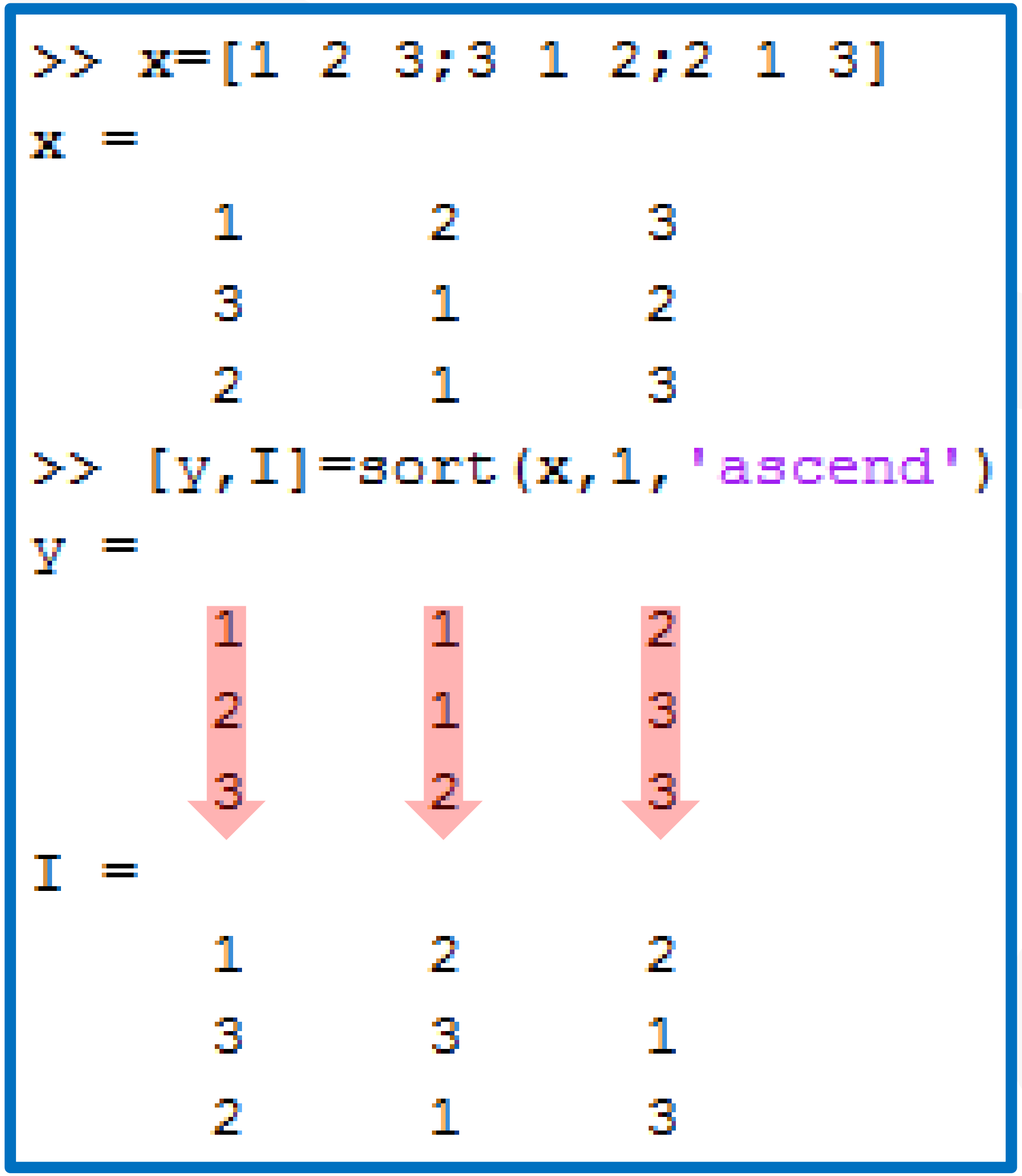


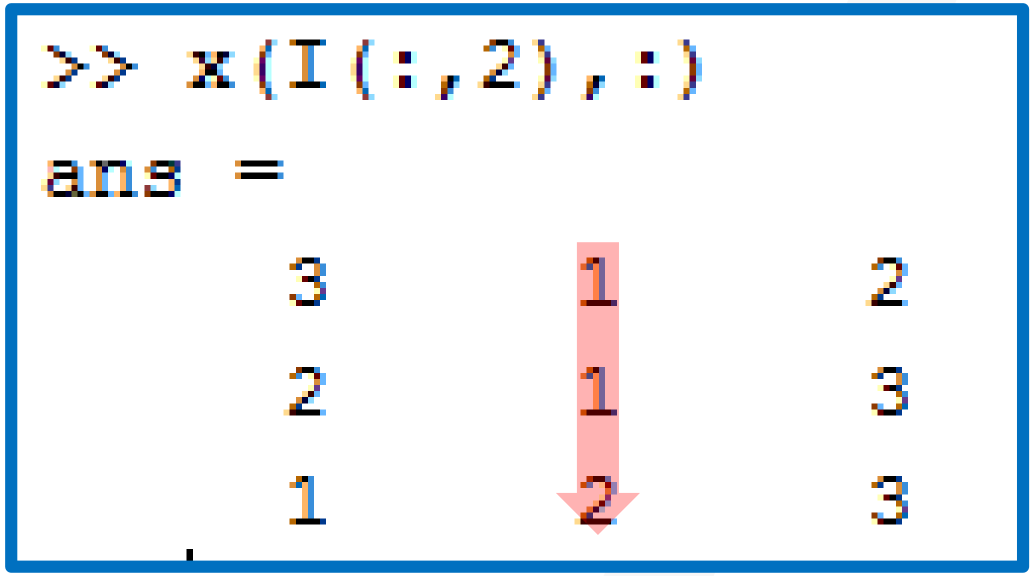
```
>> help sort
 sort    Sort in ascending or descending order.
    For vectors, sort(X) sorts the elements of X in ascending order.
    For matrices, sort(X) sorts each column of X in ascending order.
    For N-D arrays, sort(X) sorts along the first non-singleton
    dimension of X. When X is a cell array of strings, sort(X) sorts
    the strings in ASCII dictionary order.

    Y = sort(X,DIM,MODE)
    has two optional parameters.
    DIM selects a dimension along which to sort.
    MODE selects the direction of the sort
       'ascend' results in ascending order
       'descend' results in descending order
    The result is in Y which has the same shape and type as X.

    [Y,I] = sort(X,DIM,MODE) also returns an index matrix I.
    If X is a vector, then Y = X(I).
    If X is an m-by-n matrix and DIM=1, then
        for j = 1:n, Y(:,j) = X(I(:,j),j); end
```



```
>> x=[1 2 3;3 1 2;2 1 3]
x =
     1     2     3
     3     1     2
     2     1     3
>> [y,I]=sort(x,1,'ascend')
y =
     1     1     2
     2     1     3
     3     2     3
I =
     1     2     2
     3     3     1
     2     1     3
```



```
>> x(I(:,2),:)
ans =
     3     1     2
     2     1     3
     1     2     3
```

`x(I(:,2),:)` sort **`x`** using the second column.

