Introduction to Programming in Python

Imperative Programming: Collection Data Types

Outline

One Dimensional (1D) Lists

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A list (object of type `list`), also known as an array, is an ordered collection of objects

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Creating a 1D list

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<name> = [<expression>, <expression>, ...]
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Creating a 1D list

```
<name> = [<expression>, <expression>, ...]
```

Example

```
suits = ["Clubs", "Diamonds", "Hearts", "Spades"]
powersOfTwo = [0.0625, 0.125, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 32.0]
```

One Dimensional (1D) Lists

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Appending to a 1D list

```
<name> += [<expression>]
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<name> += [<expression>]
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Example (creating a 1D list a with 3 zeros)

```
a = []
for i in range(3):
    a += [0]
```

line #	a	i

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<name> += [<expression>]
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Example (creating a 1D list a with 3 zeros)

```
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```

line #	a	i
1	[]	

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<name> += [<expression>]
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```
a = []
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line #	a	i
2	[]	0

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line #	a	i
3	[0]	0

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line #	a	i
2	[0]	1

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line #	a	i
3	[0, 0]	1

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Example (creating a 1D list a with 3 zeros)

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line #	a	i
2	[0, 0]	2

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2	[0, 0, 0]	

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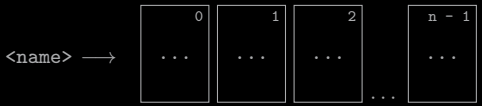
Memory model



One Dimensional (1D) Lists

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The `stdarray` library provides a function for creating 1D lists

`create1D(n, value = None)`	creates and returns a 1D list of size `n`, with each element initialized to `value`

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Python has several built-in functions that operate on lists

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`create1D(n, value = None)`	creates and returns a 1D list of size `n`, with each element initialized to `value`

Python has several built-in functions that operate on lists

For example, given a list `x`

- `len(x)` returns the number of elements in `x`
- `sum(x)` returns the sum of the elements in `x`
- `min(x)` returns the minimum element in `x`
- `max(x)` returns the maximum element in `x`

One Dimensional (1D) Lists

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The ith element in a list `x` is accessed as `x[i]`, where `0 <= i < len(x)`

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The ith element in a list x is accessed as x[i], where 0 <= i < len(x)

The ith element in a list x is assigned a value as

```
x[i] = <expression>
```

One Dimensional (1D) Lists

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Example (Averaging Numbers in a List)

```
a = [2.0, 4.0, 6.0]

total = 0.0
for i in range(len(a)):
    total += a[i]

avg = total / len(a)
```

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3	0.0		

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line #	total	i	avg
5	2.0	0	

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line #	total	i	avg
4	6.0	2	

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line #	total	i	avg
5	12.0	2	

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line #	total	v	avg
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Example (Identity Permutation)

```
1  import stdarray
2
3  perm = stdarray.create1D(5, 0)
4
5  for i in range(5):
6      perm[i] = i
```

line #	perm	i

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line #	perm	i
3	[0, 0, 0, 0, 0]	

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line #	perm	i
5	[0, 0, 0, 0, 0]	0

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3  perm = stdarray.create1D(5, 0)
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5  for i in range(5):
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line #	perm	i
6	[0, 0, 0, 0, 0]	0

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3  perm = stdarray.create1D(5, 0)
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line #	perm	i
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line #	perm	i
6	[0, 1, 0, 0, 0]	1

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```

line #	perm	i
5	[0, 1, 0, 0, 0]	2

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line #	perm	i
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line #	perm	i
5	[0, 1, 2, 0, 0]	3

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line #	perm	i
5	[0, 1, 2, 3, 0]	4

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One Dimensional (1D) Lists

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Example (In-place Reversal)

```
1  perm = [0, 1, 2, 3, 4]
2
3  for i in range(5 // 2):
4      temp = perm[i]
5      perm[i] = perm[4 - i]
6      perm[4 - i] = temp
```

line #	perm	i	temp

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line #	perm	i	temp
3	[4,1,2,3,0]	1	

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line #	perm	i	temp
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line #	perm	i	temp

One Dimensional (1D) Lists

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Example (Knuth Shuffle)

```
1  import StdRandom
2
3  perm = [0, 1, 2, 3, 4]
4
5  for i in range(5):
6      r = StdRandom.uniform(i, 5)
7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r

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6      r = StdRandom.uniform(i, 5)
7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r
5	[0,1,2,3,4]	0	

One Dimensional (1D) Lists

Example (Knuth Shuffle)

```
1  import StdRandom
2
3  perm = [0, 1, 2, 3, 4]
4
5  for i in range(5):
6      r = StdRandom.uniform(i, 5)
7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r
6	[0,1,2,3,4]	0	3

