ENGR 101 – Chapter 2

Vectors and Matrices

Laura Alford, James Juett, Rick Niciejewski 9/3/2020

Vectors and Matrices

- A key strength of MATLAB is support for working with vectors and matrices just as easily as scalar values.

- Scalar: A plain old number
- Vector: A one-dimensional sequence of numbers

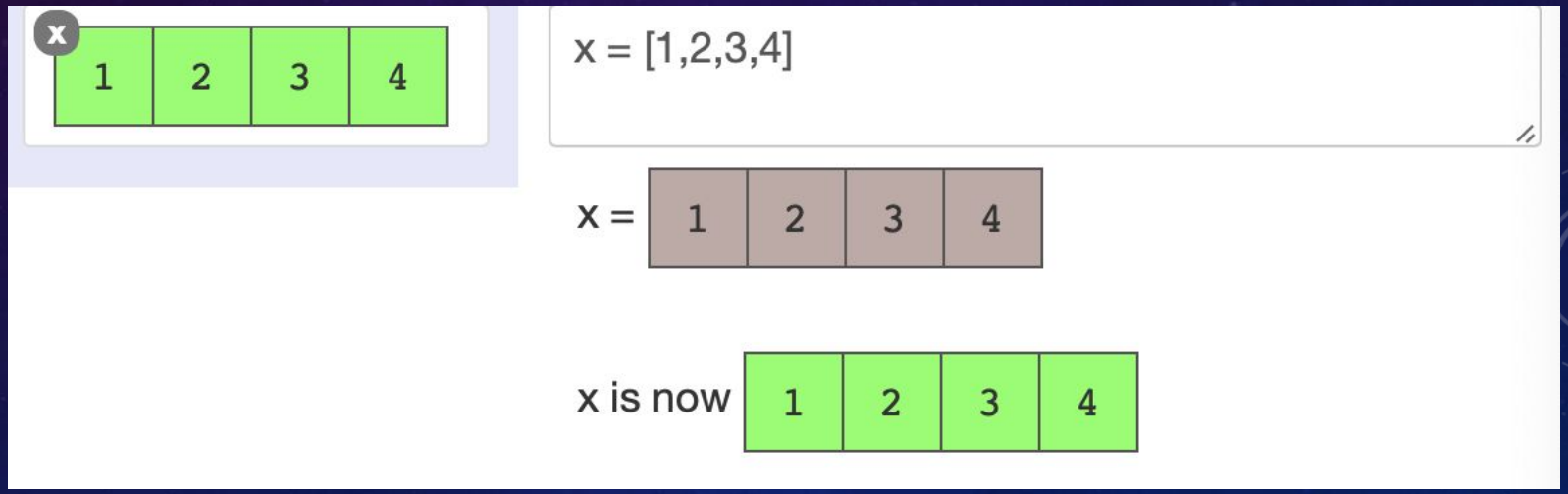
1	3	6	7	9

- Matrix: A two-dimensional grid of numbers

7	3	9
5	7	2

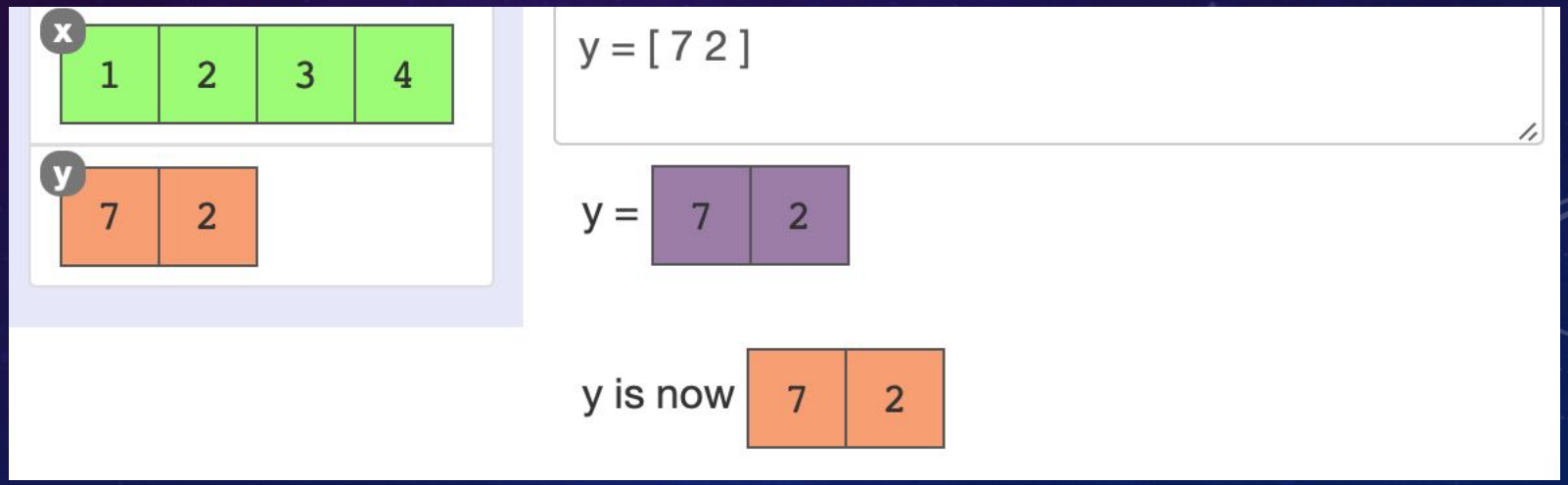
Creating Vectors

- Use the square brackets [ ] to create a vector.
- Elements may be separated by spaces or commas.



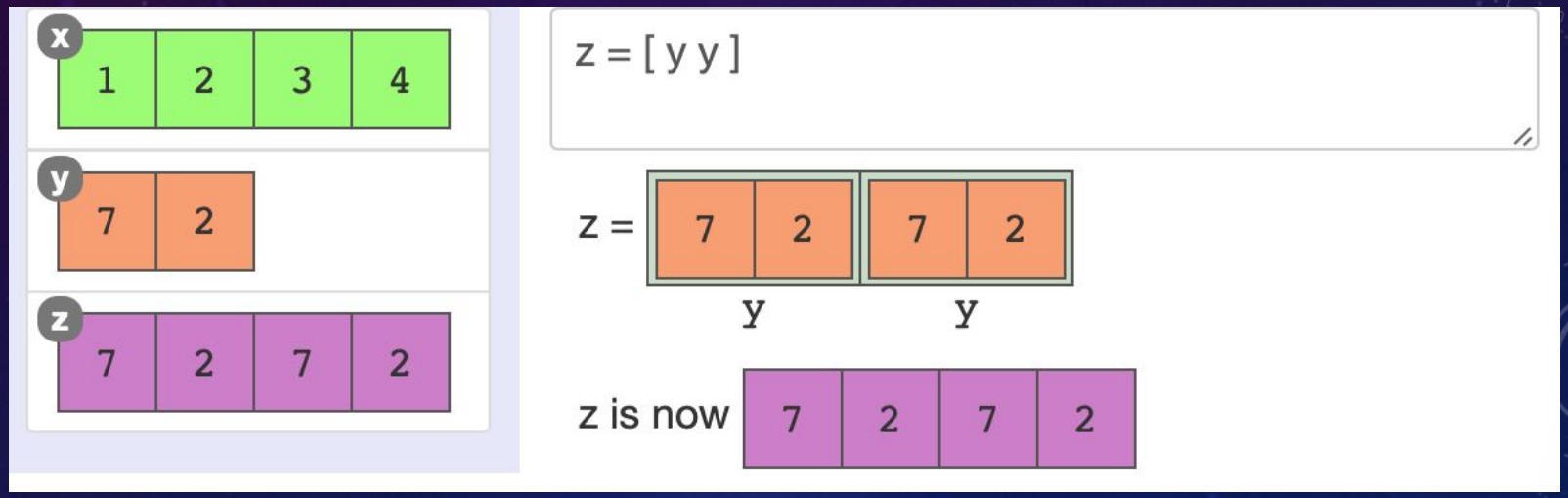
Creating Vectors

- Use the square brackets [ ] to create a vector.
- Elements may be separated by spaces or commas.



Creating Vectors

- An "element" might also be another vector, which is essentially pasted into the new one.