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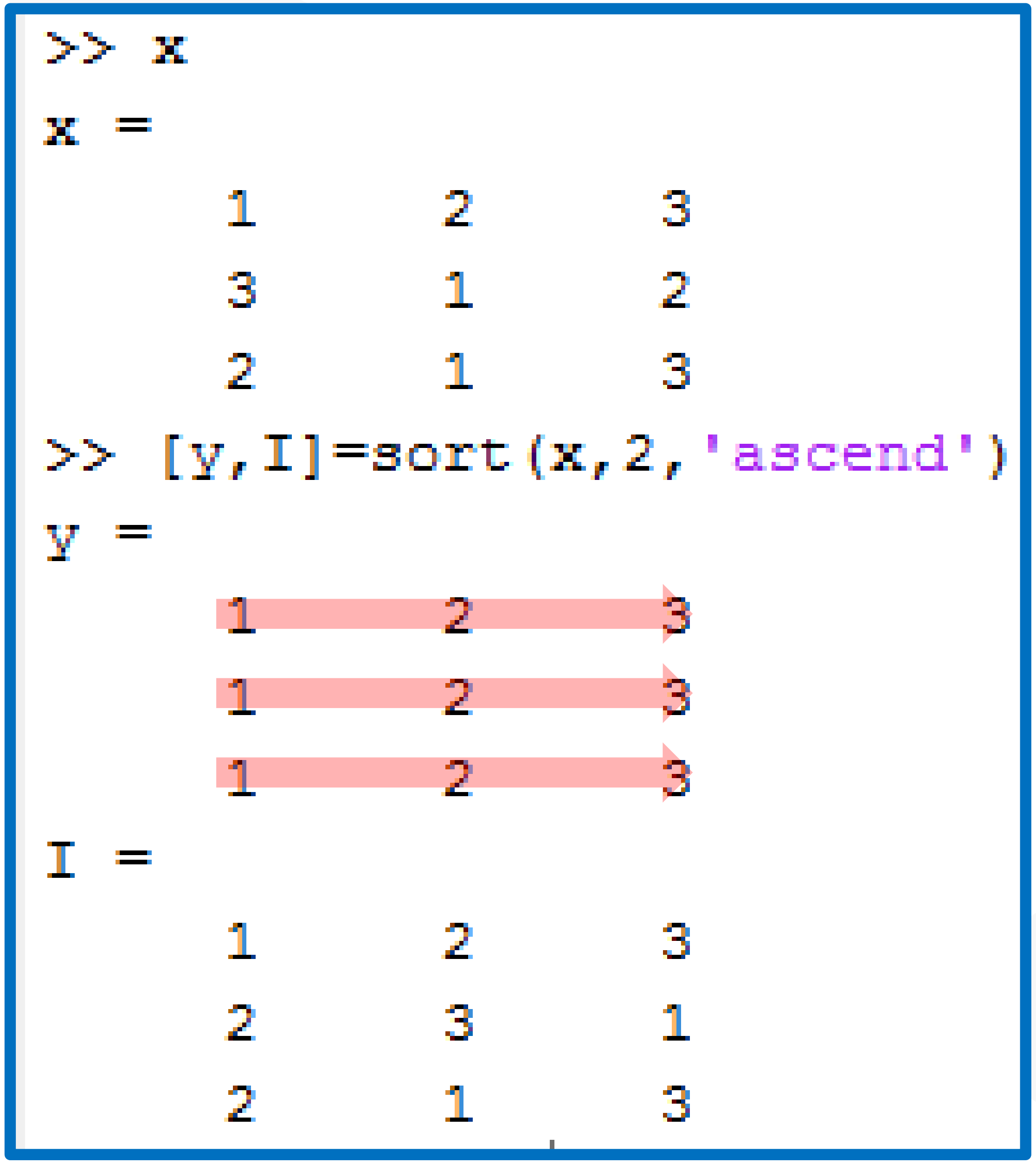
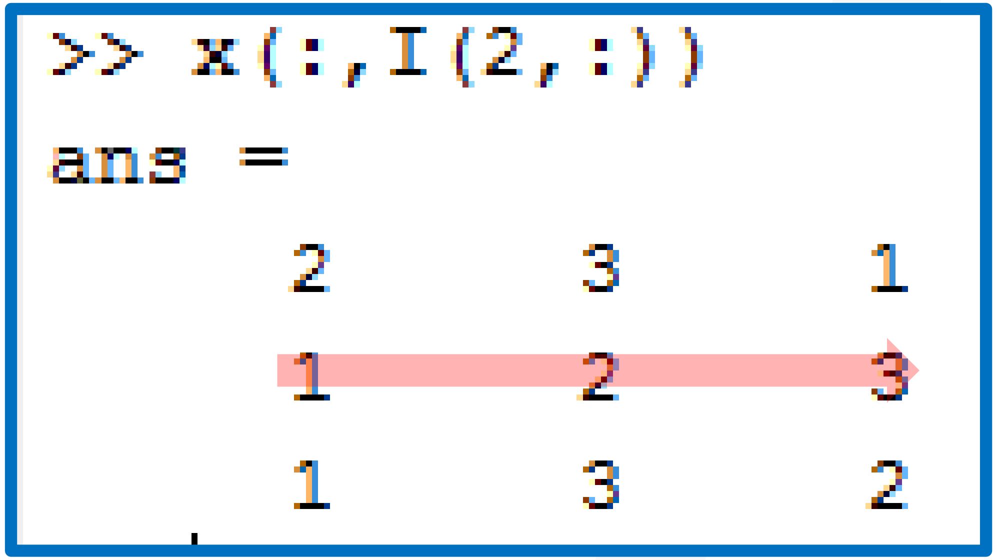


```
>> x

x =

     1     2     3
     3     1     2
     2     1     3

>> [y,I]=sort(x,2,'ascend')

y =

     1     2     3
     1     2     3
     1     2     3

I =

     1     2     3
     2     3     1
     2     1     3
```



```
>> x(:,I(2,:))

ans =

     2     3     1
     1     2     3
     1     3     2
```

`x(:,I(2,:))` sort `x` using the second row.

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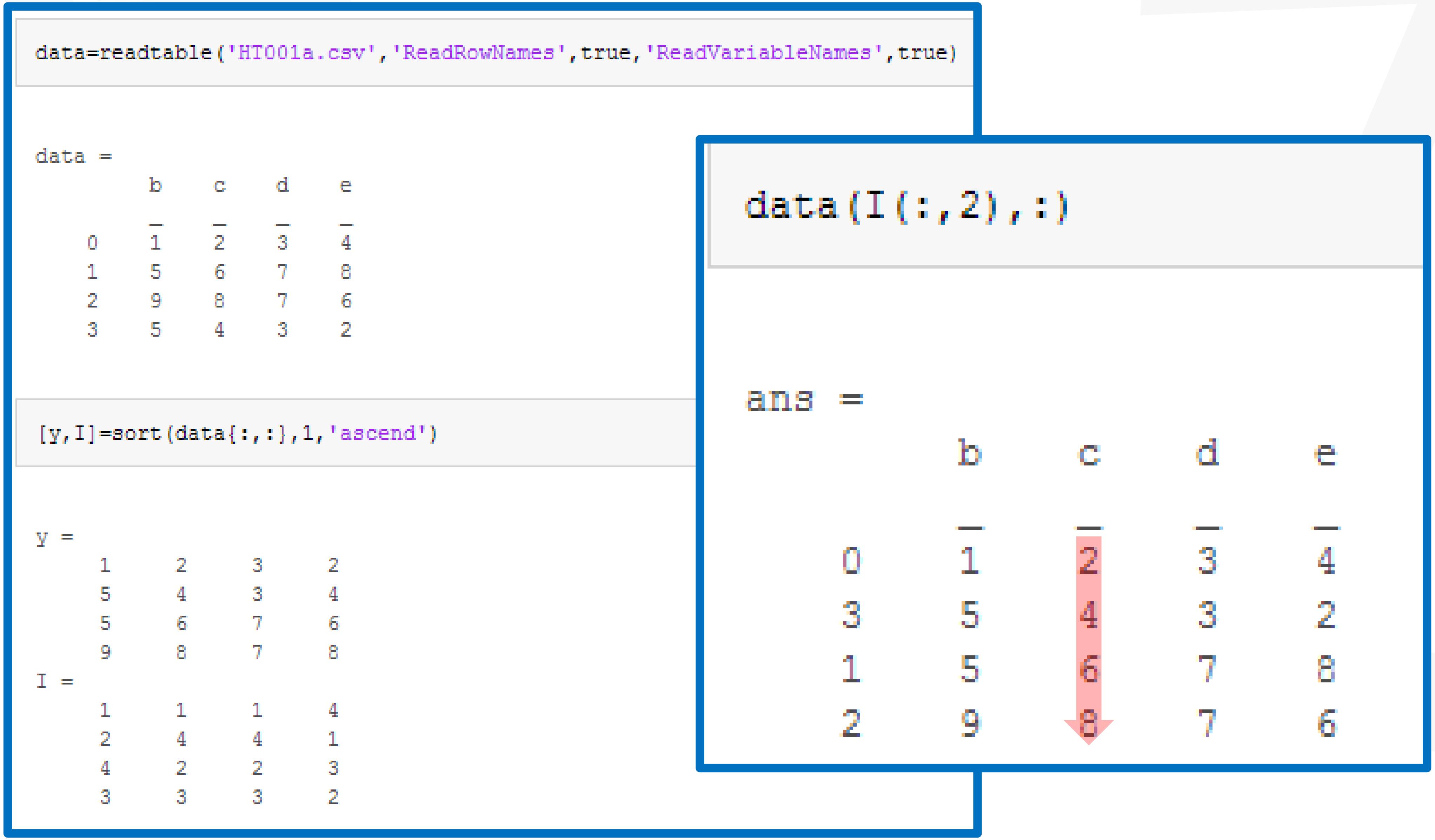
⇨How to use **sort** to sort **data**?



```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
```

```
data =
             b      c      d      e
             _      _      _      _
      0      1      2      3      4
      1      5      6      7      8
      2      9      8      7      6
      3      5      4      3      2
```

```
[y,I]=sort(data{:,:},1,'ascend')
```

```
y =
      1      2      3      2
      5      4      3      4
      5      6      7      6
      9      8      7      8
I =
      1      1      1      4
      2      4      4      1
      4      2      2      3
      3      3      3      2
```

```
data(I(:,2),:)
```

```
ans =
             b      c      d      e
             _      _      _      _
      0      1      2      3      4
      3      5      4      3      2
      1      5      6      7      8
      2      9      8      7      6
```