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```

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8	[0,1,2,0,4]	0	3

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```

line #	perm	i	r
9	[3,1,2,0,4]	0	3

One Dimensional (1D) Lists

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1  import StdRandom
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9      perm[i] = temp
```

line #	perm	i	r
5	[3,1,2,0,4]	1	

One Dimensional (1D) Lists

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3  perm = [0, 1, 2, 3, 4]
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```

line #	perm	i	r
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```

line #	perm	i	r
5	[3,2,1,0,4]	2	

One Dimensional (1D) Lists

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```

line #	perm	i	r
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```

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```

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```

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```

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9	[3,2,1,4,0]	3	4

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6      r = StdRandom.uniform(i, 5)
7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r
5	[3,2,1,4,0]	4	

One Dimensional (1D) Lists

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```
1  import StdRandom
2
3  perm = [0, 1, 2, 3, 4]
4
5  for i in range(5):
6      r = StdRandom.uniform(i, 5)
7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r
6	[3,2,1,4,0]	4	4

One Dimensional (1D) Lists

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4
5  for i in range(5):
6      r = StdRandom.uniform(i, 5)
7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r
7	[3,2,1,4,0]	4	4

One Dimensional (1D) Lists

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7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r
8	[3,2,1,4,0]	4	4

One Dimensional (1D) Lists

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2
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5  for i in range(5):
6      r = StdRandom.uniform(i, 5)
7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r
9	[3,2,1,4,0]	4	4

One Dimensional (1D) Lists

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5  for i in range(5):
6      r = StdRandom.uniform(i, 5)
7      temp = perm[r]
8      perm[r] = perm[i]
9      perm[i] = temp
```

line #	perm	i	r
5	[3,2,1,4,0]	5	

One Dimensional (1D) Lists

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```
1  import StdRandom
2
3  perm = [0, 1, 2, 3, 4]
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9      perm[i] = temp
```

line #	perm	i	r

One Dimensional (1D) Lists

One Dimensional (1D) Lists

`sample.py`

- Command-line input: m (int) and n (int)
- Standard output: a random sample (without replacement) of m integers, each from the interval $[0, n)$

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```
× ~/workspace/ipp
$ _
```

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- Command-line input: m (int) and n (int)
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```
× ~/workspace/ipp
$ python3 sample.py 6 16
```

One Dimensional (1D) Lists

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- Standard output: a random sample (without replacement) of m integers, each from the interval $[0, n)$

× ~/workspace/ipp

```
$ python3 sample.py 6 16
11 10 12 13 6 8
$ _
```

One Dimensional (1D) Lists

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× ~/workspace/ipp

```
$ python3 sample.py 6 16
11 10 12 13 6 8
$ python3 sample.py 10 1000
```

One Dimensional (1D) Lists

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× ~/workspace/ipp

```
$ python3 sample.py 6 16
11 10 12 13 6 8
$ python3 sample.py 10 1000
21 432 270 287 166 484 437 675 78 213
$ _
```

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$ python3 sample.py 10 1000
21 432 270 287 166 484 437 675 78 213
$ python3 sample.py 20 20


```

One Dimensional (1D) Lists

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- Command-line input: m (int) and n (int)
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× ~/workspace/ipp

```
$ python3 sample.py 6 16
11 10 12 13 6 8
$ python3 sample.py 10 1000
21 432 270 287 166 484 437 675 78 213
$ python3 sample.py 20 20
9 0 15 13 4 8 11 17 3 18 16 5 7 19 14 12 2 1 10 6
$ _
```

One Dimensional (1D) Lists

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9
perm[i]	0	0	0	0	0	0	0	0	0	0

m = 5, n = 10

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9
perm[i]	0	1	2	3	4	5	6	7	8	9

m = 5, n = 10

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9
perm[i]	3	7	2	9	1	5	6	4	8	0

m = 5, n = 10

One Dimensional (1D) Lists

One Dimensional (1D) Lists

× sample.py

```
import stdarray
import stdio
import stdrandom
import sys

m = int(sys.argv[1])
n = int(sys.argv[2])
perm = stdarray.create1D(n, 0)
for i in range(n):
    perm[i] = i
for i in range(m):
    r = stdrandom.uniformInt(i, n)
    temp = perm[r]
    perm[r] = perm[i]
    perm[i] = temp
for i in range(m):
    stdio.write(str(perm[i]) + " ")
stdio.writeln()
```

One Dimensional (1D) Lists

One Dimensional (1D) Lists

`couponcollector.py`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

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```
× ~/workspace/ipp
$ _
```

One Dimensional (1D) Lists

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- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

```
× ~/workspace/ipp
$ python3 couponcollector.py 1000
```

One Dimensional (1D) Lists

couponcollector.py

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

× ~/workspace/ipp

```
$ python3 couponcollector.py 1000
8317
$ _
```

One Dimensional (1D) Lists

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× ~/workspace/ipp

```
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8317
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```

One Dimensional (1D) Lists

`couponcollector.py`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

× ~/workspace/ipp

```
$ python3 couponcollector.py 1000
8317
$ python3 couponcollector.py 1000
7867
$ _
```

One Dimensional (1D) Lists

`couponcollector.py`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

× ~/workspace/ipp

```
$ python3 couponcollector.py 1000
8317
$ python3 couponcollector.py 1000
7867
$ python3 couponcollector.py 1000000


```

One Dimensional (1D) Lists

`couponcollector.py`

- Command-line input: n (int)
- Standard output: number of coupons one must collect before obtaining at least one of the n unique coupons