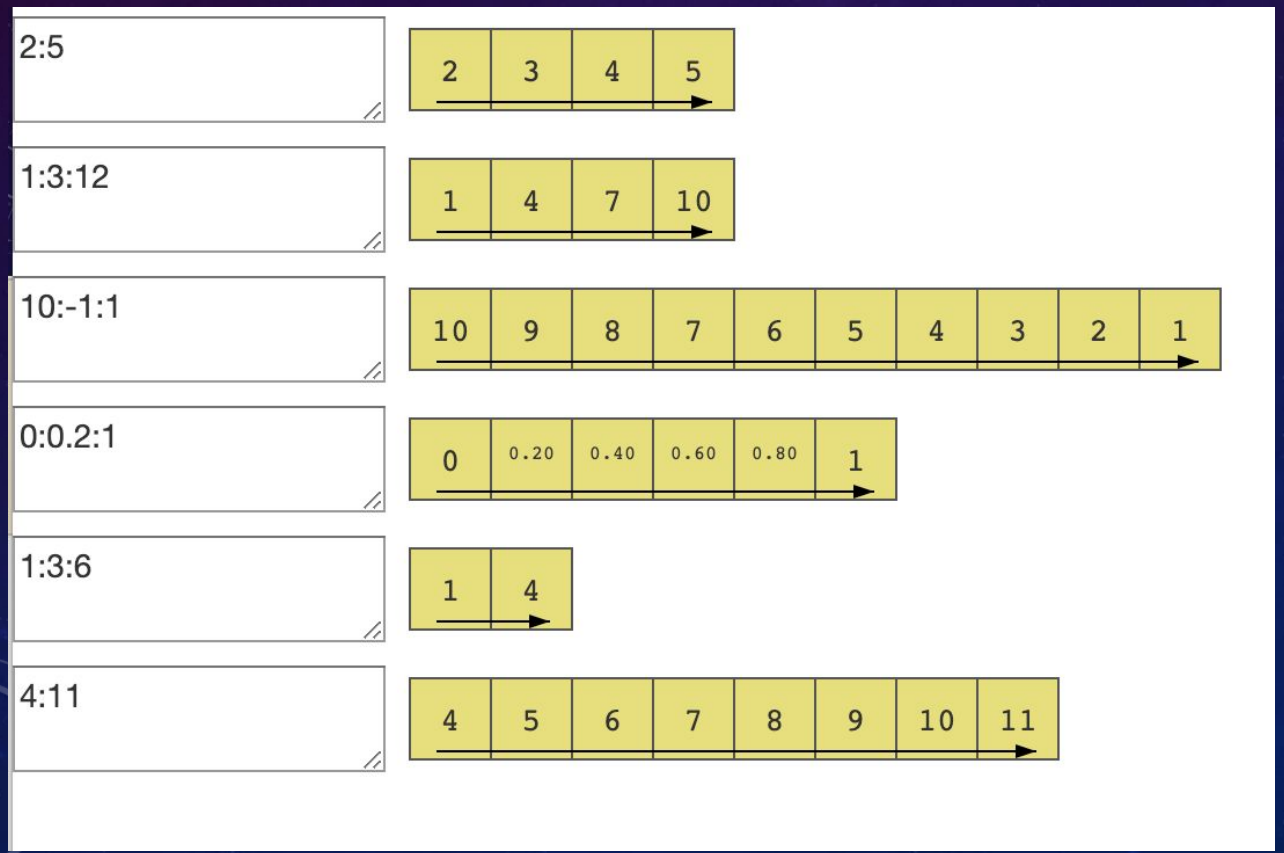


Creating Ranges of Values

- Use the colon (`:`) operator to create evenly-spaced vectors.

```
first:step:last
```

- `step` may be omitted. It defaults to 1.



Creating Matrices

- A matrix is also created with [ ]
  - Rows are separated with a semicolon ";" (or a newline)

```
x = [3,7;2,8]
```

x =

3	7
2	8

x is now

3	7
2	8

```
y = [1:4;4:-1:1]
```

y =

1	2	3	4
4	3	2	1

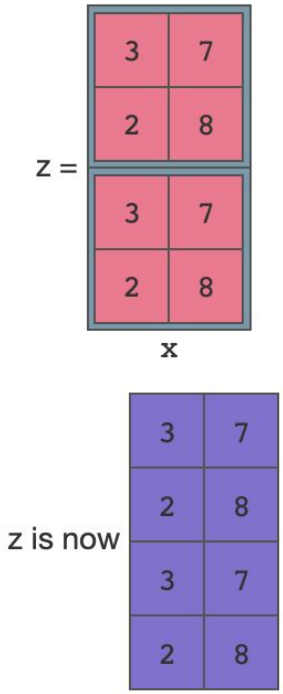
y is now

1	2	3	4
4	3	2	1

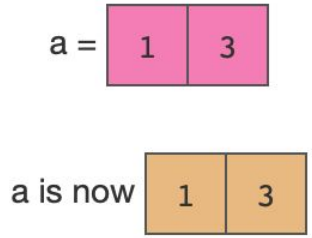
Creating Matrices

- You can use smaller matrices as components.

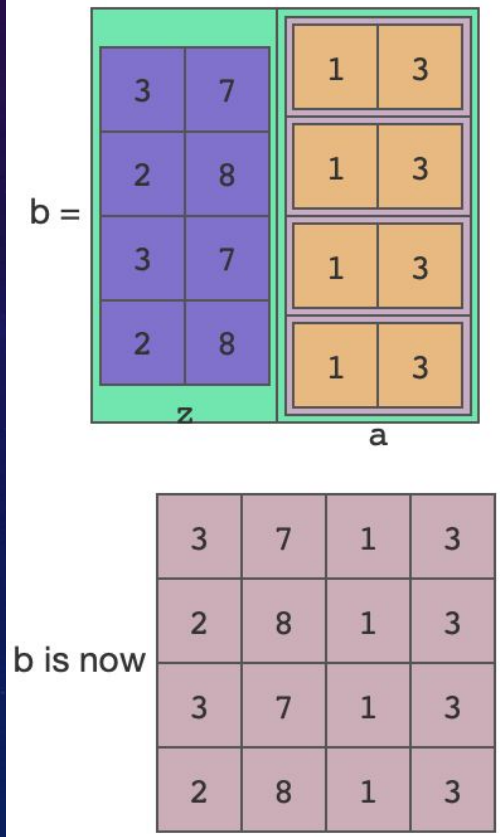
```
z = [ x ; x ]
```




```
a = [1 3]
```




```
b = [z [a;a;a;a] ]
```



Exercise: Creating Matrices

- Use either MATLAB or lobster.eecs.umich.edu/matlab
- Create these matrices (reuse is your friend):

3	6
9	8

1	6	11	16	21

1
2
3
4

1	6	11	16	21	3	6
1	6	11	16	21	9	8

Solution: Creating Matrices

3	6
9	8

```
x = [3,6;9,8]
```

1	6	11	16	21

```
y = 1:5:21
```

1	6	11	16	21	3	6
1	6	11	16	21	9	8

```
z = [[y;y], x]
```

1
2
3
4

```
w = [1;2;3;4]
```

Everything in MATLAB is an **Array**

- MATLAB treats all data as a grid-like structure called an **array**.

	Scalar	Vector	Matrix	…
Number of Dimensions	0	1	2	…
Size	1x1	*m* x 1 or 1 x *n*	*m* x *n*	…
Examples	1x1 7	3x1 3 7 6 "column vector" 1x3 8 2 9 "row vector"	3x3 3 8 3 5 7 8 3 2 1	…

Generalizing Your Code for Any Size Array

- `numel(x)` yields the # of elements in x.
- `length(x)` yields the # of elements along the **longest dimension** of x.
- `size(x)` yields a vector with the # of elements along each dimension of x.
  - For 2D matrices, this is a vector containing: [# of rows, # of cols]

2	1	4
1	3	7

```
numel:  6
length: 3
size:   [2,3]
```

1
1
1

```
numel:  3
length: 3
size:   [3,1]
```

1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

```
numel:  16
length: 4
size:   [4,4]
```

Addition with Arrays and Scalars

- Adding a scalar to an array **just adds it to each element**.

1	2	3	+	5	ans =	6	7	8
z								

- Adding two arrays will add them **element-by-element**.
  - The dimensions of the matrices must match EXACTLY!

1	3	5		7	3	4		8	6	9
3	3	1	+	6	7	2	ans =	9	10	3
2	1	5		7	1	2		9	2	7
x				y						

- This behavior is a specific case of an **array operation**.

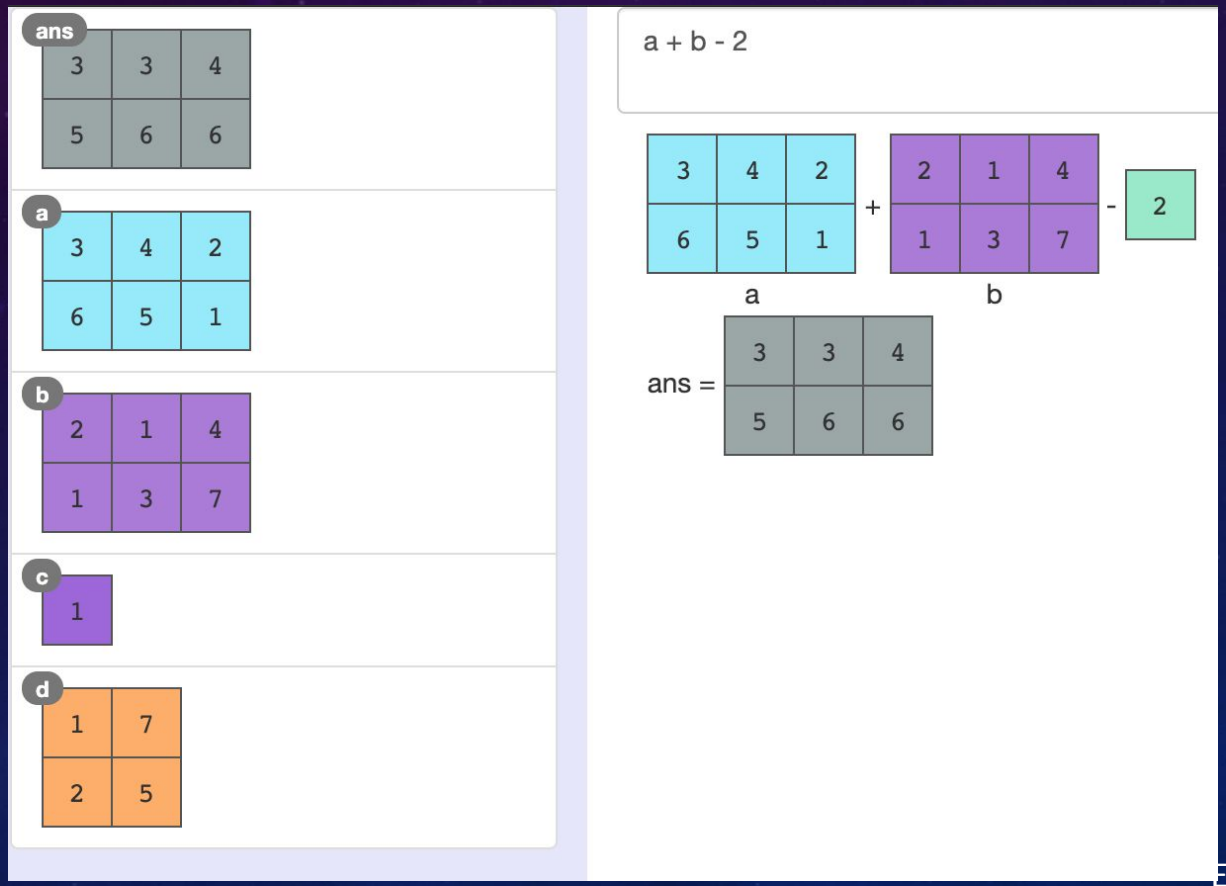
Arithmetic Array Operations

- "Array operations" work with arrays **element-by-element**.
  - The dimensions of the two arrays must match EXACTLY!