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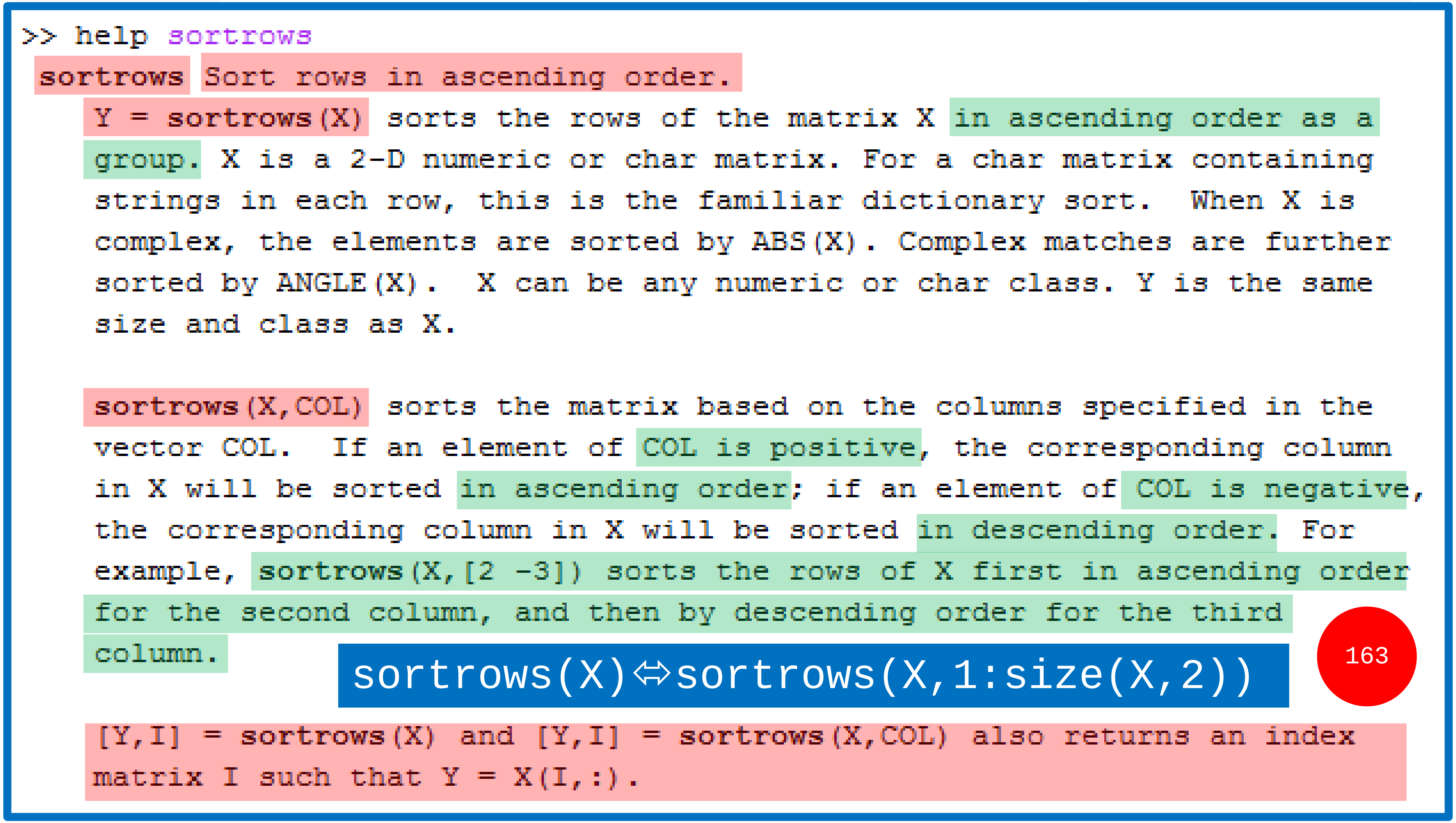

```
>> help sortrows
 sortrows Sort rows in ascending order.
    Y = sortrows(X) sorts the rows of the matrix X in ascending order as a
    group. X is a 2-D numeric or char matrix. For a char matrix containing
    strings in each row, this is the familiar dictionary sort.  When X is
    complex, the elements are sorted by ABS(X). Complex matches are further
    sorted by ANGLE(X).  X can be any numeric or char class. Y is the same
    size and class as X.

    sortrows(X,COL) sorts the matrix based on the columns specified in the
    vector COL.  If an element of COL is positive, the corresponding column
    in X will be sorted in ascending order; if an element of COL is negative,
    the corresponding column in X will be sorted in descending order. For
    example, sortrows(X,[2 -3]) sorts the rows of X first in ascending order
    for the second column, and then by descending order for the third
    column.

    [Y,I] = sortrows(X) and [Y,I] = sortrows(X,COL) also returns an index
    matrix I such that Y = X(I,:).
```

sortrows(X)⇔sortrows(X,1:size(X,2))

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QF666
Programming and
Computational
Finance

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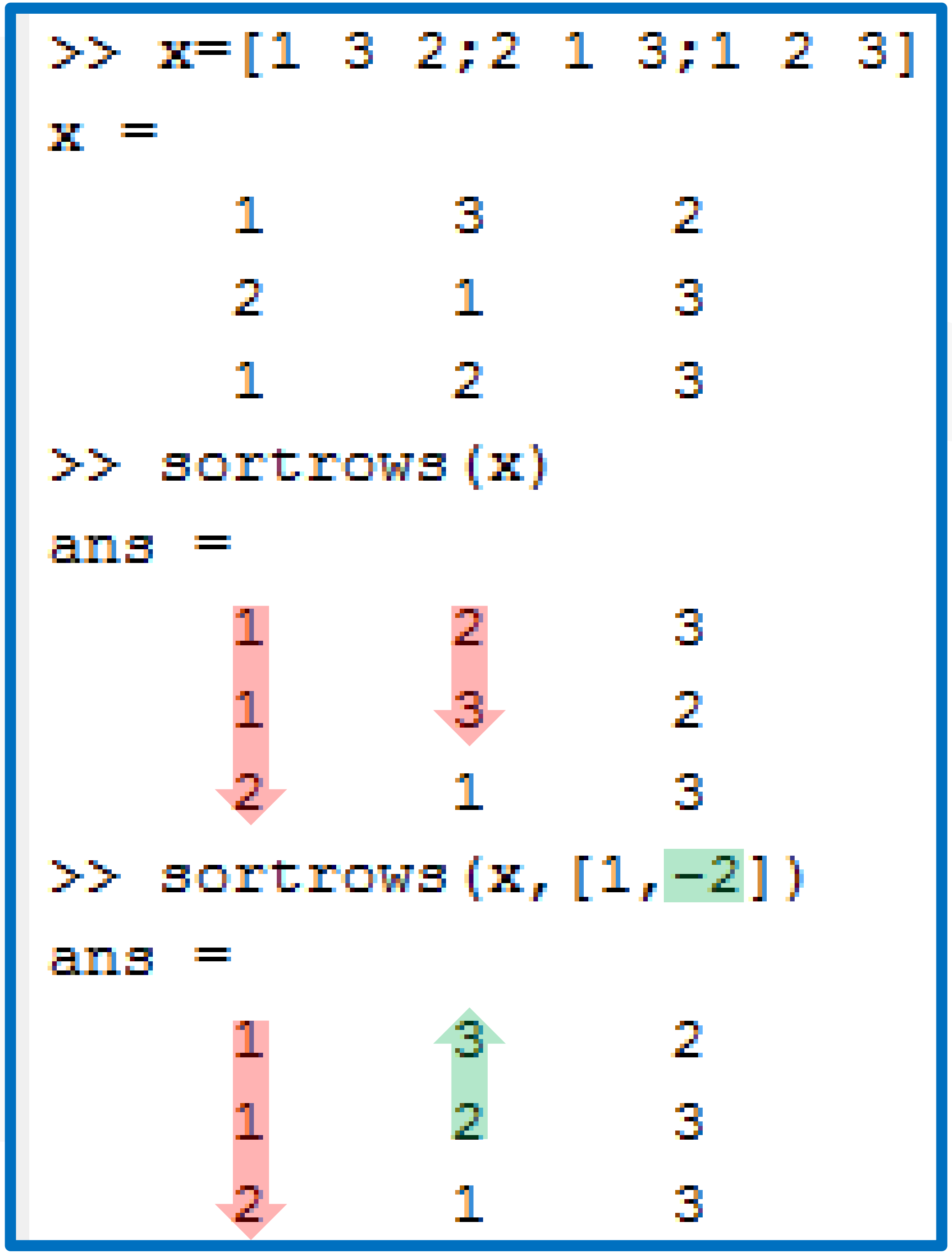
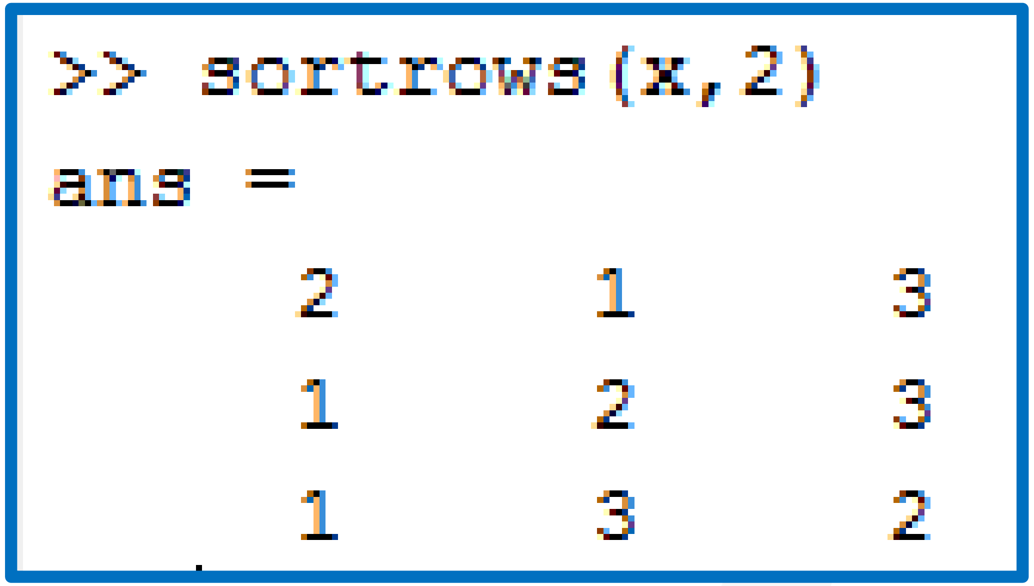
Finance



```
>> x=[1 3 2;2 1 3;1 2 3]
x =
     1     3     2
     2     1     3
     1     2     3
>> sortrows(x)
ans =
     1     2     3
     1     3     2
     2     1     3
>> sortrows(x,[1,-2])
ans =
     1     3     2
     1     2     3
     2     1     3
```



```
>> sortrows(x,2)
ans =
     2     1     3
     1     2     3
     1     3     2
```

`sortrows(x,2)` sort `x` using the second column.

