Mutable Values

Announcements

Objects

(Demo)

Objects

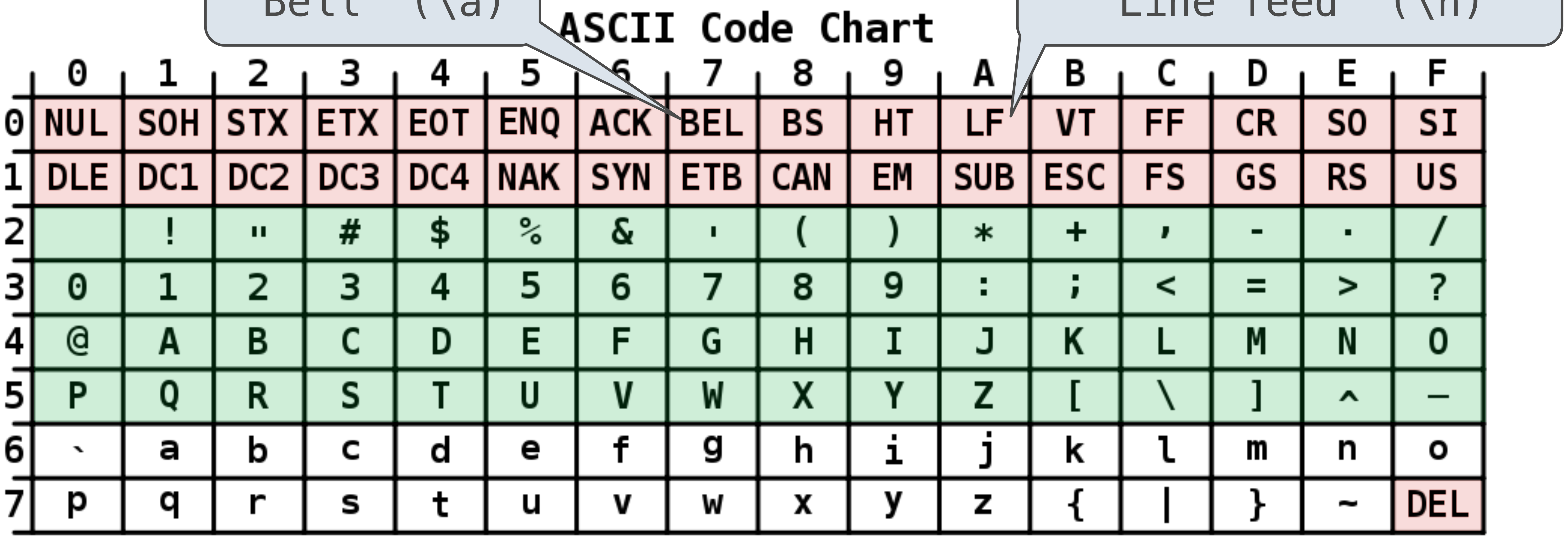
- Objects represent information
- They consist of data and behavior, bundled together to create abstractions
- Objects can represent things, but also properties, interactions, & processes
- A type of object is called a class; **classes** are first-class values in Python
- Object-oriented programming:
  - A metaphor for organizing large programs
  - Special syntax that can improve the composition of programs
- In Python, every value is an object
  - All **objects** have **attributes**
  - A lot of data manipulation happens through object **methods**
  - Functions do one thing; objects do many related things

Example: Strings

(Demo)

Representing Strings: the ASCII Standard

American Standard Code for Information Interchange



"Bell" (\a)

"Line feed" (\n)

ASCII Code Chart

		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0 0 0	0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
0 0 1	1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
0 1 0	2		!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
0 1 1	3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
1 0 0	4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1 0 1	5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
1 1 0	6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
1 1 1	7	p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	DEL