	Array Operator	Matrix Operator
Addition	+	+
Subtraction	-	-
Multiplication	.*	*
Division	./	/
Exponentiation	.^	^

Operating on Matrices and Vectors

In MATLAB, anything that you can do with scalars, you can do with arrays (i.e. vectors and matrices).



4 min

Exercise: Arithmetic Array Operations

- Given these variables:

3	4	2
6	5	1

a

2	1	4
1	3	7

b

1

c

1	7
2	5

d

- Find the result of the following expressions:

```
a * b          b - c .* 2          d ./ c

a + d          10 – d              a .* b
```

Solution: Arithmetic Array Operations

- Given these variables:

3	4	2
6	5	1

a

2	1	4
1	3	7

b

1

c

1	7
2	5

d

- Find the result of the following expressions:

```
a * b
```

Don't forget the dot in .*!

[illegible]	4	[illegible]
[illegible]	15	[illegible]

```
b - c .* 2
```

0	-1	2
-1	1	5

```
d ./ c
```

1	7
2	5

```
a + d
```

Error: Dimension mismatch!

```
10 - d
```

9	3
8	5

```
a .* b
```

6	4	8
6	15	7

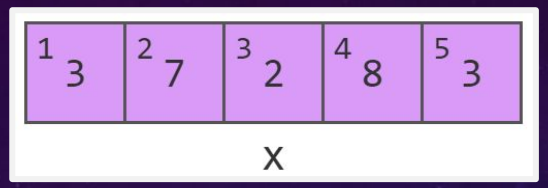
Break Time

We'll start again in 5 minutes.

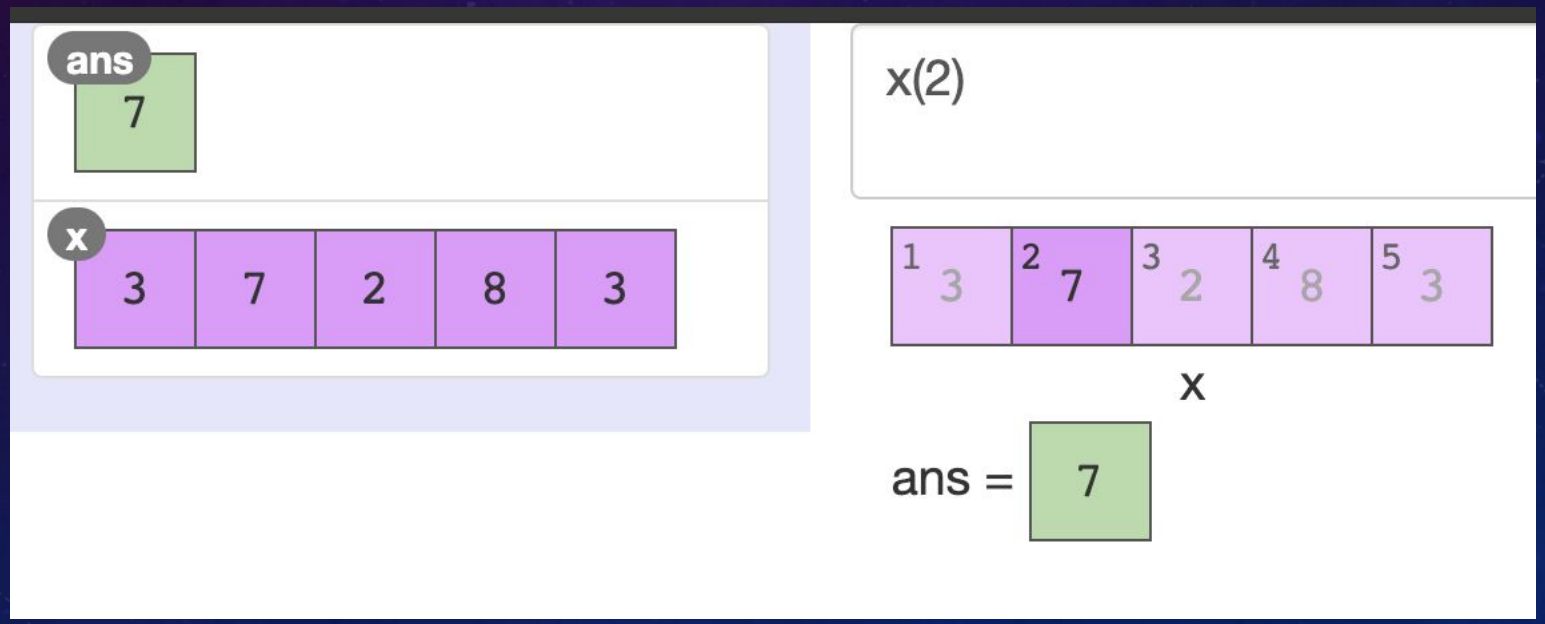
Vector Indexing

- All elements in a vector are numbered by their index, starting at 1.

```
x = [3,7,2,8,3]
```



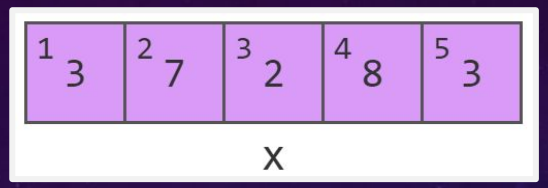
- To select elements, use the **indexing** operator, ( ).
  - Specify the index of the element you want in order to select it.



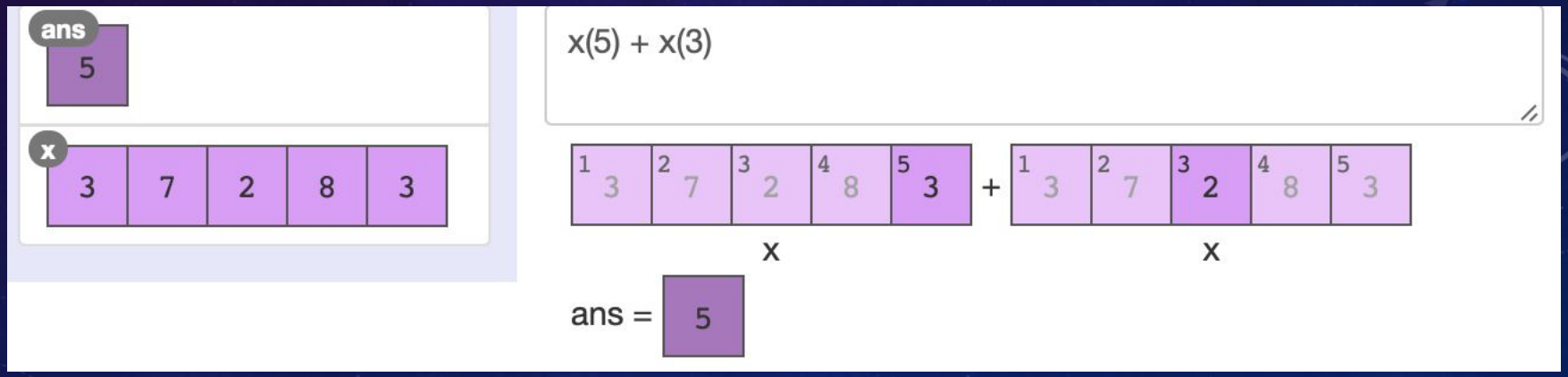
Vector Indexing

- All elements in a vector are numbered by their index, starting at 1.

```
x = [3,7,2,8,3]
```



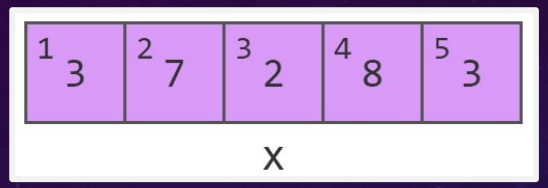
- To select elements, use the **indexing** operator, ( ).
  - Specify the index of the element you want in order to select it.
  - You can use the result in an expression …