Q: How to use `sortrows` to sort `x` using the second row?
[Hint: `transpose(x)`]

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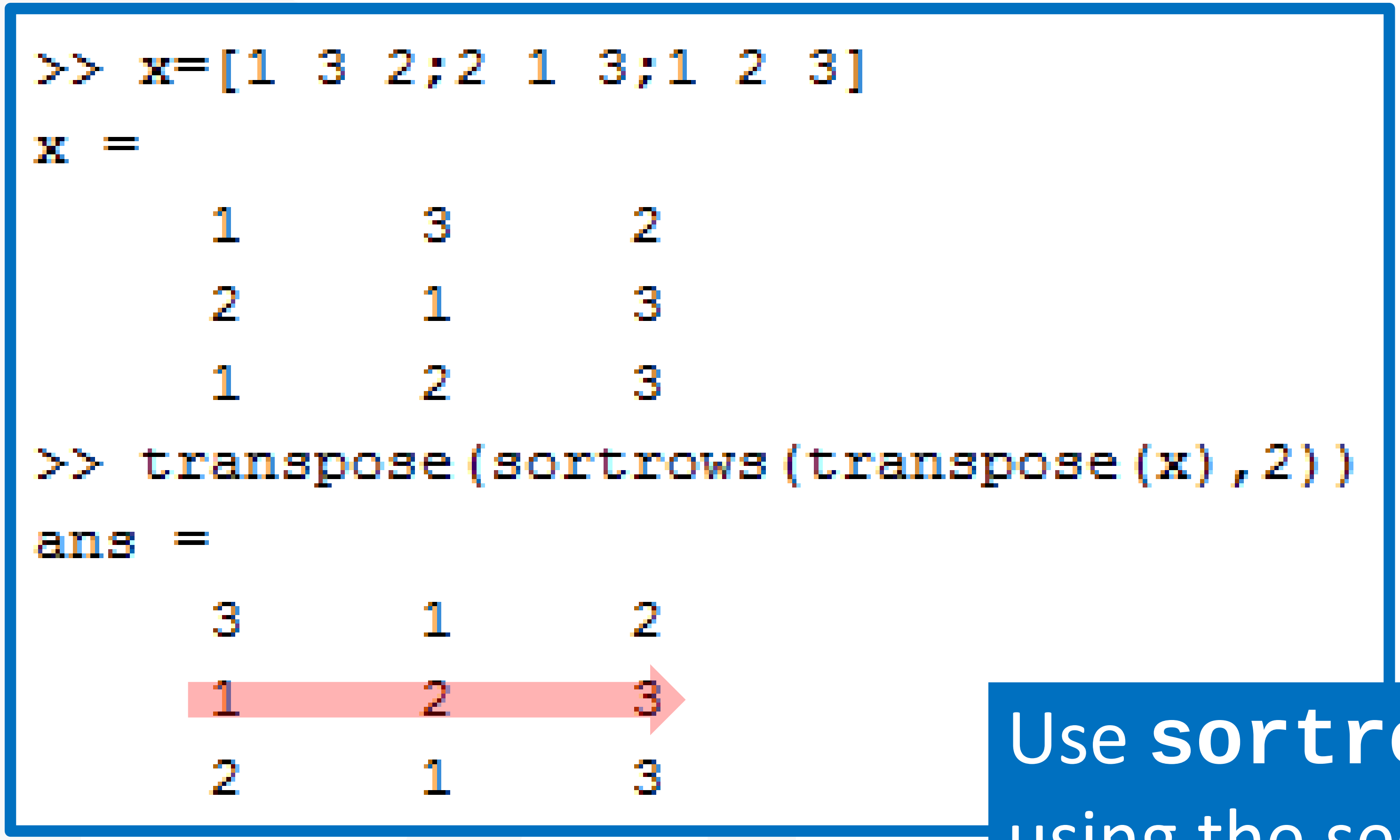

```
>> x=[1 3 2;2 1 3;1 2 3]

x =

     1     3     2
     2     1     3
     1     2     3

>> transpose(sortrows(transpose(x),2))

ans =

     3     1     2
     1     2     3
     2     1     3
```

Use **`sortrows`** to sort **`x`** using the second row?

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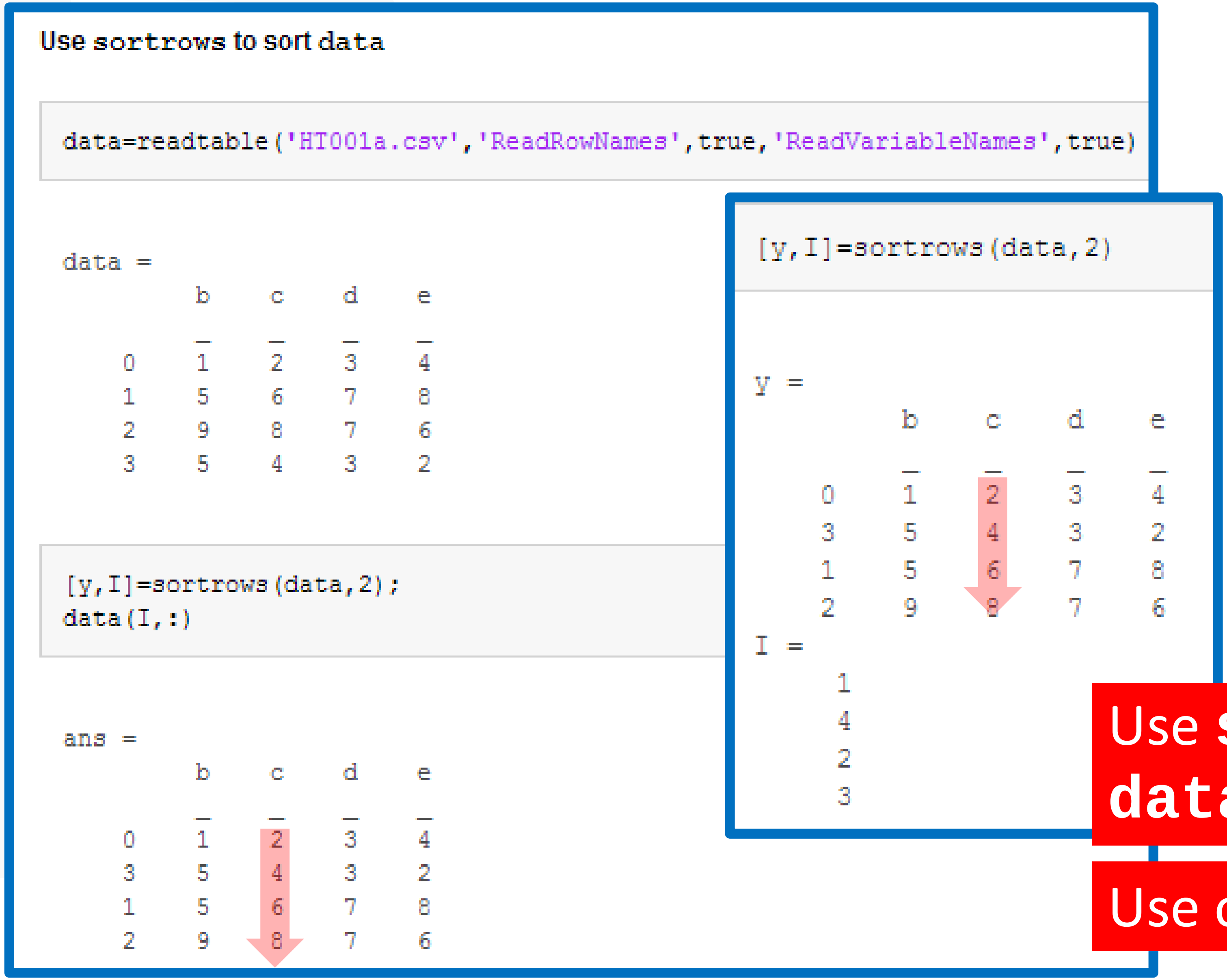
⇨How to use **sortrows** to sort **data**?