× ~/workspace/ipp

```
$ python3 couponcollector.py 1000
8317
$ python3 couponcollector.py 1000
7867
$ python3 couponcollector.py 1000000
15942756
$ _
```

One Dimensional (1D) Lists

One Dimensional (1D) Lists

value	count	collectedCount
	0	0

value	0	1	2
isCollected[value]	F	F	F

One Dimensional (1D) Lists

value	count	collectedCount
1	1	1

value	0	1	2
isCollected[value]	F	T	F

One Dimensional (1D) Lists

value	count	collectedCount
1	2	1

value	0	1	2
isCollected[value]	F	T	F

One Dimensional (1D) Lists

value	count	collectedCount
1	3	1

value	0	1	2
isCollected[value]	F	T	F

One Dimensional (1D) Lists

value	count	collectedCount
2	4	2

value	0	1	2
isCollected[value]	F	T	T

One Dimensional (1D) Lists

value	count	collectedCount
0	5	3

value	0	1	2
isCollected[value]	T	T	T

One Dimensional (1D) Lists

One Dimensional (1D) Lists

× couponcollector.py

```
import stdarray
import stdio
import stdrandom
import sys

n = int(sys.argv[1])
count = 0
collectedCount = 0
isCollected = stdarray.create1D(n, False)
while collectedCount < n:
    value = stdrandom.uniformInt(0, n)
    count += 1
    if not isCollected[value]:
        collectedCount += 1
        isCollected[value] = True
stdio.writeln(count)
```

One Dimensional (1D) Lists

One Dimensional (1D) Lists

`primesieve.py`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

One Dimensional (1D) Lists

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```
× ~/workspace/ipp
$ _
```

One Dimensional (1D) Lists

`primesieve.py`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

```
× ~/workspace/ipp
$ python3 primesieve.py 10
```

One Dimensional (1D) Lists

`primesieve.py`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

× ~/workspace/ipp

```
$ python3 primesieve.py 10
4
$ _
```

One Dimensional (1D) Lists

`primesieve.py`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

× ~/workspace/ipp

```
$ python3 primesieve.py 10
4
$ python3 primesieve.py 100
```

One Dimensional (1D) Lists

`primesieve.py`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

× ~/workspace/ipp

```
$ python3 primesieve.py 10
4
$ python3 primesieve.py 100
25
$ _
```

One Dimensional (1D) Lists

`primesieve.py`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

× ~/workspace/ipp

```
$ python3 primesieve.py 10
4
$ python3 primesieve.py 100
25
$ python3 primesieve.py 1000


```

One Dimensional (1D) Lists

`primesieve.py`

- Command-line input: n (int)
- Standard output: number of primes that are less than or equal to n

× ~/workspace/ipp

```
$ python3 primesieve.py 10
4
$ python3 primesieve.py 100
25
$ python3 primesieve.py 1000
168
$ _
```

One Dimensional (1D) Lists

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	F	F	F	F	F	F	F	F	F

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	T	T	T	T	T	T	T

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	T	T	T	T	T	T	T

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	T	F

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	T	F

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Lists

i	0	1	2	3	4	5	6	7	8	9	10
isPrime[i]	F	F	T	T	F	T	F	T	F	F	F

One Dimensional (1D) Lists

One Dimensional (1D) Lists

× primesieve.py

```
1  import stdarray
2  import stdio
3  import sys
4
5  n = int(sys.argv[1])
6  isPrime = stdarray.create1D(n + 1, False)
7  for i in range(2, n + 1):
8      isPrime[i] = True
9  for i in range(2, n):
10     if isPrime[i]:
11         for j in range(2, n // i + 1):
12             isPrime[i * j] = False
13 count = 0
14 for i in range(2, n + 1):
15     count += 1 if isPrime[i] else 0
16 stdio.writeln(count)
```

One Dimensional (1D) Lists

One Dimensional (1D) Lists

Aliasing refers to the situation where two variables refer to the same object

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Example

```
import stdio

x = [1, 3, 7]
y = x
x[1] = 42

stdio.writeln(x)
stdio.writeln(y)
```

writes

```
[1, 42, 7]
[1, 42, 7]
```

One Dimensional (1D) Lists

One Dimensional (1D) Lists

Example (creating a copy of a list `x`)

- Method 1 (using a loop)

```
y = []
for v in x:
    y += [v]
```

One Dimensional (1D) Lists

Example (creating a copy of a list `x`)

- Method 1 (using a loop)

```
y = []
for v in x:
    y += [v]
```

- Method 2 (using the slicing operator)

```
y = x[ : ]
```

One Dimensional (1D) Lists

Example (creating a copy of a list `x`)

- Method 1 (using a loop)

```
y = []
for v in x:
    y += [v]
```

- Method 2 (using the slicing operator)

```
y = x[ : ]
```

Slicing operator in general: `x[i : j]` returns a sublist `[x[i], ..., x[j - 1]]`, with `i = 0` and `j = len(x)` if either is unspecified

One Dimensional (1D) Lists

One Dimensional (1D) Lists

- Strings can be manipulated like lists

One Dimensional (1D) Lists

Strings can be manipulated like lists

Example

```
import stdio

s = "Hello, World!"
for c in s[7 : len(s) - 1]:
    stdio.write(c)
stdio.writeln()
```

writes