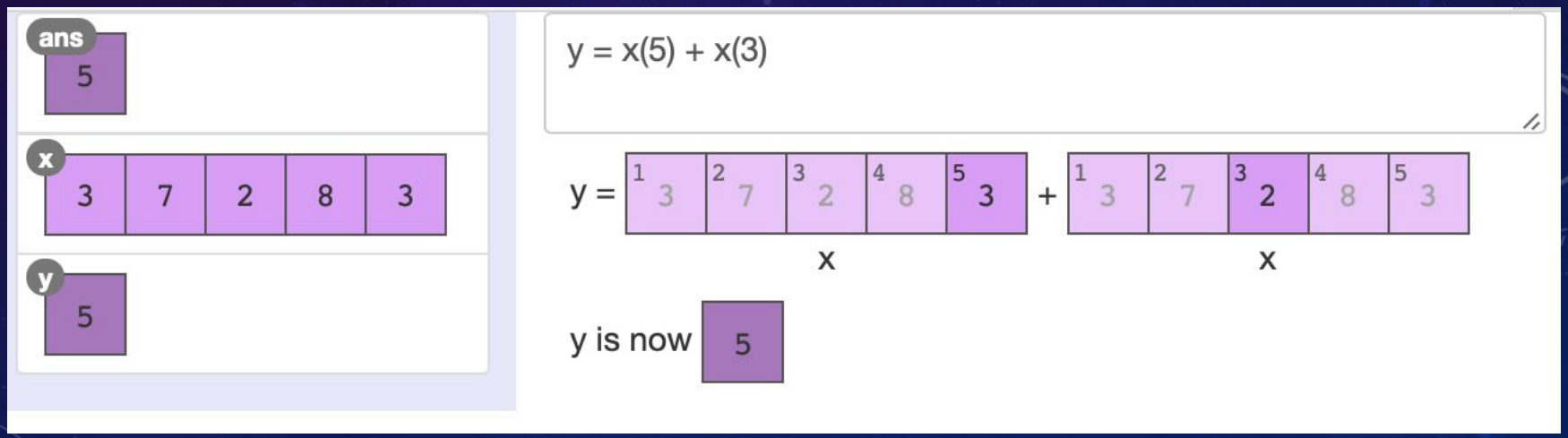
Vector Indexing

- All elements in a vector are numbered by their index, starting at 1.

```
x = [3,7,2,8,3]
```



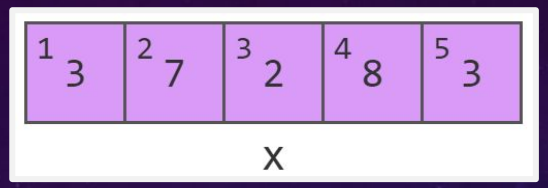
- To select elements, use the **indexing** operator, ( ).
  - Specify the index of the element you want in order to select it.
  - You can use the result in an expression … and/or store it into a variable.



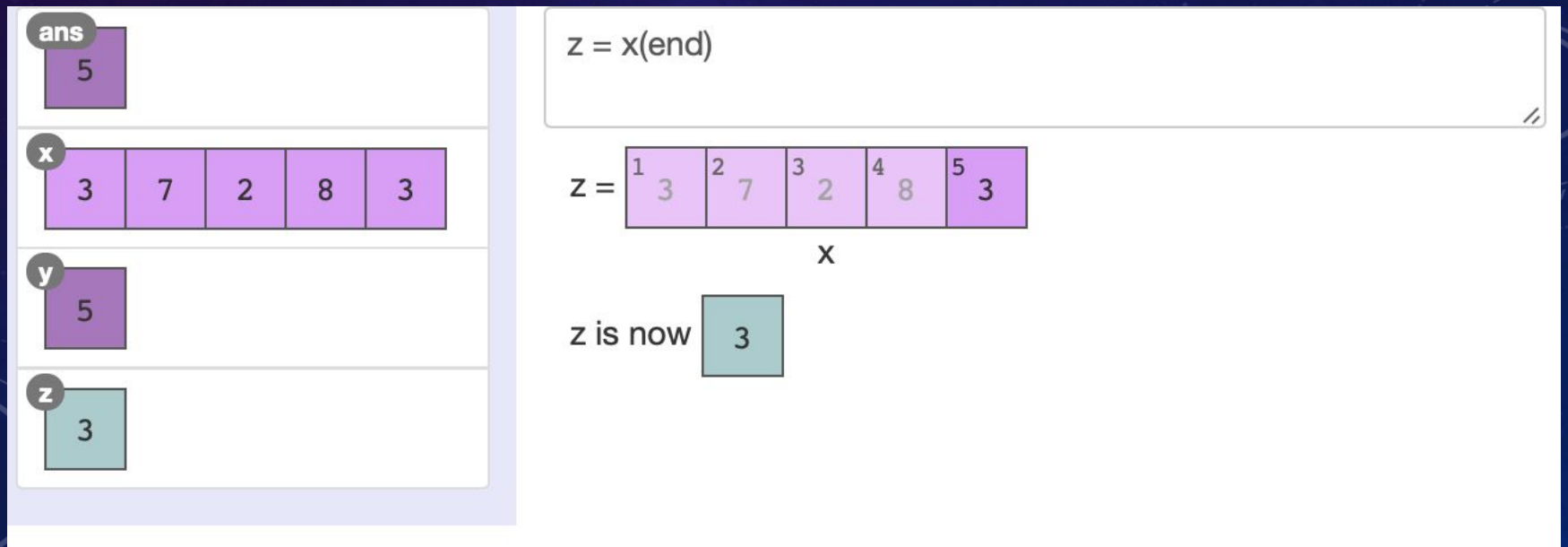
Vector Indexing

- All elements in a vector are numbered by their index, starting at 1.

```
x = [3,7,2,8,3]
```



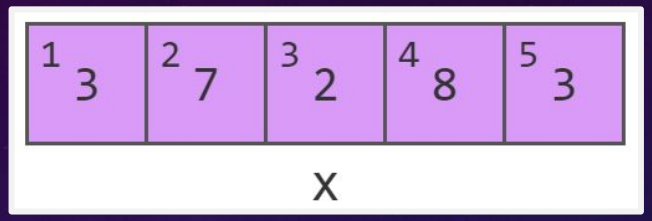
- To select elements, use the **indexing** operator, ( ).
  - Specify the index of the element you want in order to select it.
  - You can use the result in an expression or store it into a variable.
  - The **end** keyword gives the last index. (Why is this useful?)



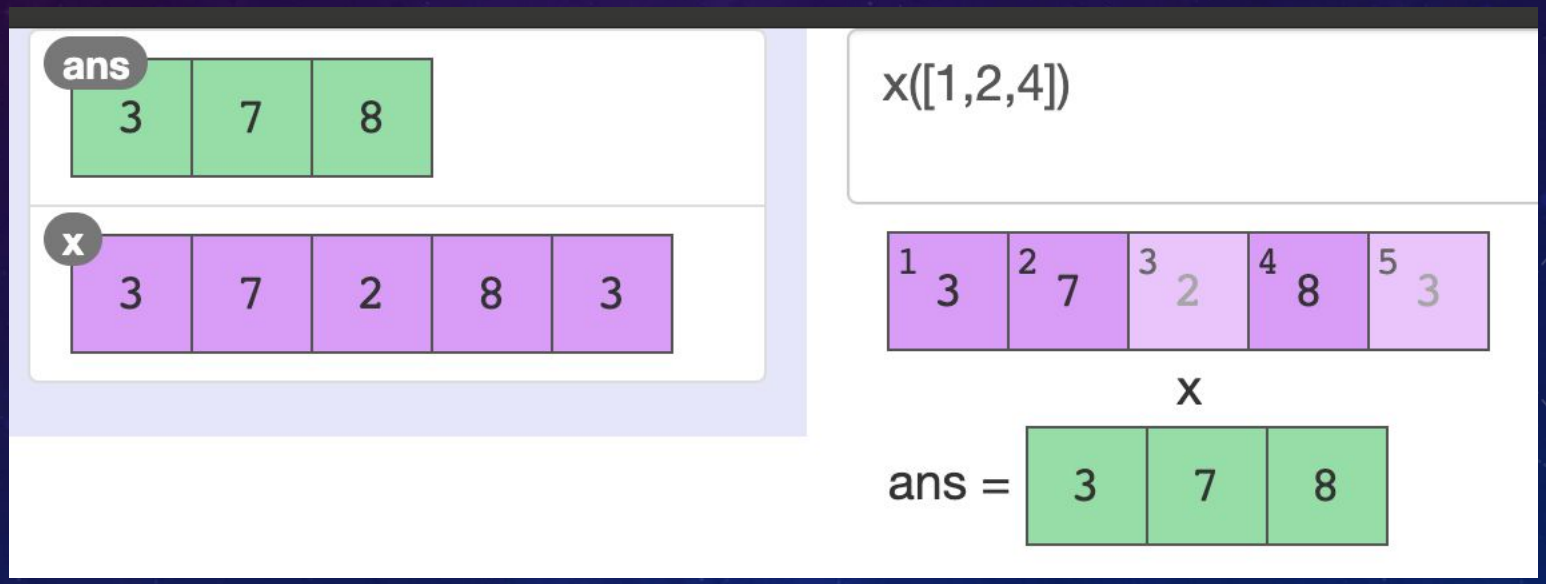
Selecting Multiple Elements

- All elements in a vector are numbered, starting at 1.

```
x = [3,7,2,8,3]
```



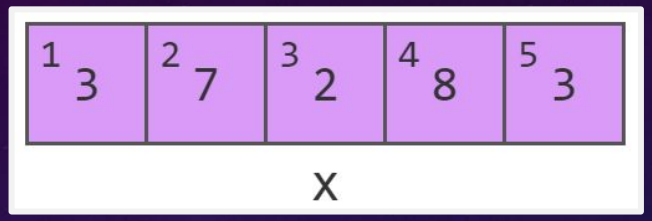
- To select multiple elements, put a **vector of indices** in the ( ).