Use sortrows to sort data

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
```

```
data =
             b     c     d     e

             _     _     _     _
       0     1     2     3     4
       1     5     6     7     8
       2     9     8     7     6
       3     5     4     3     2
```

```
[y,I]=sortrows(data,2);
data(I,:)
```

```
ans =
             b     c     d     e

             _     _     _     _
       0     1     2     3     4
       3     5     4     3     2
       1     5     9     7     8
       2     9     8     7     6
```

```
[y,I]=sortrows(data,2)
```

```
y =
             b     c     d     e

             _     _     _     _
       0     1     2     3     4
       3     5     4     3     2
       1     5     6     7     8
       2     9     8     7     6
I =
        1
        4
        2
        3
```

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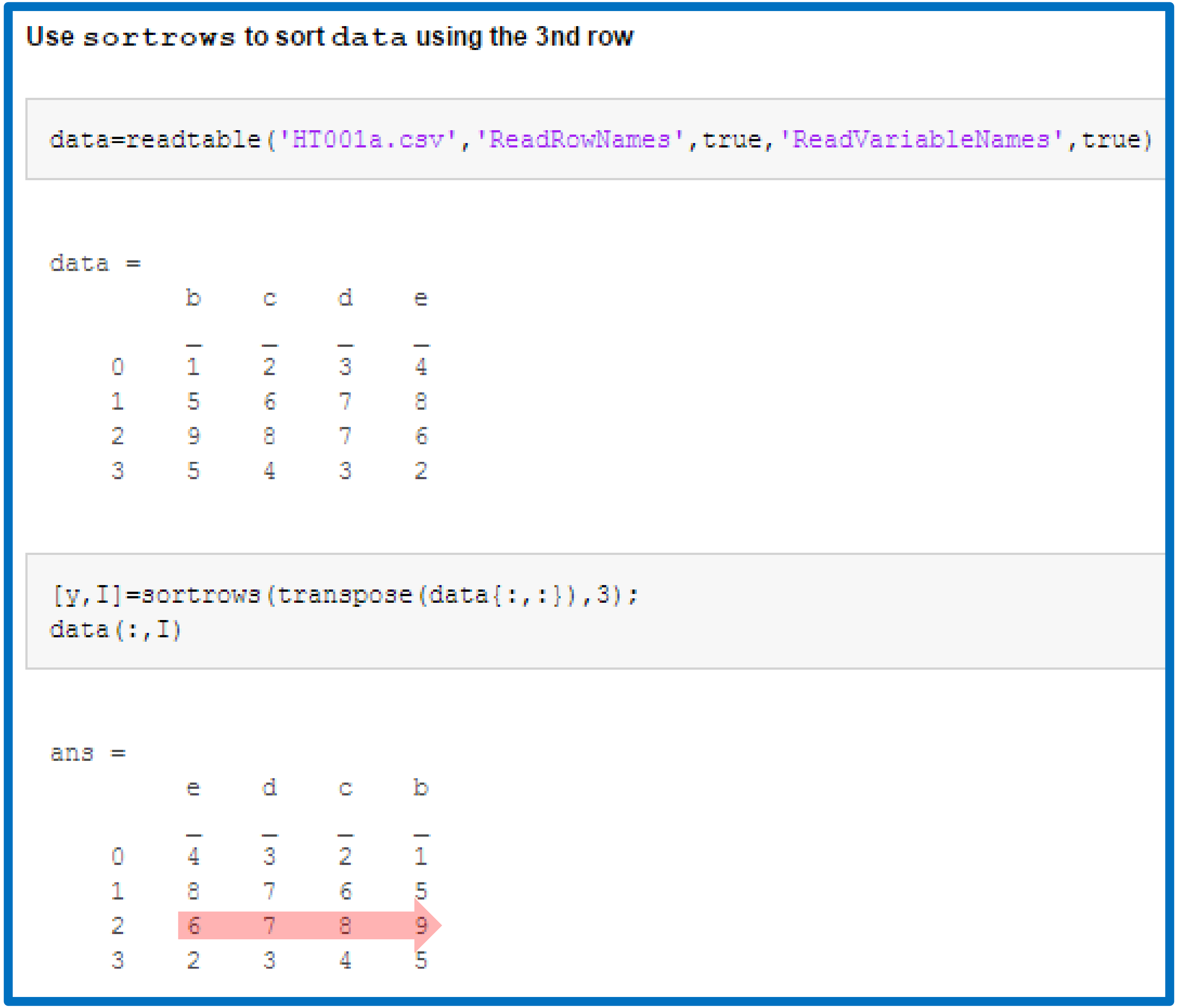
Use **sortrows** to sort **data** using a row?

Use one command?



Use sortrows to sort data using the 3nd row

```
data=readtable('HT001a.csv','ReadRowNames',true,'ReadVariableNames',true)
```

```
data =
                b    c    d    e

                _    _    _    _
        0       1    2    3    4
        1       5    6    7    8
        2       9    8    7    6
        3       5    4    3    2
```

```
[y,I]=sortrows(transpose(data{:,:}),3);
data(:,I)
```

```
ans =
                e    d    c    b

                _    _    _    _
        0       4    3    2    1
        1       8    7    6    5
        2       6    7    8    9
        3       2    3    4    5
```

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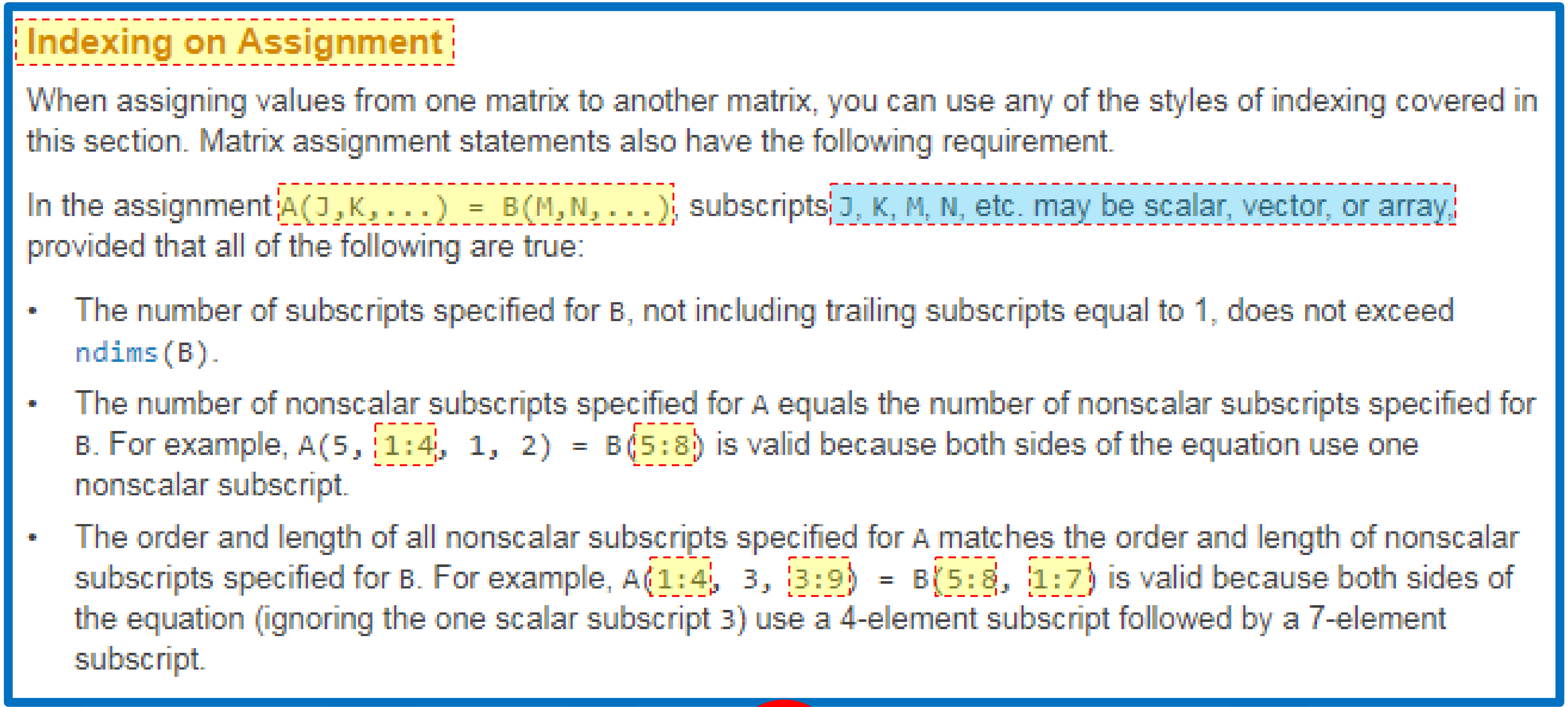
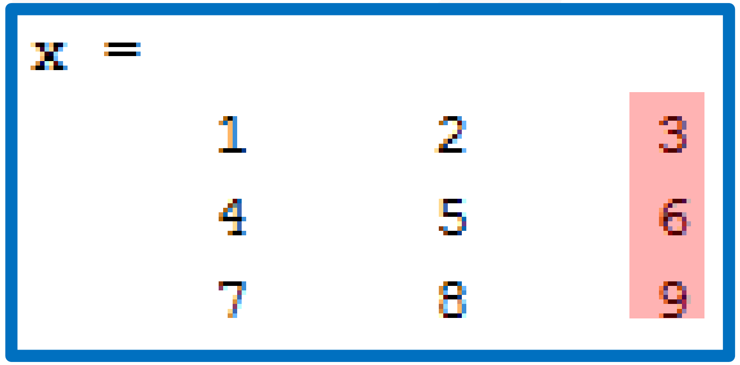


Indexing on Assignment

When assigning values from one matrix to another matrix, you can use any of the styles of indexing covered in this section. Matrix assignment statements also have the following requirement.

In the assignment `A(J,K,...) = B(M,N,...)`, subscripts `J`, `K`, `M`, `N`, etc. may be scalar, vector, or array, provided that all of the following are true:

- The number of subscripts specified for `B`, not including trailing subscripts equal to 1, does not exceed `ndims(B)`.
- The number of nonscalar subscripts specified for `A` equals the number of nonscalar subscripts specified for `B`. For example, `A(5, 1:4, 1, 2) = B(5:8)` is valid because both sides of the equation use one nonscalar subscript.
- The order and length of all nonscalar subscripts specified for `A` matches the order and length of nonscalar subscripts specified for `B`. For example, `A(1:4, 3, 3:9) = B(5:8, 1:7)` is valid because both sides of the equation (ignoring the one scalar subscript `3`) use a 4-element subscript followed by a 7-element subscript.