```
World
```

Two Dimensional (2D) Lists

Two Dimensional (2D) Lists

Creating a 2D list

```
<name> = [[<expression>, <expression>, ..., <expression>],
          [<expression>, <expression>, ..., <expression>],
          ...
          [<expression>, <expression>, ..., <expression>]]
```

Two Dimensional (2D) Lists

Creating a 2D list

```
<name> = [[<expression>, <expression>, ..., <expression>],
          [<expression>, <expression>, ..., <expression>],
          ...
          [<expression>, <expression>, ..., <expression>]]
```

Example

```
identity = [[1, 0, 0],
            [0, 1, 0],
            [0, 0, 1]]

pascal = [[1, 0, 0, 0, 0],
          [1, 1, 0, 0, 0],
          [1, 2, 1, 0, 0],
          [1, 3, 3, 1, 0],
          [1, 4, 6, 4, 1]]
```

Two Dimensional (2D) Lists

Two Dimensional (2D) Lists

Appending to a 2D list

```
<name> += [[<expression>, <expression>, ...]]
```

Two Dimensional (2D) Lists

Appending to a 2D list

```
<name> += [[<expression>, <expression>, ...]]
```

Example (creating a list 2 x 3 list a with 6 zeros)

```
import stdarray

a = []
for i in range(3):
    a += [stdarray.create1D(2, 0)]
```

line #	a	i

Two Dimensional (2D) Lists

Appending to a 2D list

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```

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import stdarray

a = []
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    a += [stdarray.create1D(2, 0)]
```

line #	a	i
1		

Two Dimensional (2D) Lists

Appending to a 2D list

```
<name> += [[<expression>, <expression>, ...]]
```

Example (creating a list 2 x 3 list a with 6 zeros)

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import stdarray

a = []
for i in range(3):
    a += [stdarray.create1D(2, 0)]
```

line #	a	i
3	[]	

Two Dimensional (2D) Lists

Appending to a 2D list

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<name> += [[<expression>, <expression>, ...]]
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```
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a = []
for i in range(3):
    a += [stdarray.create1D(2, 0)]
```

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4	[]	0

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```
<name> += [[<expression>, <expression>, ...]]
```

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```
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for i in range(3):
    a += [stdarray.create1D(2, 0)]
```

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5	[[0,0]]	0

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<name> += [[<expression>, <expression>, ...]]
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    a += [stdarray.create1D(2, 0)]
```

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a = []
for i in range(3):
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line #	a	i
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```
import stdarray

a = []
for i in range(3):
    a += [stdarray.create1D(2, 0)]
```

line #	a	i
4	[[0,0],[0,0]]	2

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for i in range(3):
    a += [stdarray.create1D(2, 0)]
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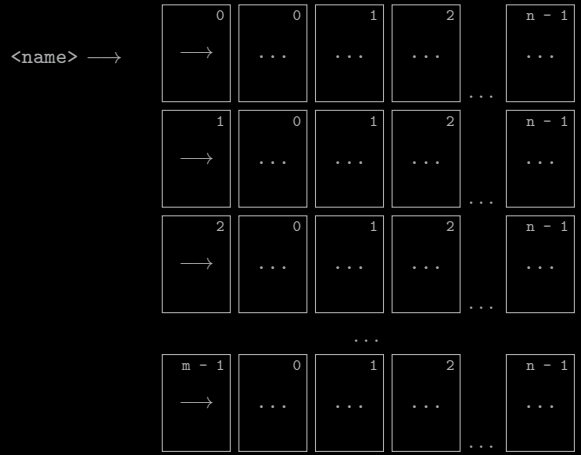
```

line #	a	i

Two Dimensional (2D) Lists

Two Dimensional (2D) Lists



Two Dimensional (2D) Lists

Two Dimensional (2D) Lists

The `stdarray` library also provides a function for creating 2D lists

`create2D(m, n, value = None)`	creates and returns a 2D list of size `m` x `n`, with each element initialized to `value`

Two Dimensional (2D) Lists

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The number of rows (say `m`) in a list `x` is obtained as `len(x)`

Two Dimensional (2D) Lists

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Two Dimensional (2D) Lists

- The number of rows (say `m`) in a list `x` is obtained as `len(x)`
- The number of columns (say `n`) in a list `x` is obtained as `len(x[0])`
- The element in row `i` and column `j` of a list `x` is accessed as `x[i][j]`, where `0 <= i < m` and `0 <= j < n`

Two Dimensional (2D) Lists

The number of rows (say `m`) in a list `x` is obtained as `len(x)`

The number of columns (say `n`) in a list `x` is obtained as `len(x[0])`

The element in row `i` and column `j` of a list `x` is accessed as `x[i][j]`, where `0 <= i < m` and `0 <= j < n`

The element in row `i` and column `j` of a list `x` is assigned a value as

```
x[i][j] = <expression>
```

Two Dimensional (2D) Lists

Two Dimensional (2D) Lists

Example (Matrix Addition)