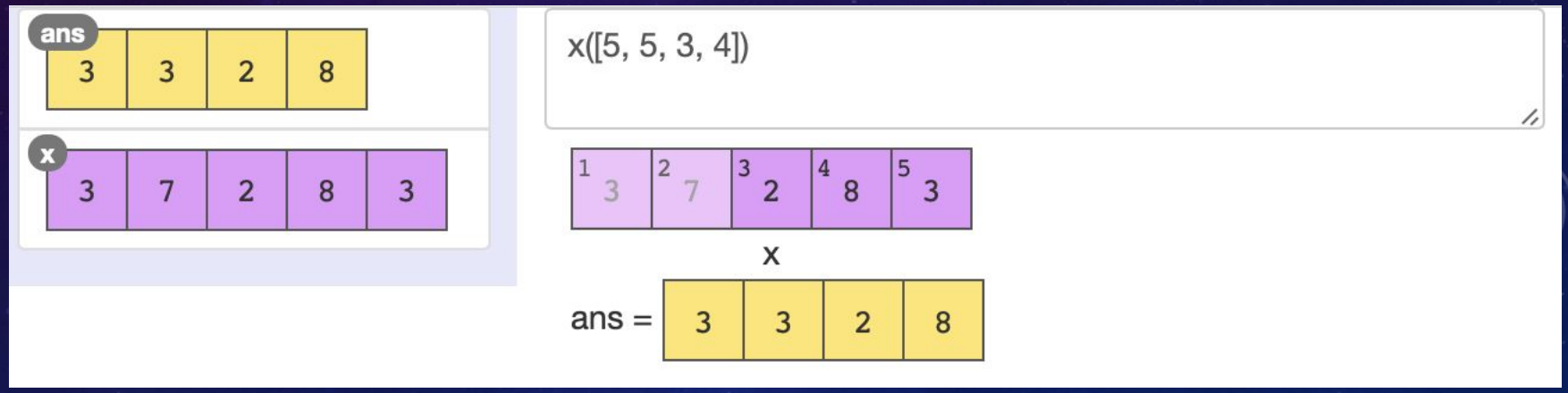
Selecting Multiple Elements

- All elements in a vector are numbered, starting at 1.

```
x = [3,7,2,8,3]
```



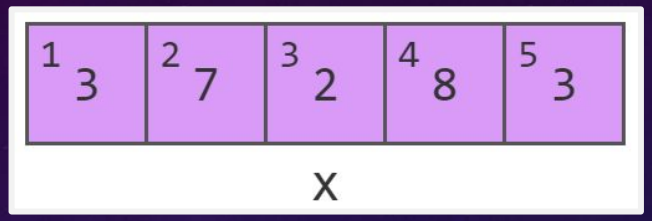
- To select multiple elements, put a **vector of indices** in the ( ).



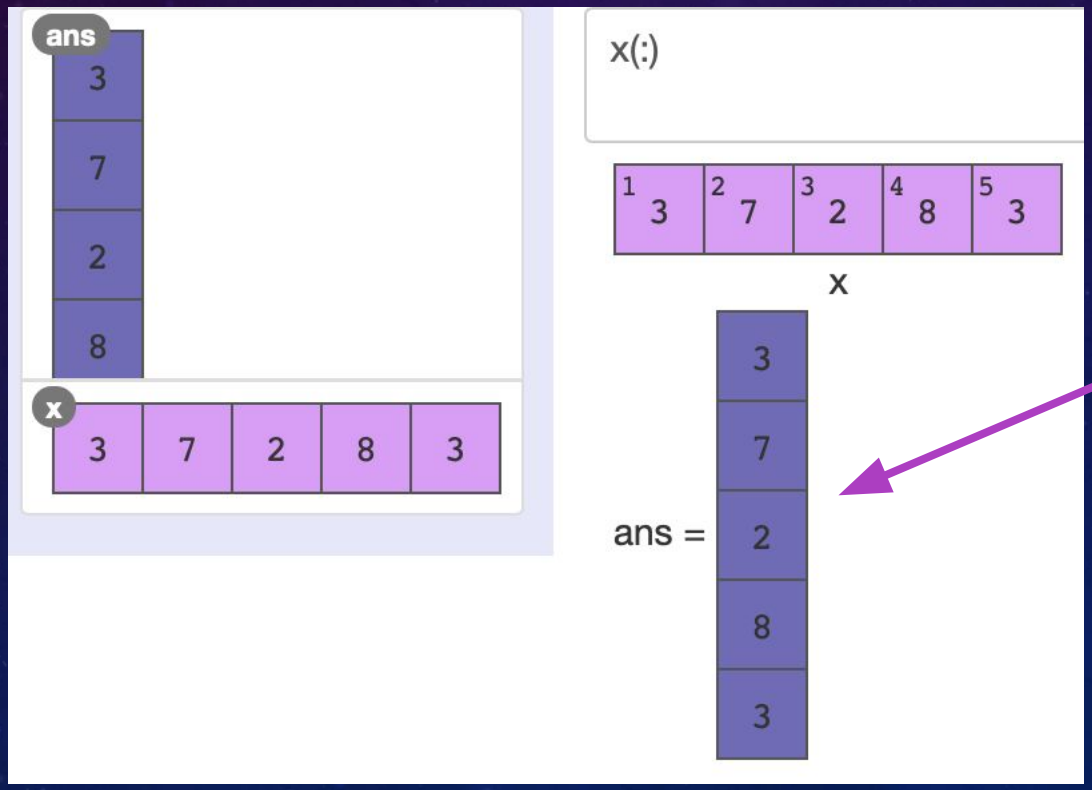
Selecting Multiple Elements

- All elements in a vector are numbered, starting at 1.

```
x = [3,7,2,8,3]
```



- To select all elements, use the **:** operator in the ( ).



Note that this yields a column matrix when read out

1 min

Minute Exercise: Matching

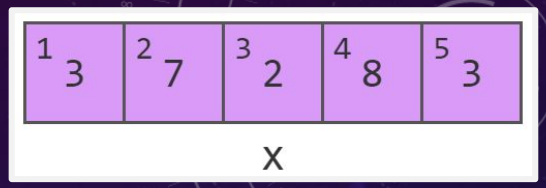
- Which code snippet goes with which output?

1 3	2 7	3 2	4 8	5 3	
x					

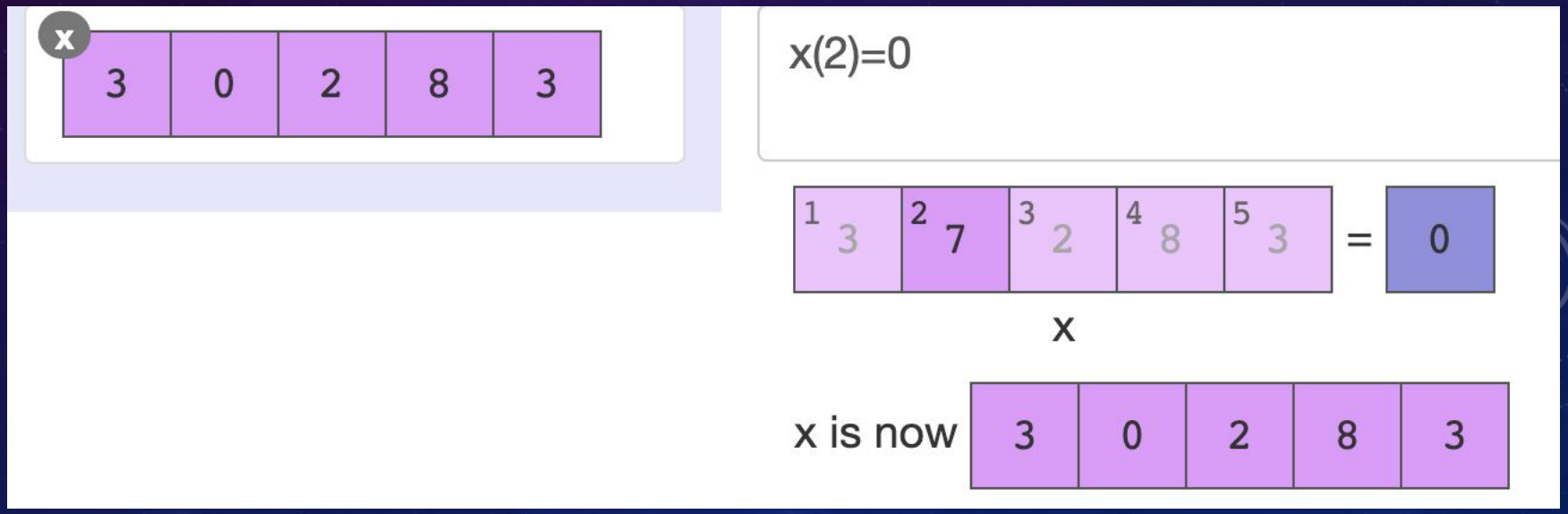
A	x([5,1,1])
B	x(2)
C	x(2:4)
D	x([5:-1:1])

1	7	2	8		
2	3	8	2	7	3
3	3	3	3		
4	7				

Indexing and Assignment



- Use indexing in the LHS of an assignment to select the elements you want to write over.
- The RHS specifies the new values.



1 min

Minute Exercise: Vector Indexing

- Replace the elements with odd indices by 0.