8 rows: 3 bits

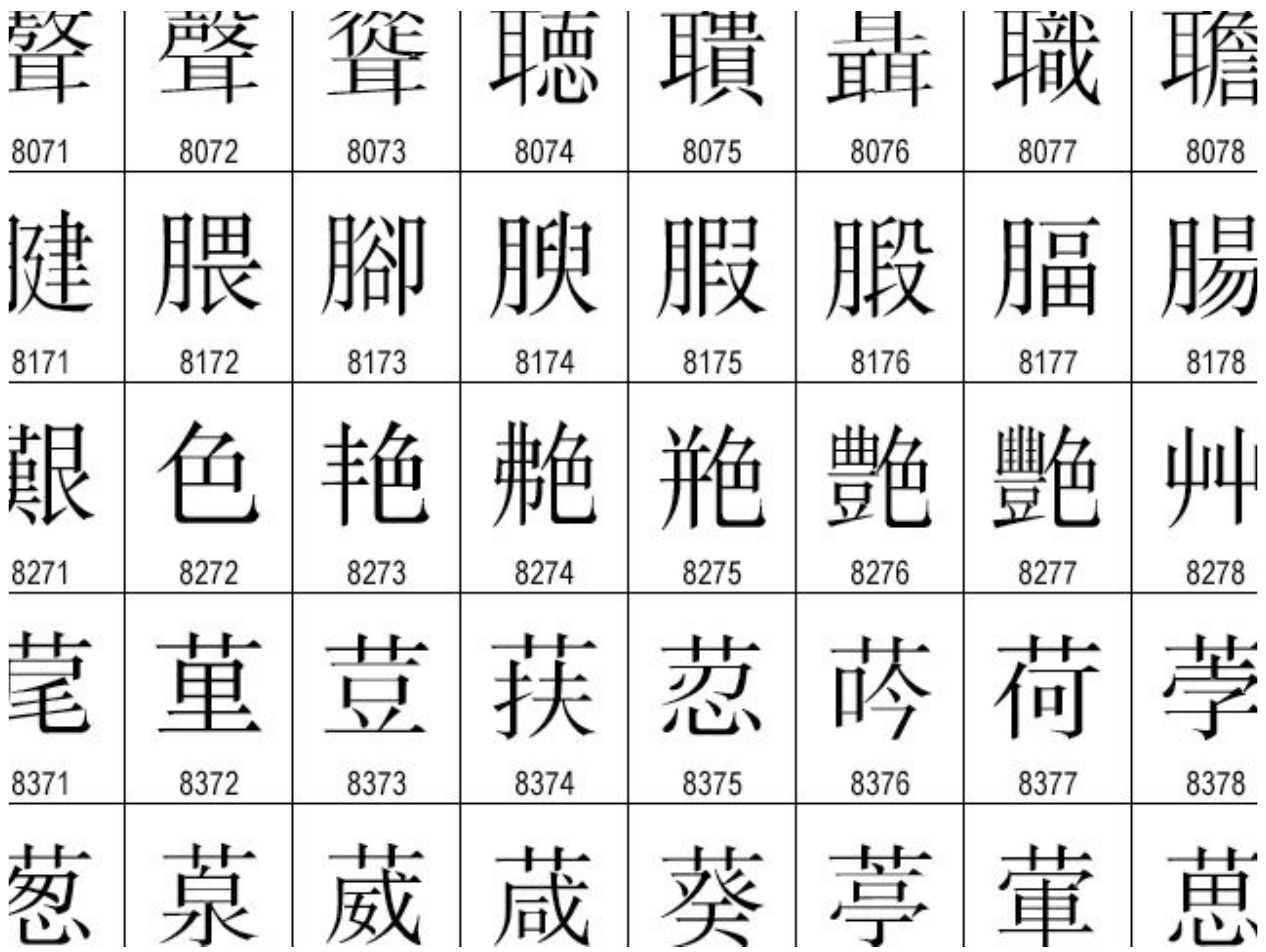
16 columns: 4 bits

- Layout was chosen to support sorting by character code
- Rows indexed 2-5 are a useful 6-bit (64 element) subset
- Control characters were designed for transmission

(Demo)

Representing Strings: the Unicode Standard

- 137,994 characters in Unicode 12.1
- 150 scripts (organized)
- Enumeration of character properties, such as case
- Supports bidirectional display order
- A canonical name for every character



聱	聲	聳	聴	聵	聶	職	聸
8071	8072	8073	8074	8075	8076	8077	8078
腱	腲	腳	腴	腵	腶	腷	腸
8171	8172	8173	8174	8175	8176	8177	8178
艱	色	艳	艴	艵	艶	艷	艸
8271	8272	8273	8274	8275	8276	8277	8278
荱	荲	荳	荴	荵	荶	荷	荸
8371	8372	8373	8374	8375	8376	8377	8378
葱	葲	葳	葴	葵	葶	葷	葸

http://ian-albert.com/unicode_chart/unichart-chinese.jpg

LATIN CAPITAL LETTER A

DIE FACE-6 '⚅' '♪'

EIGHTH NOTE

(Demo)