```
1  a = [[1, 2], [3, 4]]
2  b = [[2, 3], [4, 5]]
3
4  c = [[0, 0], [0, 0]]
5  for i in range(2):
6      for j in range(2):
7          c[i][j] = a[i][j] + b[i][j]
```

line #	c	i	j

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line #	c	i	j
1			

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```

line #	c	i	j

Two Dimensional (2D) Lists

Two Dimensional (2D) Lists

`selfavoid.py`

- Command-line input: n (int) and *trials* (int)
- Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

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```
× ~/workspace/ipp
$ _
```

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```
× ~/workspace/ipp
$ python3 selfavoid.py 20 1000
```

Two Dimensional (2D) Lists

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- Command-line input: n (int) and *trials* (int)
- Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
× ~/workspace/ipp
$ python3 selfavoid.py 20 1000
32% dead ends
$ _
```

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```
× ~/workspace/ipp
$ python3 selfavoid.py 20 1000
32% dead ends
$ python3 selfavoid.py 40 1000
```

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- Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

```
× ~/workspace/ipp
$ python3 selfavoid.py 20 1000
32% dead ends
$ python3 selfavoid.py 40 1000
75% dead ends
$ _
```

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- Command-line input: n (int) and *trials* (int)
- Standard output: percentage of dead ends encountered in *trials* self-avoiding random walks on an $n \times n$ lattice

× ~/workspace/ipp

```
$ python3 selfavoid.py 20 1000
32% dead ends
$ python3 selfavoid.py 40 1000
75% dead ends
$ python3 selfavoid.py 80 1000
```

Two Dimensional (2D) Lists

`selfavoid.py`

- Command-line input: n (int) and *trials* (int)
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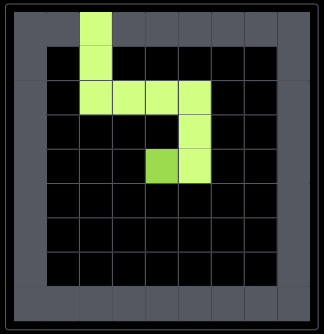
× ~/workspace/ipp

```
$ python3 selfavoid.py 20 1000
32% dead ends
$ python3 selfavoid.py 40 1000
75% dead ends
$ python3 selfavoid.py 80 1000
98% dead ends
$ _
```

Two Dimensional (2D) Lists

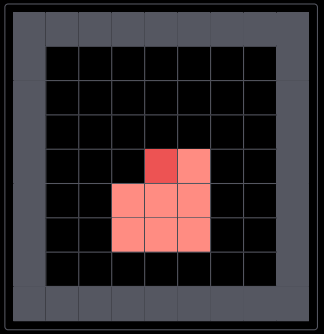
Two Dimensional (2D) Lists

Escape



→ ↑ ↑ ← ← ← ↑ ↑

Dead End



→ ↓ ↓ ← ← ↑ →

Two Dimensional (2D) Lists

Two Dimensional (2D) Lists

× selfavoid.py 1/2

```
import stdarray
import stdio
import stdrandom
import sys

n = int(sys.argv[1])
trials = int(sys.argv[2])
deadEnds = 0
for t in range(trials):
    a = stdarray.create2D(n, n, False)
    x = n // 2
    y = n // 2
    while x > 0 and x < n - 1 and y > 0 and y < n - 1:
        a[x][y] = True
        if a[x - 1][y] and a[x + 1][y] and a[x][y - 1] and a[x][y + 1]:
            deadEnds += 1
            break
        r = stdrandom.uniformInt(1, 5)
        if r == 1 and not a[x + 1][y]:
            x += 1
```

Two Dimensional (2D) Lists

Two Dimensional (2D) Lists

× selfavoid.py 2/2

```
        elif r == 2 and not a[x - 1][y]:
            x -= 1
        elif r == 3 and not a[x][y + 1]:
            y += 1
        elif r == 4 and not a[x][y - 1]:
            y -= 1
stdio.writeln(str(100 * deadEnds // trials) + "% dead ends")
```

Converting 2D Lists to 1D Lists and Vice Versa

Converting 2D Lists to 1D Lists and Vice Versa

Converting an $m \times n$ list X into a 1D list Y

- The element $X(i, j)$ maps to the element $Y(k)$, where $k = n \cdot i + j$

Converting 2D Lists to 1D Lists and Vice Versa

Converting an $m \times n$ list X into a 1D list Y

- The element $X(i, j)$ maps to the element $Y(k)$, where $k = n \cdot i + j$

Converting a 1D list Y of size l into an $m \times n$ list X

- The element $Y(k)$ maps to the element $X(i, j)$, where $i = \left\lfloor \frac{k}{n} \right\rfloor$, $j = k \bmod n$, and $m = \frac{l}{n}$

Converting 2D Lists to 1D Lists and Vice Versa

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Converting a 1D list Y of size l into an $m \times n$ list X

- The element $Y(k)$ maps to the element $X(i, j)$, where $i = \left\lfloor \frac{k}{n} \right\rfloor$, $j = k \bmod n$, and $m = \frac{l}{n}$

Example

$$X = \begin{array}{c} \begin{array}{cccccc} 0 & 1 & 2 & 3 & 4 & \\ \end{array} \\ \begin{bmatrix} A & B & C & D & E \\ F & G & H & I & J \\ K & L & M & N & O \end{bmatrix} \begin{array}{c} 0 \\ 1 \\ 2 \end{array} \end{array}$$

$$Y = \begin{array}{cccccccccccccccc} 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & \\ [A & B & C & D & E & F & G & H & I & J & K & L & M & N & O &] \end{array}$$

Ragged Lists

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A ragged list is a 2D list in which the rows have unequal number of columns

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The number of columns in the `i`th row of a ragged list `x` is obtained as `x[i].length`

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A ragged list is a 2D list in which the rows have unequal number of columns

The number of columns in the ith row of a ragged list `x` is obtained as `x[i].length`

Example (printing a ragged list)