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

x

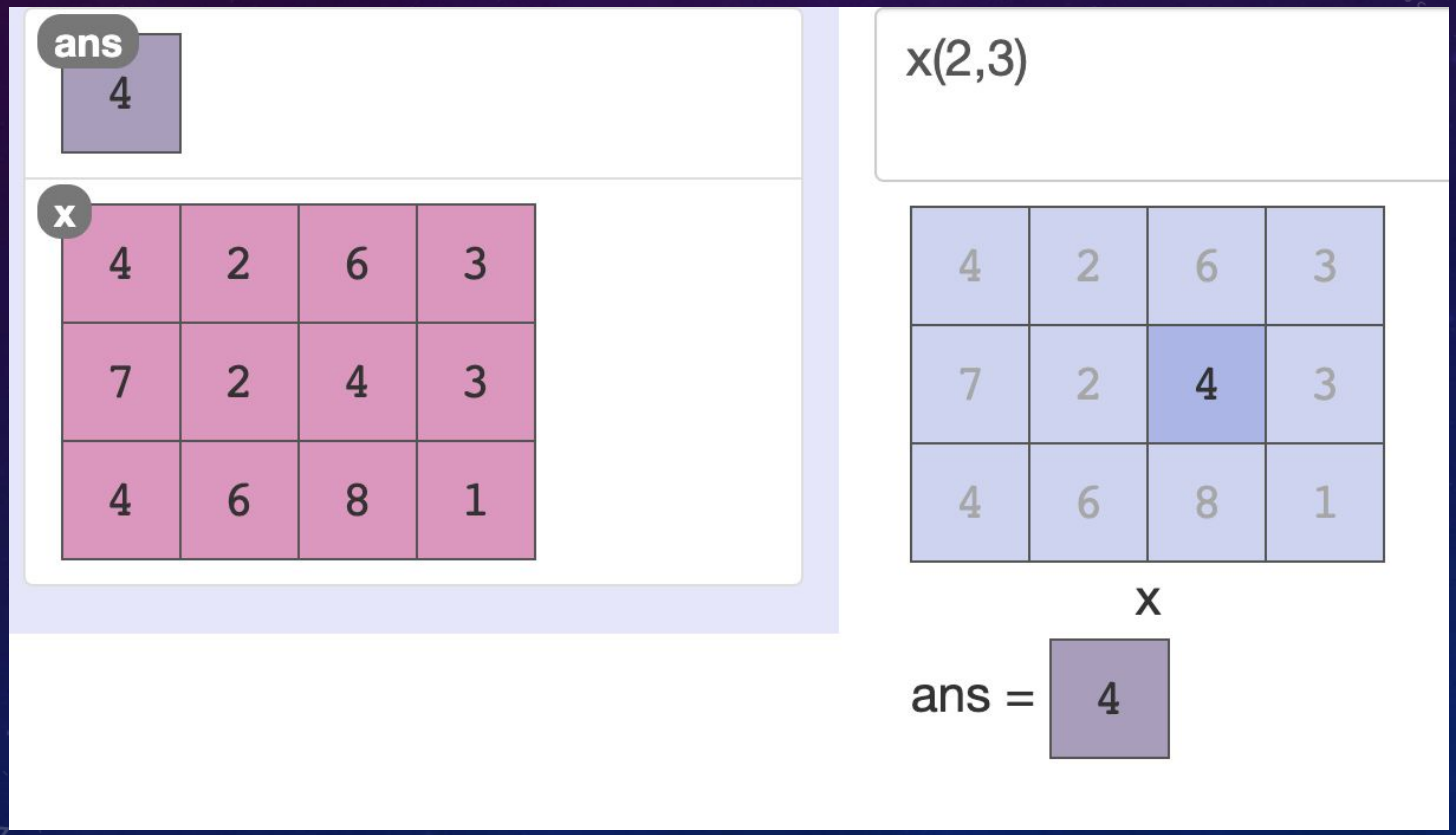
Minute Solution: Vector Indexing

- There are lots of ways to do this. A few examples:
  - ```
    x(1) = 0;
    x(3) = 0;
    x(5) = 0;
    x(7) = 0;
    ```
  - `x([1,3,5,7]) = 0;`
  - `x(1:2:7) = 0;`
  - `x(1:2:end) = 0;`

The end keyword gives the last index of the array. This is equivalent to `x(1:2:7)` in our specific case.
    ```

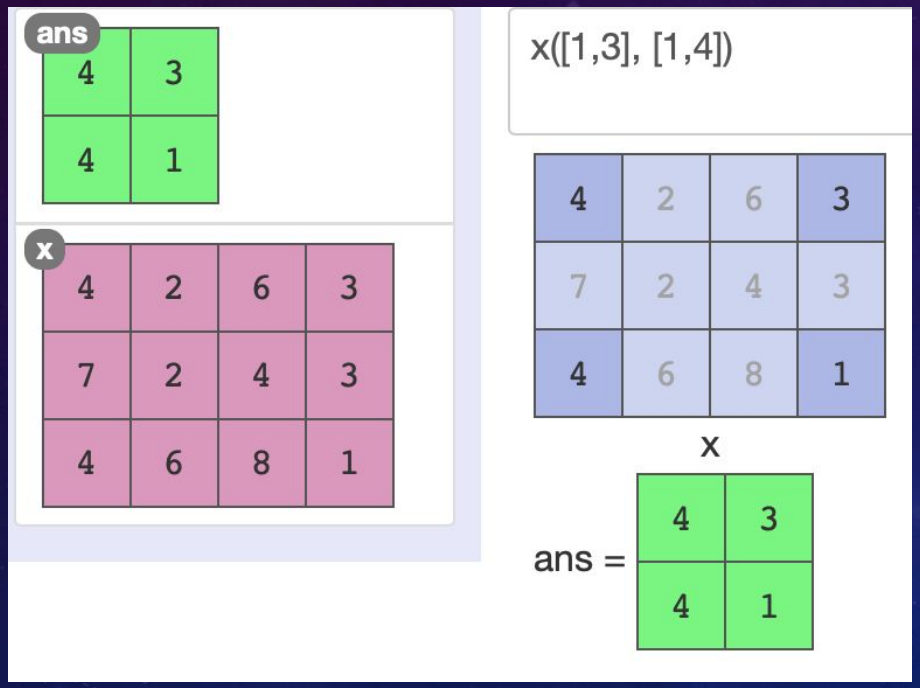
Matrices and Row/Column Indexing

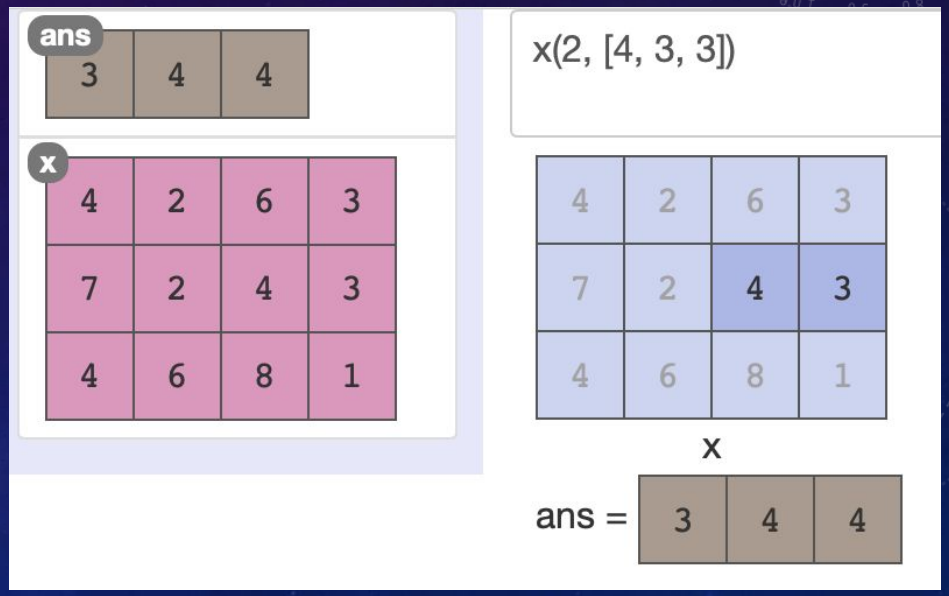
- Specify separate row/column indices.
  - Rows first, then columns, separated by a comma.
  - Again, we can use either a **single number**,



Matrices and Row/Column Indexing

- Specify separate row/column indices.
  - Rows first, then columns, separated by a comma.
  - Again, we can use either a **single number**, a **matrix of several**,

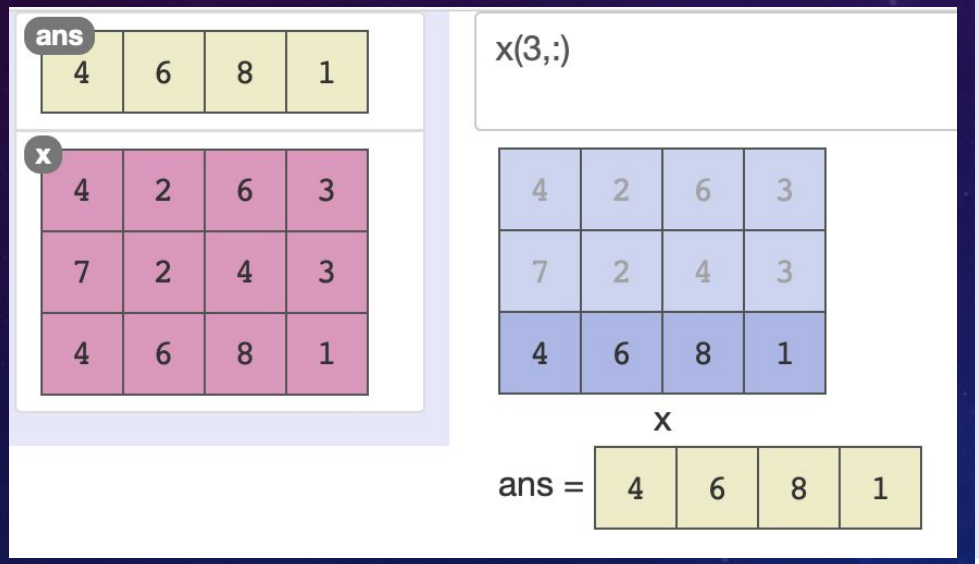


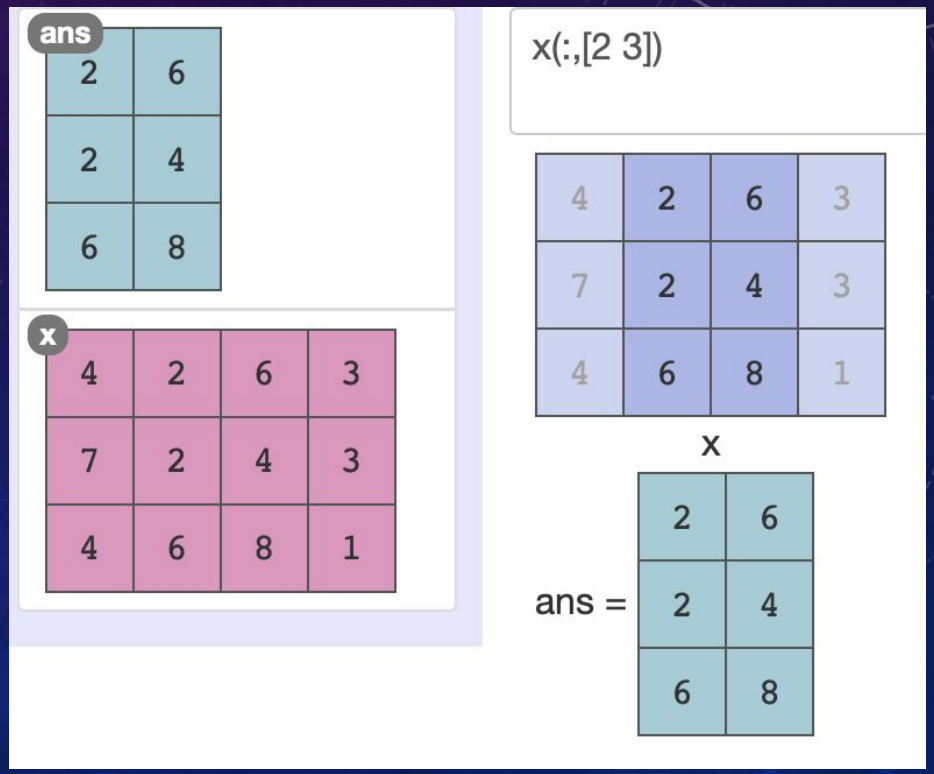


Matrices and Row/Column Indexing

- Specify separate row/column indices.
  - Rows first, then columns, separated by a comma.
  - Again, we can use either a **single number**, a **matrix of several**, or a **:**.

The : is useful for selecting full rows and/or columns.

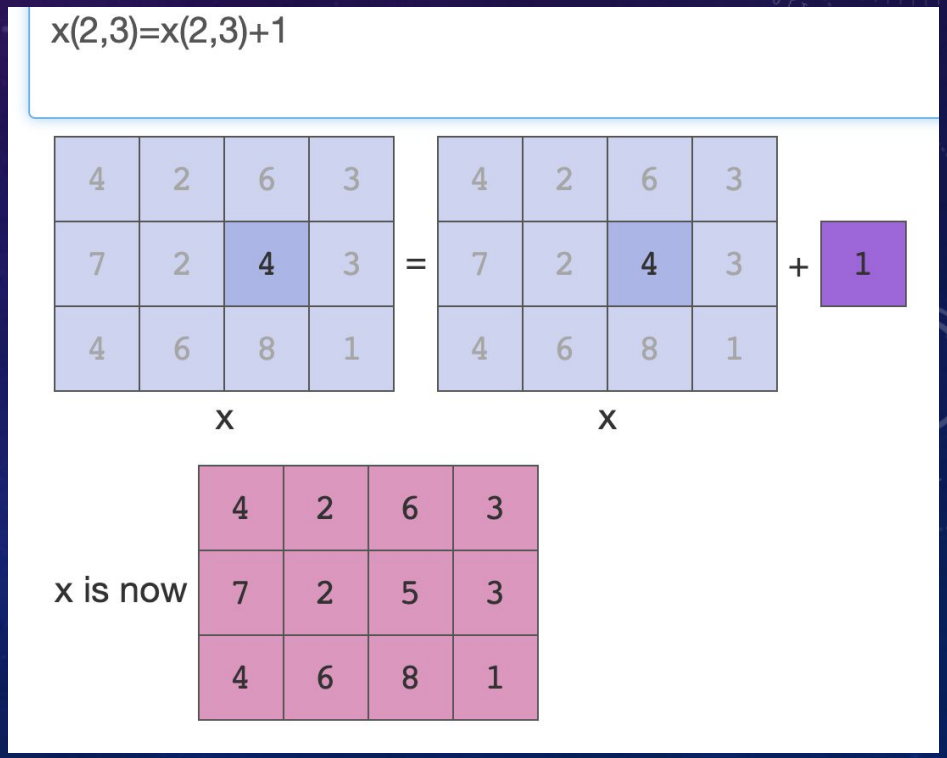




Updating Elements with Indexing

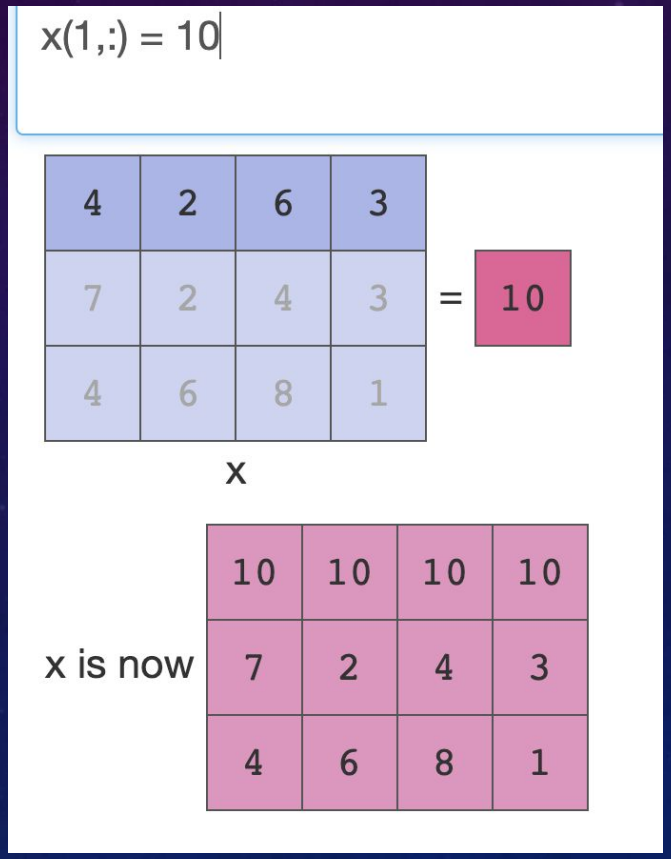
- Recall that in an update assignment, the same variable appears on the LHS and RHS (e.g. `x = x + 1`);
- To update element(s) with indexing…
  - The indexing expression for those elements appears on the LHS and RHS.