```
x =

     1     2     3
     4     5     6
     7     8     9
```

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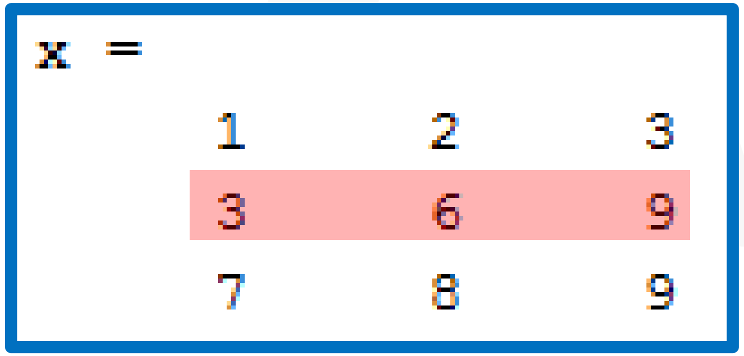
x(2,:)=x(:,3)



```
x =

     1     2     3
     3     6     9
     7     8     9
```

Caution: Numpy Array (Slicings are Views)

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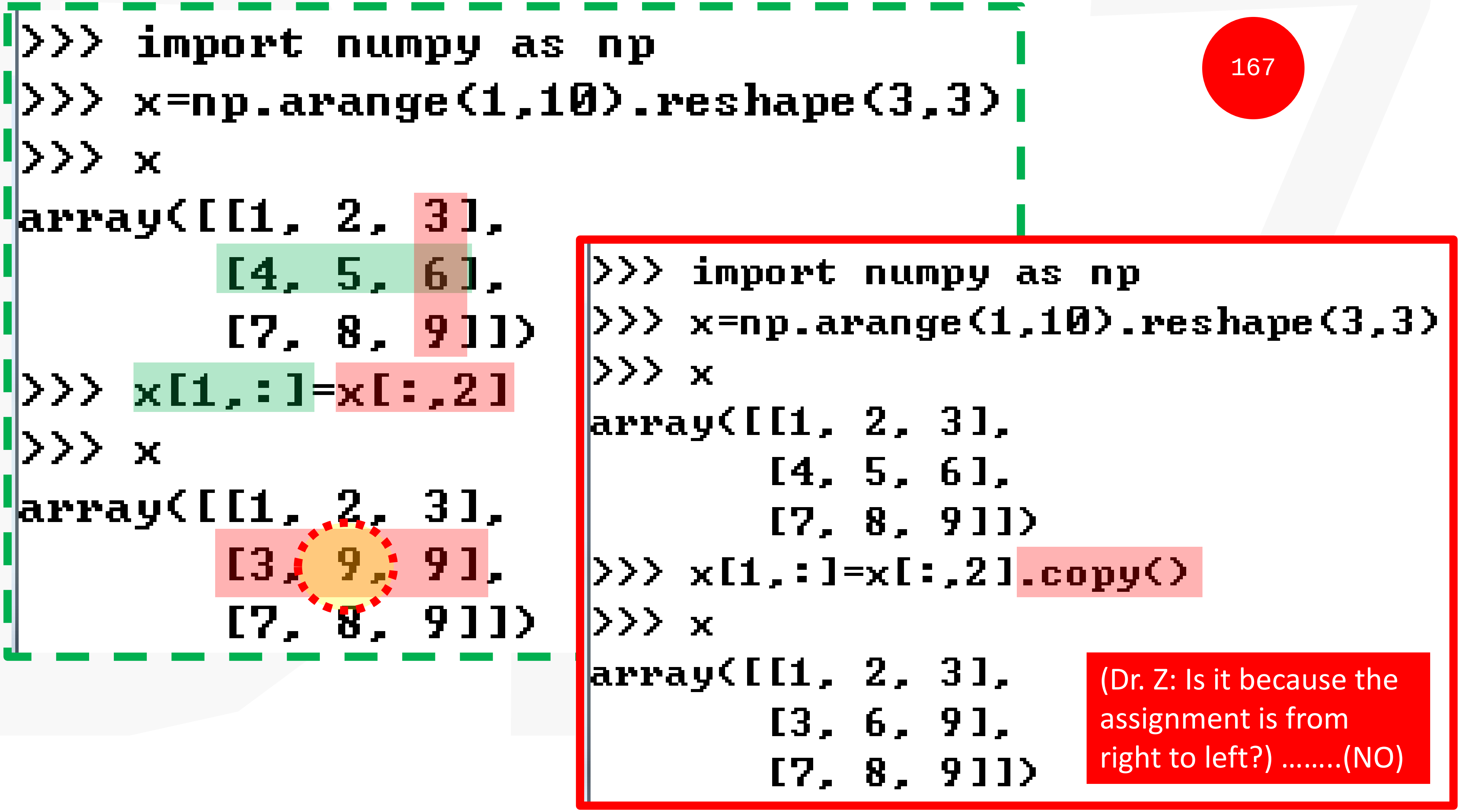

```
>>> import numpy as np
>>> x=np.arange(1,10).reshape(3,3)
>>> x
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
>>> x[1,:]=x[:,2]
>>> x
array([[1, 2, 3],
       [3, 9, 9],
       [7, 8, 9]])
```

```
>>> import numpy as np
>>> x=np.arange(1,10).reshape(3,3)
>>> x
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
>>> x[1,:]=x[:,2].copy()
>>> x
array([[1, 2, 3],
       [3, 6, 9],
       [7, 8, 9]])
```

(Dr. Z: Is it because the assignment is from right to left?) ....(NO)

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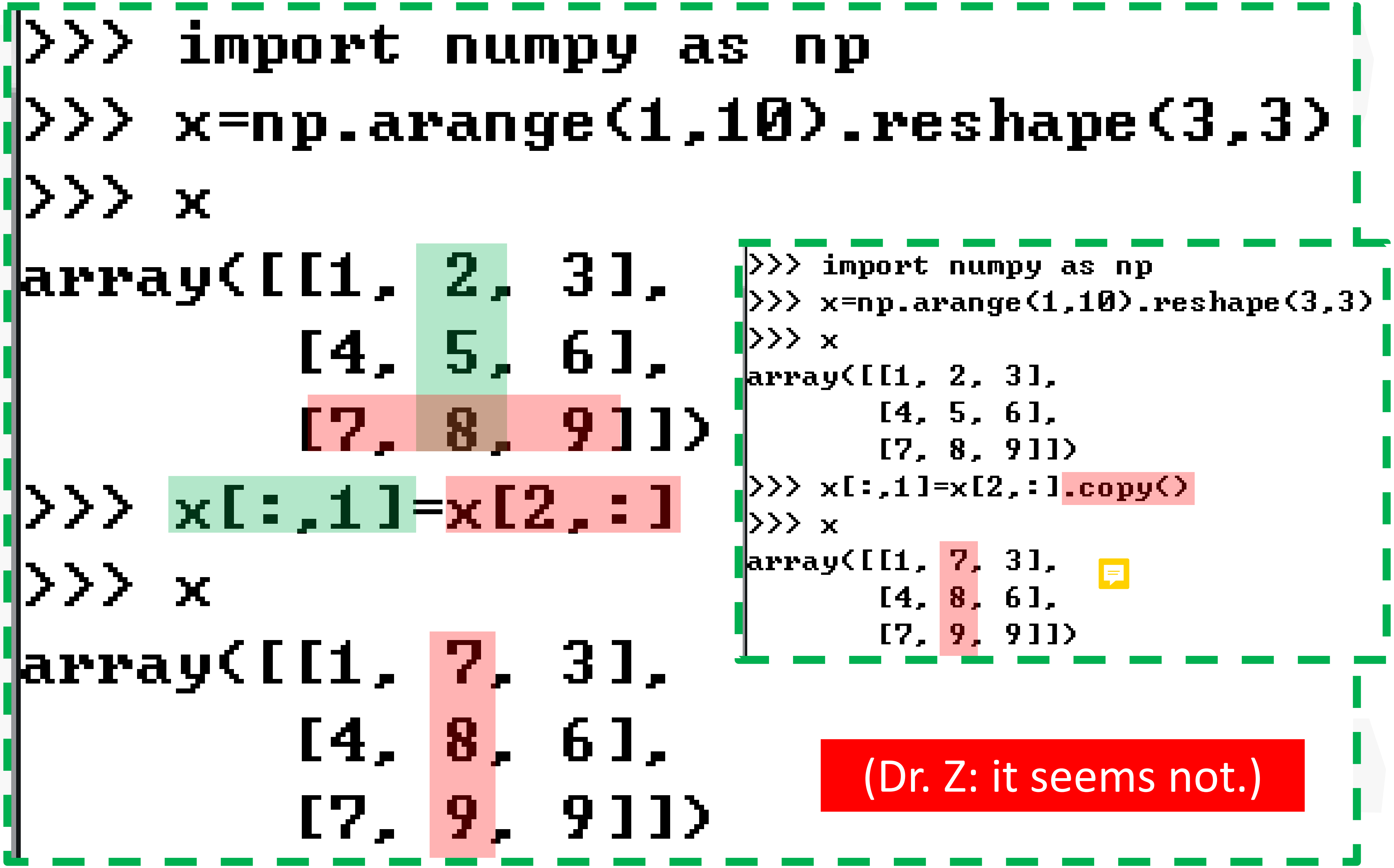

```
>>> import numpy as np
>>> x=np.arange(1,10).reshape(3,3)
>>> x
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
>>> x[:,1]=x[2,:]
>>> x
array([[1, 7, 3],
       [4, 8, 6],
       [7, 9, 9]])
```