```
import stdio

pascal = [[1], [1, 1], [1, 2, 1], [1, 3, 3, 1], [1, 4, 6, 4, 1]]

for i in range(len(pascal)):
    for j in range(len(pascal[i])):
        stdio.write(str(pascal[i][j]) + " ")
    stdio.writeln()
```

writes

```
1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
```

Tuples

Tuples

A tuple (object of type `tuple`) is an immutable, ordered collection of objects

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```
× ~/workspace/ipp
>>> _
```

Tuples

A tuple (object of type `tuple`) is an immutable, ordered collection of objects

```
× ~/workspace/ipp
>>> t = 42, 1729, "Hello"
```

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× ~/workspace/ipp
>>> t = 42, 1729, "Hello"
>>> t
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>>> t = 42, 1729, "Hello"
>>> t
(42, 1729, "Hello")
>>> _
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Tuples

A tuple (object of type `tuple`) is an immutable, ordered collection of objects

```
× ~/workspace/ipp
>>> t = 42, 1729, "Hello"
>>> t
(42, 1729, "Hello")
>>> 1729 in t
```

Tuples

A tuple (object of type `tuple`) is an immutable, ordered collection of objects

```
× ~/workspace/ipp
>>> t = 42, 1729, "Hello"
>>> t
(42, 1729, "Hello")
>>> 1729 in t
True
>>> _
```

Tuples

A tuple (object of type `tuple`) is an immutable, ordered collection of objects

```
× ~/workspace/ipp
>>> t = 42, 1729, "Hello"
>>> t
(42, 1729, "Hello")
>>> 1729 in t
True
>>> t[1]
```

Tuples

A tuple (object of type `tuple`) is an immutable, ordered collection of objects

```
× ~/workspace/ipp
>>> t = 42, 1729, "Hello"
>>> t
(42, 1729, "Hello")
>>> 1729 in t
True
>>> t[1]
1729
>>> _
```

Tuples

A tuple (object of type `tuple`) is an immutable, ordered collection of objects

```
× ~/workspace/ipp
>>> t = 42, 1729, "Hello"
>>> t
(42, 1729, "Hello")
>>> 1729 in t
True
>>> t[1]
1729
>>> t[2] = "Hello, World"
```

Tuples

A tuple (object of type `tuple`) is an immutable, ordered collection of objects

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>>> t = 42, 1729, "Hello"
>>> t
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True
>>> t[1]
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Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> _
```

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Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> empty = ()
```

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Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> empty = ()
>>> len(empty)
```

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>>> t
(42, 1729, "Hello")
>>> 1729 in t
True
>>> t[1]
1729
>>> t[2] = "Hello, World"
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> empty = ()
>>> len(empty)
0
>>> _
```

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>>> t
(42, 1729, "Hello")
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True
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1729
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Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> empty = ()
>>> len(empty)
0
>>> singleton = "Hello",
```

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Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> empty = ()
>>> len(empty)
0
>>> singleton = "Hello",
>>> _
```

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```

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Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> empty = ()
>>> len(empty)
0
>>> singleton = "Hello",
>>> len(singleton)
1
>>> _
```

Sets

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

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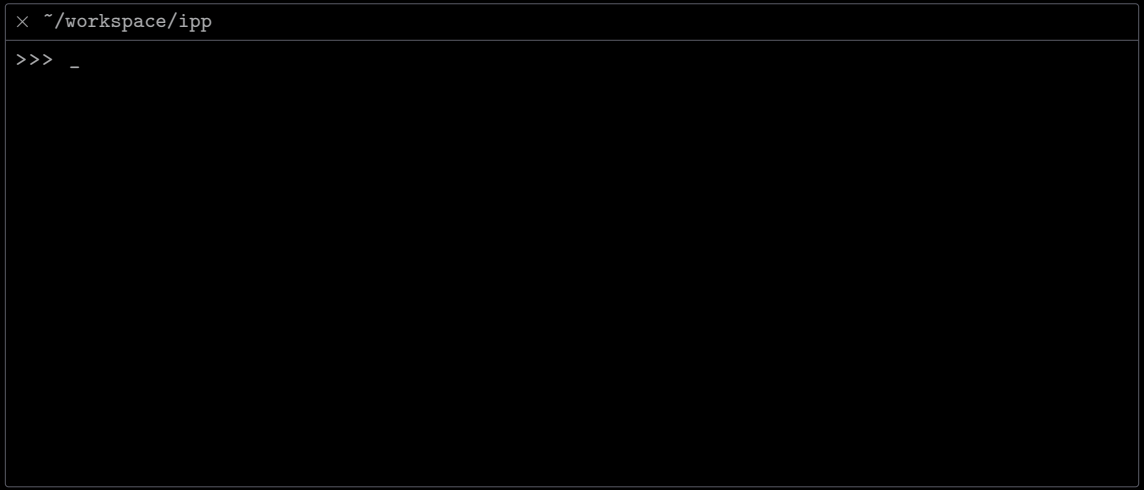

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

× ~/workspace/ipp