```
x(2,3) = x(2,3) + 1
```



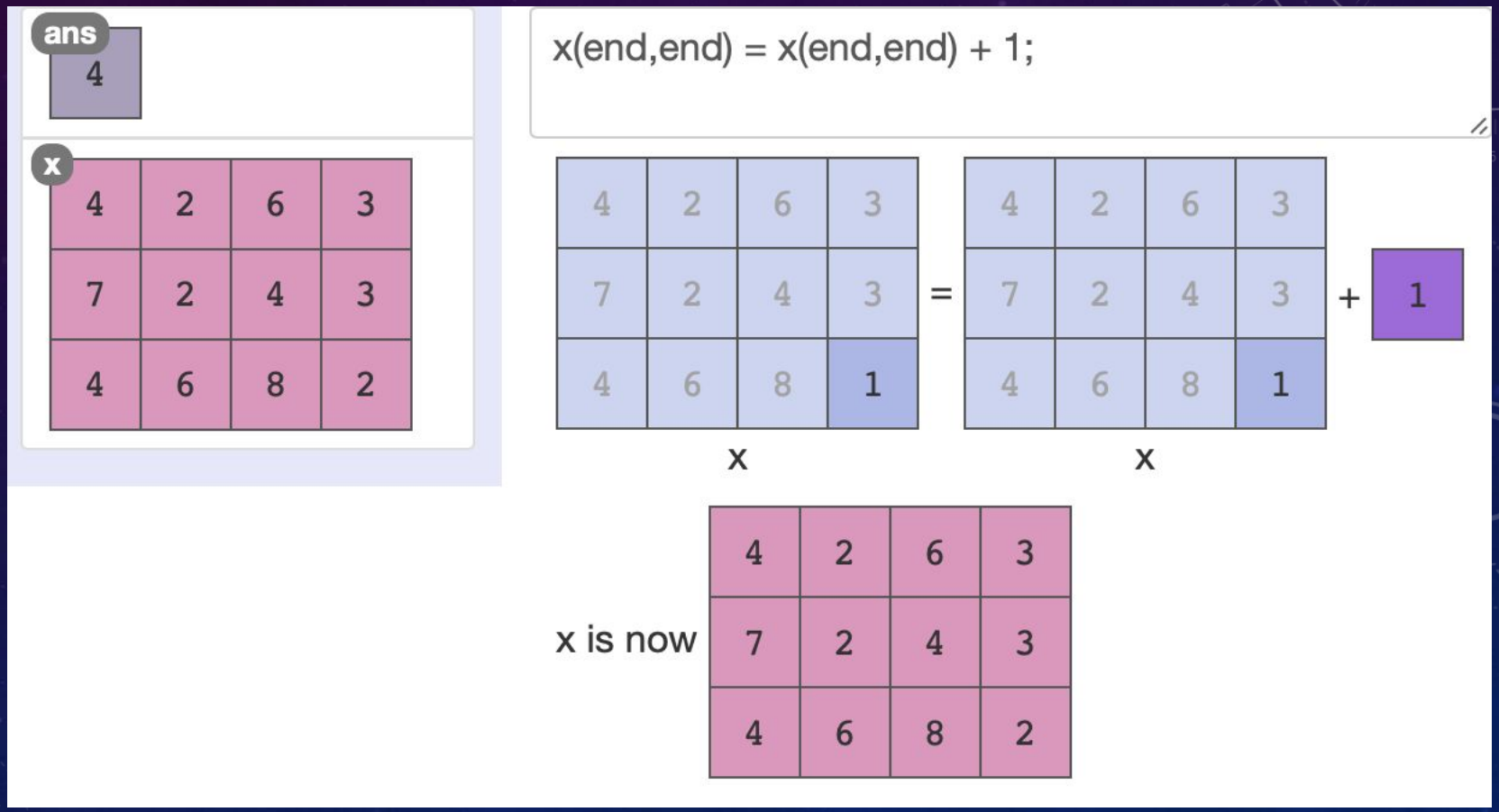
Examples: Row/Column Indexing

- Here are several examples of row/column indexing tasks:
  - Set all elements in the first row to 10. `x(1,:) = 10;`



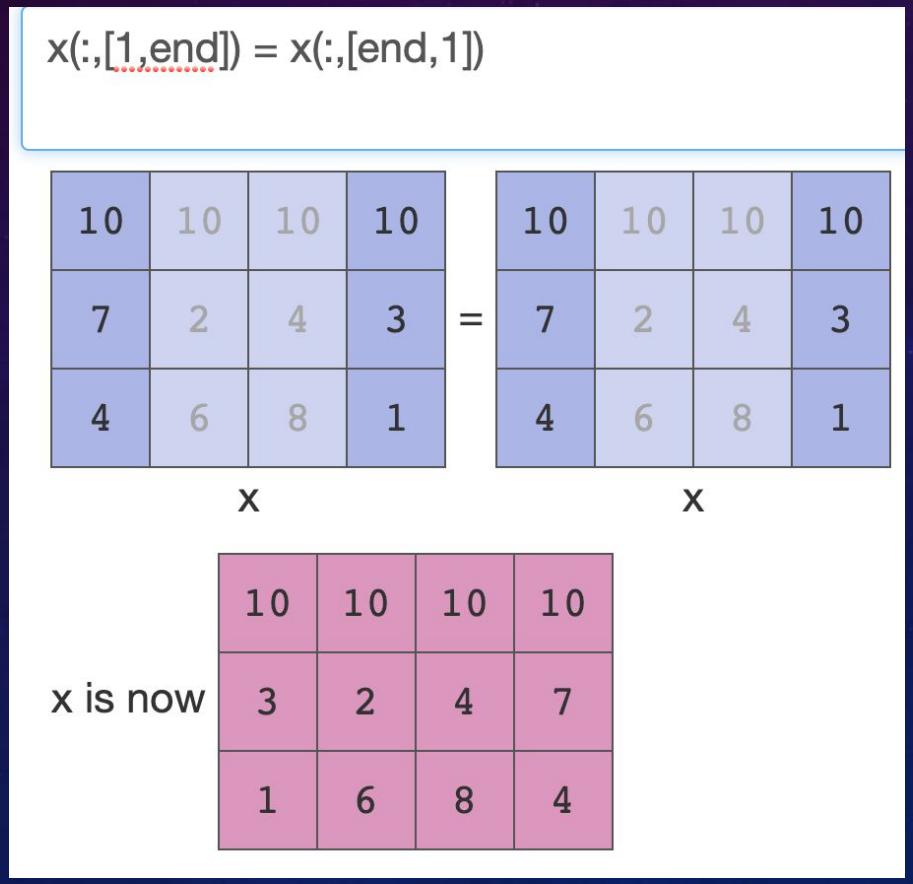
Examples: Row/Column Indexing

- Here are several examples of row/column indexing tasks:
  - Increase the bottom-right element by 1. `x(end,end) = x(end,end) + 1;`



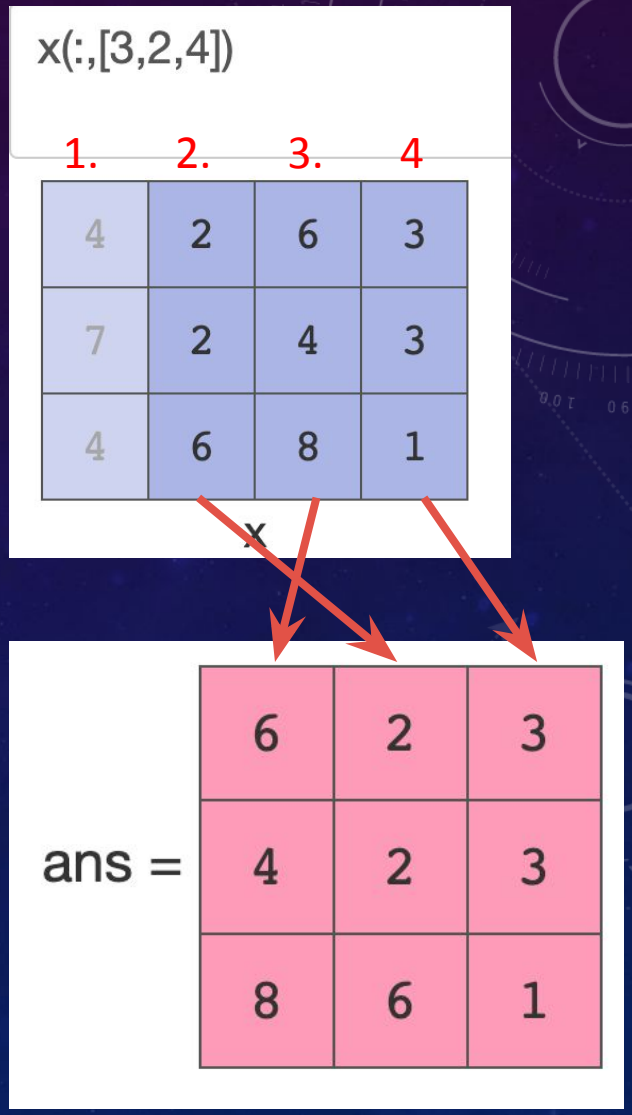
Examples: Row/Column Indexing

- Here are several examples of row/column indexing tasks:
  - Swap the first and last column. `x(:,[1,end]) = x(:,[end,1]);`



Rearranging Using Indexing

Just as with regular indexing, the order in which you specify rows/columns matters. You can use this to rearrange rows/columns.



Removing Rows/Columns with "Delete Syntax"

- To remove rows or columns from a matrix, assign `[]` to them.

1	2	3
4	5	6
7	8	9

x