```
>>> import numpy as np
>>> x=np.arange(1,10).reshape(3,3)
>>> x
array([[1, 2, 3],
       [4, 5, 6],
       [7, 8, 9]])
>>> x[:,1]=x[2,:].copy()
>>> x
array([[1, 7, 3],
       [4, 8, 6],
       [7, 9, 9]])
```

(Dr. Z: it seems not.)

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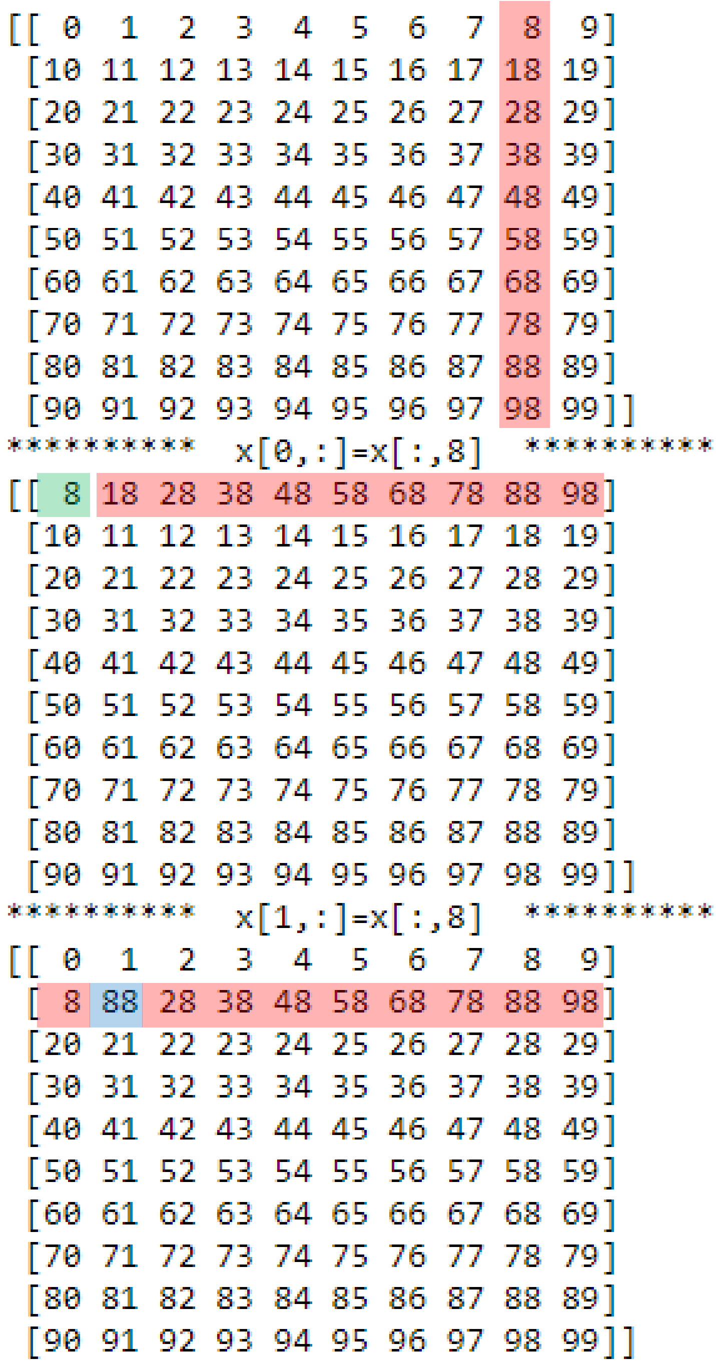
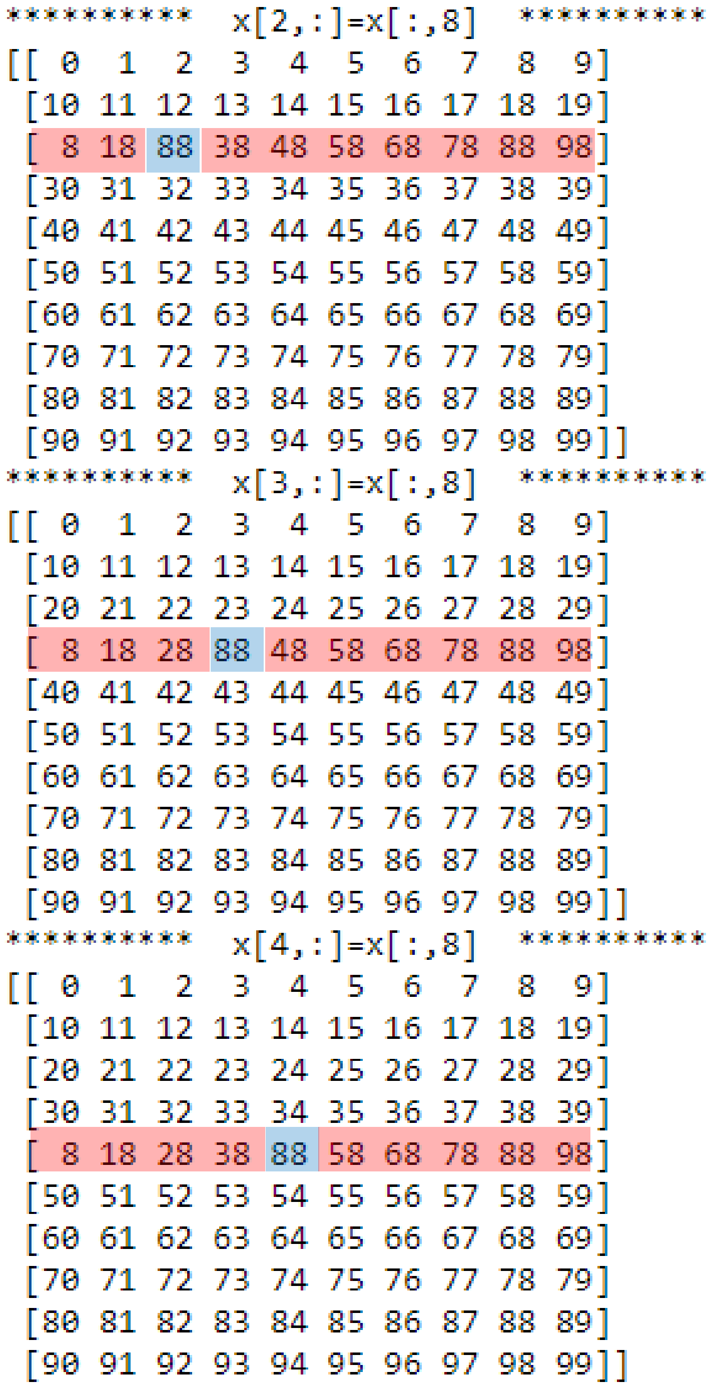


```
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
**********  x[0,:]=x[:,8]  **********
[[ 8 18 28 38 48 58 68 78 88 98]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
**********  x[1,:]=x[:,8]  **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [ 8 88 28 38 48 58 68 78 88 98]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
```