```
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> a - b
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> a - b
{"b", "d", "r"}
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> a - b
{"b", "d", "r"}
>>> a | b
```

Sets

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```
× ~/workspace/ipp
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> a - b
{"b", "d", "r"}
>>> a | b
{"l", "c", "d", "z", "a", "r", "m", "b"}
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

× ~/workspace/ipp

```
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
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>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> a - b
{"b", "d", "r"}
>>> a | b
{"l", "c", "d", "z", "a", "r", "m", "b"}
>>> a & b
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

× ~/workspace/ipp

```
>>> basket = ["orange", "apple", "pear", "orange", "banana", "apple"]
>>> fruit = set(basket)
>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> a - b
{"b", "d", "r"}
>>> a | b
{"l", "c", "d", "z", "a", "r", "m", "b"}
>>> a & b
{"c", "a"}
>>> _
```

Sets

A set (object of type `set`) is an unordered collection of objects with no duplicates

× ~/workspace/ipp

```
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>>> fruit
{"banana", "pear", "orange", "apple"}
>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> a - b
{"b", "d", "r"}
>>> a | b
{"l", "c", "d", "z", "a", "r", "m", "b"}
>>> a & b
{"c", "a"}
>>> a ^ b
```

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>>> "orange" in fruit
True
>>> a = set("abracadabra")
>>> b = set("alacazam")
>>> a - b
{"b", "d", "r"}
>>> a | b
{"l", "c", "d", "z", "a", "r", "m", "b"}
>>> a & b
{"c", "a"}
>>> a ^ b
{"l", "r", "d", "m", "b", "z"}
>>> _
```

Advanced Looping Techniques

Advanced Looping Techniques

`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

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Example

```
1  import stdio
2
3  for i, v in enumerate(["A", "B", "C"]):
4      stdio.writeln(str(i) + " " + v)
```

line #	i	v

×

```
1
2
3
```

Advanced Looping Techniques

`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1 import stdio
2
3 for i, v in enumerate(["A", "B", "C"]):
4     stdio.writeln(str(i) + " " + v)
```

line #	i	v
1		

```
1
2
3
```

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`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1  import stdio
2
3  for i, v in enumerate(["A", "B", "C"]):
4      stdio.writeln(str(i) + " " + v)
```

line #	i	v
3	0	"A"

```
1
2
3
```

Advanced Looping Techniques

`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1 import stdio
2
3 for i, v in enumerate(["A", "B", "C"]):
4     stdio.writeln(str(i) + " " + v)
```

line #	i	v
4	0	"A"

```
1 0 A
2
3
```

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`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1 import stdio
2
3 for i, v in enumerate(["A", "B", "C"]):
4     stdio.writeln(str(i) + " " + v)
```

line #	i	v
3	1	"B"

```
1 0 A
2
3
```

Advanced Looping Techniques

`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1 import stdio
2
3 for i, v in enumerate(["A", "B", "C"]):
4     stdio.writeln(str(i) + " " + v)
```

line #	i	v
4	1	"B"

```
1 0 A
2 1 B
3
```

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`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1 import stdio
2
3 for i, v in enumerate(["A", "B", "C"]):
4     stdio.writeln(str(i) + " " + v)
```

line #	i	v
3	2	"C"

```
1 0 A
2 1 B
3
```

Advanced Looping Techniques

`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1 import stdio
2
3 for i, v in enumerate(["A", "B", "C"]):
4     stdio.writeln(str(i) + " " + v)
```

line #	i	v
4	2	"C"

```
×
1 0 A
2 1 B
3 2 C
```

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`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1 import stdio
2
3 for i, v in enumerate(["A", "B", "C"]):
4     stdio.writeln(str(i) + " " + v)
```

line #	i	v
3		

```
0 A
1 B
2 C
```

Advanced Looping Techniques

`enumerate(x)` allows us to loop over the sequence `x` with access to both its elements and their indices

Example

```
1 import stdio
2
3 for i, v in enumerate(["A", "B", "C"]):
4     stdio.writeln(str(i) + " " + v)
```

line #	i	v

```
0 A
1 B
2 C
```

Advanced Looping Techniques

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`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, `...` at the same time

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Example

```
1 import stdio
2
3 questions = ["Name", "Age", "Hobby"]
4 answers = ["Alice", "19", "Coding"]
5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a

```
1
2
3
```

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Example

```
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5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a
1		

×

```
1
2
3
```

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Example

```
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5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a
3		

×

```
1
2
3
```

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Example

```
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2
3 questions = ["Name", "Age", "Hobby"]
4 answers = ["Alice", "19", "Coding"]
5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a
4		

×

```
1
2
3
```

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`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, `...` at the same time

Example