```
x(2,:) = [];
```

1	2	3
7	8	9

x

```
x(:,[1,3]) = [];
```

2
8

x

- Caution! Generally you only want to do this with whole rows/columns (i.e. use the `:` somewhere).
- An alternate way to do this is just select all rows/columns you want to keep.

Creating Similarly-Sized Matrices

- Use the `size` function to get the size of one matrix, and then create another matrix of the same size.

2	1	4
1	3	7

A

0	0	0
0	0	0

```
zeros(size(A))
```

6 min

Exercise: Row/Column Indexing

- Use row/column indexing to perform the following operations. Each one should work regardless of the size of the matrix.
  - Double the value of each element in the first row of a matrix.
  - Create a new matrix from only the odd numbered columns in an original.
  - Set the corner elements of a matrix to all zeros.

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15

Solution: Row/Column Indexing

- Use row/column indexing to perform the following operations. Each one should work regardless of the size of the matrix.
  - Double the value of each element in the first row of a matrix.

```
x(1,:) = 2 * x(1,:)
```

  - Create a new matrix from only the odd numbered columns in an original.

```
y = x(:,1:2:end)
```

  - Set the corner elements of a matrix to all zeros.

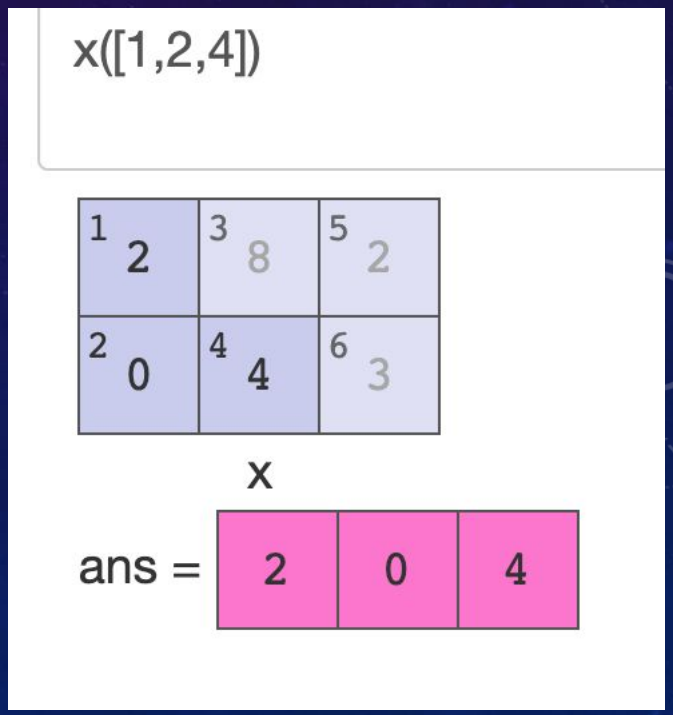
```
x([1,end],[1,end]) = 0
```

FYI: Matrices and Linear Indexing

- Each element also has a sequential index used in linear indexing (as opposed to the row/column indexing we have been using).
- Ordered first by columns, then by rows.
  - This is called "column-major" order.
  - Warning! It's easy to get this backward!
- We *highly* recommend using row/column indexing because it generally is clearer and leads to fewer headaches, but some MATLAB help files use linear indexing, so now you know what it is. ☺️

1 2	3 8	5 2
2 0	4 4	6 3

x



4 min

Challenge: Indexing (This is tricky!)

Write a single line of code to shift all columns one to the left and then move the first column to be the last column.

Challenge Solution: Indexing

Write a single line of code to shift all columns one to the left and then move the first column to be the last column.

```
x = x(:, [2:end,1])
```