```
**********  x[2,:]=x[:,8]  **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [ 8 18 88 38 48 58 68 78 88 98]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
**********  x[3,:]=x[:,8]  **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [ 8 18 28 88 48 58 68 78 88 98]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
**********  x[4,:]=x[:,8]  **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [ 8 18 28 38 88 58 68 78 88 98]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
```

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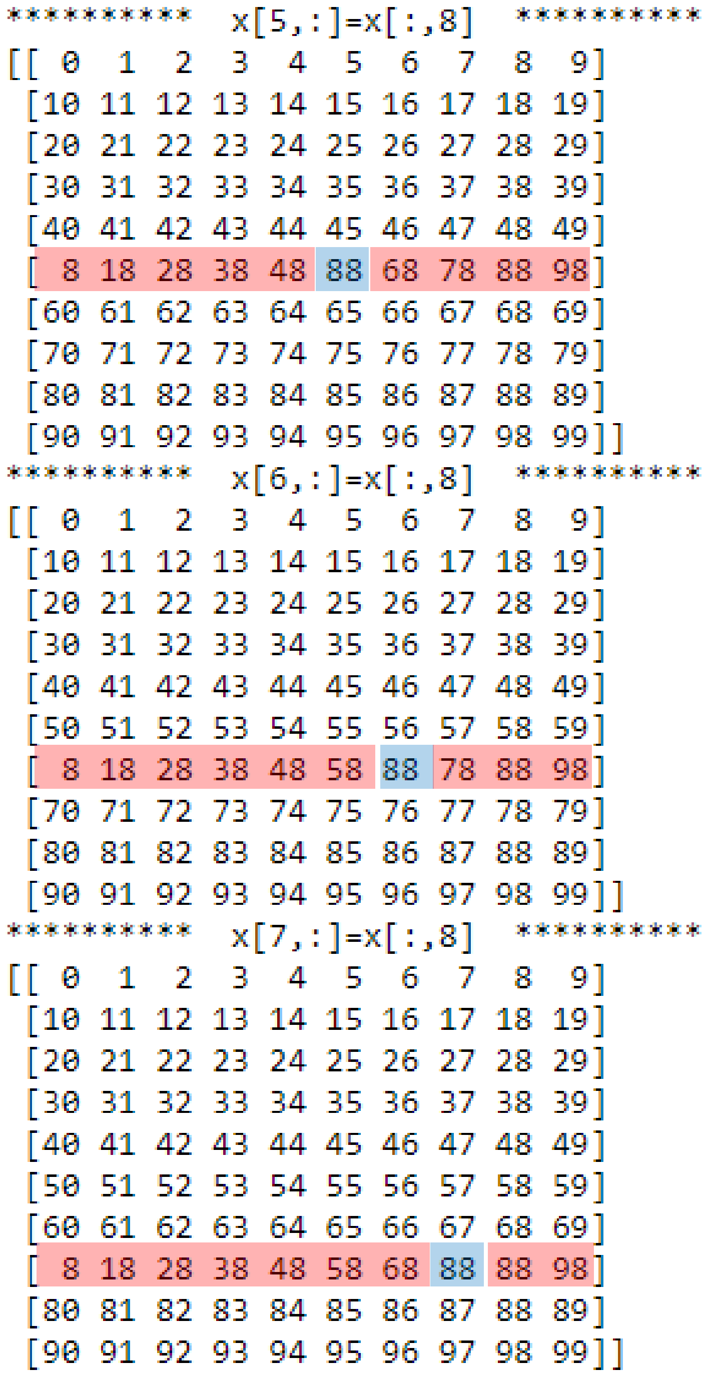
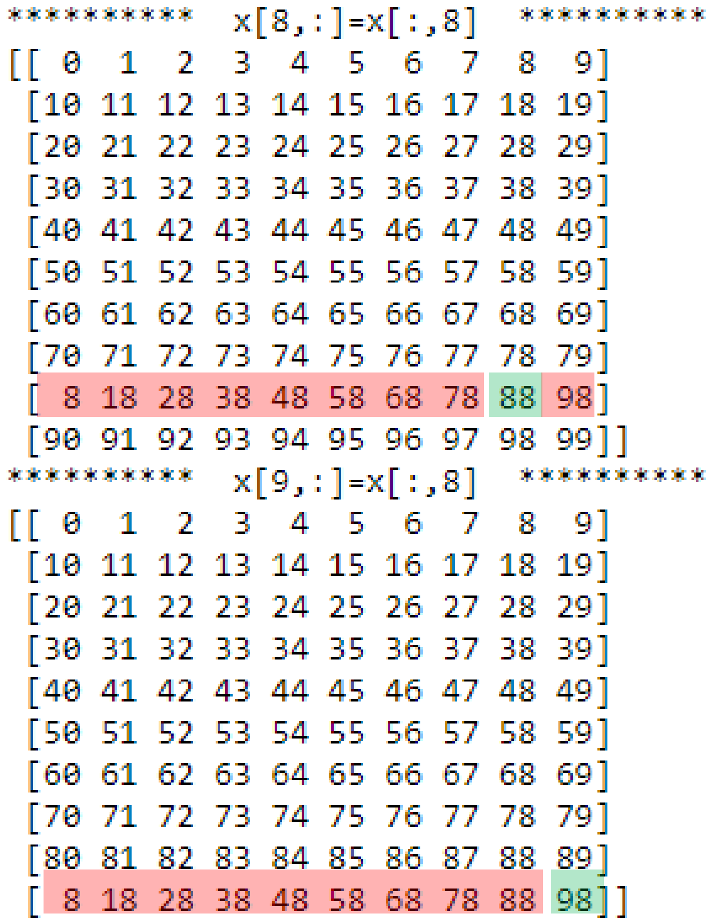


```
**********   x[5,:]=x[:,8]   **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [ 8 18 28 38 48 88 68 78 88 98]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
**********   x[6,:]=x[:,8]   **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [ 8 18 28 38 48 58 88 78 88 98]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
**********   x[7,:]=x[:,8]   **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [ 8 18 28 38 48 58 68 88 88 98]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]]
```



```
**********   x[8,:]=x[:,8]   **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [ 8 18 28 38 48 58 68 78 88 98]
 [90 91 92 93 94 95 96 97 98 99]]
**********   x[9,:]=x[:,8]   **********
[[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [ 8 18 28 38 48 58 68 78 88 98]]
```

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Dissection of the MATLAB code:

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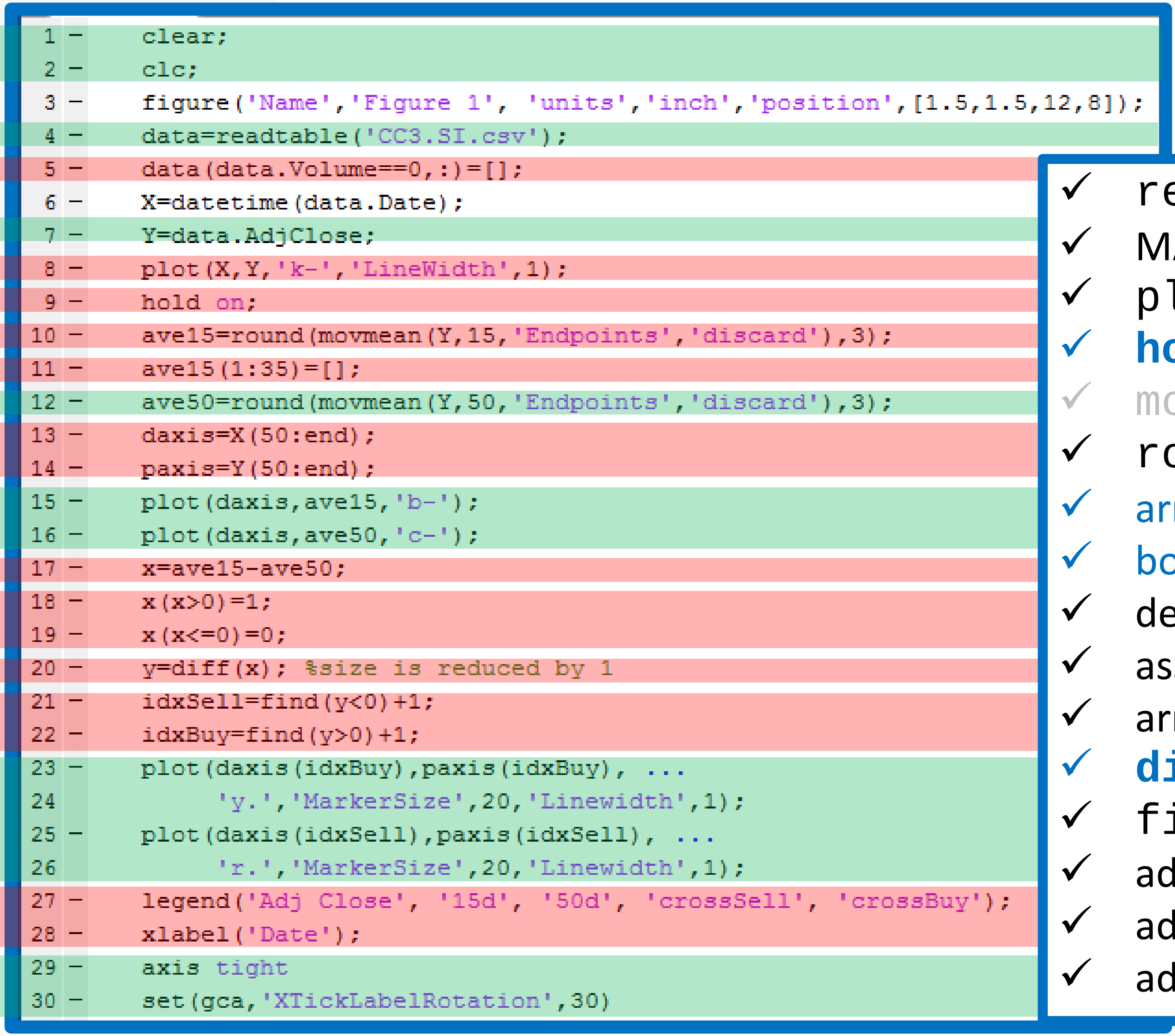

```
*    clear;
     clc;
     figure('Name','Figure 1', 'units','inch','position',[1.5,1.5,12,8]);
*    data=readtable('CC3.SI.csv');
1    data(data.Volume==0,:)=[];
     X=datetime(data.Date);
*    Y=data.AdjClose;
2    plot(X,Y,'k-','LineWidth',1);
3    hold on;
4    ave15=round(movmean(Y,15,'Endpoints','discard'),3);
5    ave15(1:35)=[];
*    ave50=round(movmean(Y,50,'Endpoints','discard'),3);
6    daxis=X(50:end);
     paxis=Y(50:end);
*    plot(daxis,ave15,'b-');
     plot(daxis,ave50,'c-');
7    x=ave15-ave50;
8    x(x>0)=1;
     x(x<=0)=0;
9    y=diff(x); %size is reduced by 1
10   idxSell=find(y<0)+1;
     idxBuy=find(y>0)+1;
*    plot(daxis(idxBuy),paxis(idxBuy), ...
             'y.','MarkerSize',20,'Linewidth',1);
     plot(daxis(idxSell),paxis(idxSell), ...
             'r.','MarkerSize',20,'Linewidth',1);
11   legend('Adj Close', '15d', '50d', 'crossSell', 'crossBuy');
     xlabel('Date');
*    axis tight
     set(gca,'XTickLabelRotation',30)
```

- ✓ `readtable`
- ✓ MATLAB table data selection
- ✓ `plot`
- ✓ **`hold on`**
- ✓ `movmean (D.N.T.)`
- ✓ `round`
- ✓ array comparison operations
- ✓ boolean index/logical array
- ✓ delete elements
- ✓ assignment
- ✓ array arithmetic operations
- ✓ **`diff`**
- ✓ `find`
- ✓ add `legend`
- ✓ add `xlabel` and `ylabel`
- ✓ add `title`

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