```
1  import stdio
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3  questions = ["Name", "Age", "Hobby"]
4  answers = ["Alice", "19", "Coding"]
5  for q, a in zip(questions, answers):
6      stdio.writeln(q + "? It is " + a)
```

line #	q	a
5	"Name"	"Alice"

×

```
1
2
3
```

Advanced Looping Techniques

`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, `...` at the same time

Example

```
1 import stdio
2
3 questions = ["Name", "Age", "Hobby"]
4 answers = ["Alice", "19", "Coding"]
5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a
6	"Name"	"Alice"

×

```
1 Name? It is Alice.
2
3
```

Advanced Looping Techniques

`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, `...` at the same time

Example

```
1 import stdio
2
3 questions = ["Name", "Age", "Hobby"]
4 answers = ["Alice", "19", "Coding"]
5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a
5	"Age"	"19"

×

```
1 Name? It is Alice.
2
3
```

Advanced Looping Techniques

`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, ... at the same time

Example

```
1 import stdio
2
3 questions = ["Name", "Age", "Hobby"]
4 answers = ["Alice", "19", "Coding"]
5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a
6	"Age"	"19"

×

```
1 Name? It is Alice.
2 Age? It is 19.
3
```

Advanced Looping Techniques

`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, `...` at the same time

Example

```
1  import stdio
2
3  questions = ["Name", "Age", "Hobby"]
4  answers = ["Alice", "19", "Coding"]
5  for q, a in zip(questions, answers):
6      stdio.writeln(q + "? It is " + a)
```

line #	q	a
5	"Hobby"	"Coding"

×

```
1  Name? It is Alice.
2  Age? It is 19.
3
```

Advanced Looping Techniques

`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, `...` at the same time

Example

```
1 import stdio
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3 questions = ["Name", "Age", "Hobby"]
4 answers = ["Alice", "19", "Coding"]
5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a
6	"Hobby"	"Coding"

×

```
1 Name? It is Alice.
2 Age? It is 19.
3 Hobby? It is Coding.
```

Advanced Looping Techniques

`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, `...` at the same time

Example

```
1 import stdio
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3 questions = ["Name", "Age", "Hobby"]
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5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a
5		

×

```
1 Name? It is Alice.
2 Age? It is 19.
3 Hobby? It is Coding.
```

Advanced Looping Techniques

`zip(x, y, ...)` allows us to loop over two or more equal-length sequences `x`, `y`, `...` at the same time

Example

```
1 import stdio
2
3 questions = ["Name", "Age", "Hobby"]
4 answers = ["Alice", "19", "Coding"]
5 for q, a in zip(questions, answers):
6     stdio.writeln(q + "? It is " + a)
```

line #	q	a

×

```
1 Name? It is Alice.
2 Age? It is 19.
3 Hobby? It is Coding.
```

Advanced Looping Techniques

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`reversed(x)` allows us to loop over the sequence `x` in reverse

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`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v

```
1
2
3
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v
1		

```
1
2
3
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v
3	["A", "B", "C"]	

```
1
2
3
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v
4	["A", "B", "C"]	"C"

```
1
2
3
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1 import stdio
2
3 x = ["A", "B", "C"]
4 for v in reversed(x):
5     stdio.writeln(v)
```

line #	x	v
5	["A", "B", "C"]	"C"

```
×
1 C
2
3
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v
4	["A", "B", "C"]	"B"

```
1  C
2
3
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v
5	["A", "B", "C"]	"B"

```
1  C
2  B
3
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v
4	["A", "B", "C"]	"A"

```
1  C
2  B
3
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v
5	["A", "B", "C"]	"A"

×

```
1  C
2  B
3  A
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v
4	["A", "B", "C"]	

×

```
1  C
2  B
3  A
```

Advanced Looping Techniques

`reversed(x)` allows us to loop over the sequence `x` in reverse

Example

```
1  import stdio
2
3  x = ["A", "B", "C"]
4  for v in reversed(x):
5      stdio.writeln(v)
```

line #	x	v

```
1  C
2  B
3  A
```

Advanced Looping Techniques

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

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`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1 import stdio
2
3 x = ["B", "A", "C"]
4 for v in sorted(x):
5     stdio.writeln(v)
```

line #	x	v

```
1
2
3
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
1		

```
1
2
3
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
3	["B", "A", "C"]	

```
1
2
3
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
4	["B", "A", "C"]	"A"

```
1
2
3
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
5	["B", "A", "C"]	"A"

```
1  A
2
3
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
4	["B", "A", "C"]	"B"

```
1  A
2
3
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
5	["B", "A", "C"]	"B"

```
1  A
2  B
3
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
4	["B", "A", "C"]	"C"

```
1  A
2  B
3
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
5	["B", "A", "C"]	"C"

```
1  A
2  B
3  C
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
4	["B", "A", "C"]	

```
1  A
2  B
3  C
```

Advanced Looping Techniques

`sorted(x)` allows us to loop over the sequence `x` in sorted order

Example

```
1  import stdio
2
3  x = ["B", "A", "C"]
4  for v in sorted(x):
5      stdio.writeln(v)
```

line #	x	v
4		

```
1  A
2  B
3  C
```