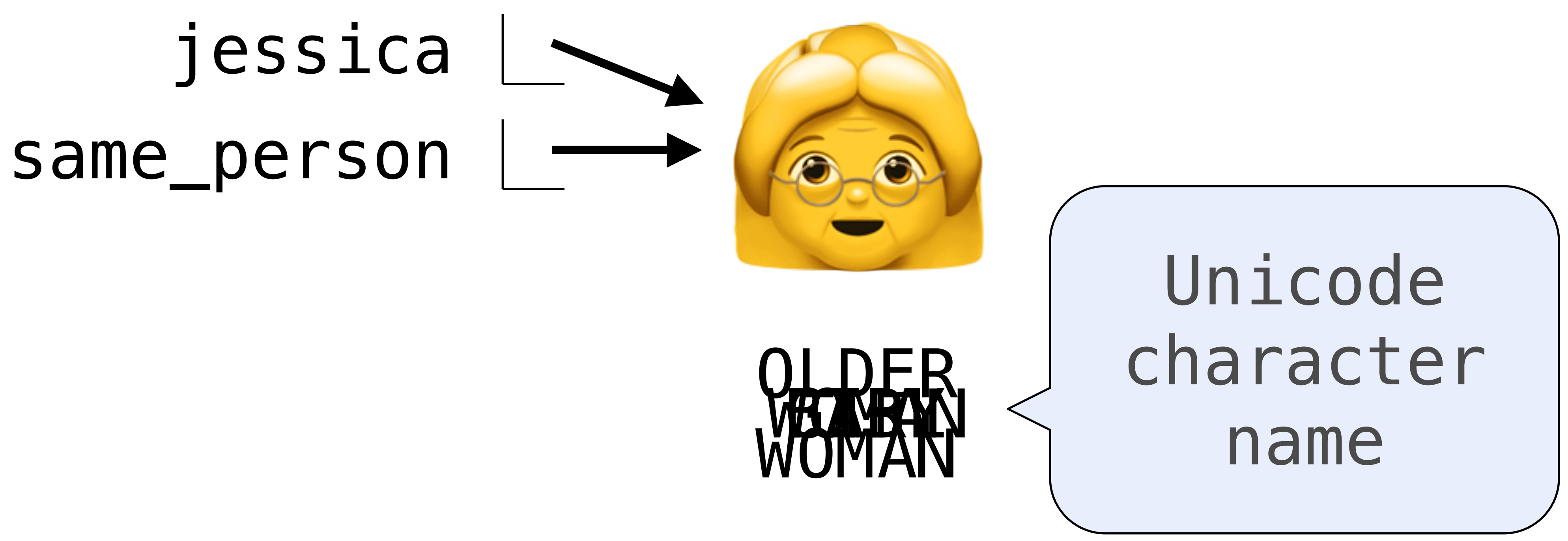
Mutation Operations

Some Objects Can Change

[Demo]

First example in the course of an object changing state

The same object can change in value throughout the course of computation



jessica

same_person

OLDER WOMAN

Unicode character name

All names that refer to the same object are affected by a mutation

Only objects of *mutable* types can change: lists & dictionaries

{Demo}

Mutation Can Happen Within a Function Call

A function can change the value of any object in its scope

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> mystery(four)
>>> len(four)
2
```

```
def mystery(s):      or   def mystery(s):
    s.pop()                   s[2:] = []
    s.pop()
```

```
>>> four = [1, 2, 3, 4]
>>> len(four)
4
>>> another_mystery() # No arguments!
>>> len(four)
2
```

```
def another_mystery():
    four.pop()
    four.pop()
```

pythontutor.com/composingprograms.html#code=def%20mystery%28s%29%3A%0A%20%20%20%20s.pop%28%29%0A%20%20%20%20s.pop%28%29%0A%0Afour%20%3D%20[1,%202,%203,%204]%0Amystery%28four%29&mode=display&origin=composingprograms.js&cumulative=true&py=3&rawInputLstJSON=[]&curInstr=0

Tuples

(Demo)

Tuples are Immutable Sequences

Immutable values are protected from mutation

```
>>> turtle = (1, 2, 3)
>>> ooze()
>>> turtle
(1, 2, 3)
```

Next lecture: ooze can change turtle's binding

```
>>> turtle = [1, 2, 3]
>>> ooze()
>>> turtle
['Anything could be inside!']
```

The value of an expression can change because of changes in names or objects

Name change:

```
>>> x = 2
>>> x + x
4
>>> x = 3
>>> x + x
6
```

Object mutation:

```
>>> x = [1, 2]
>>> x + x
[1, 2, 1, 2]
>>> x.append(3)
>>> x + x
[1, 2, 3, 1, 2, 3]
```

An immutable sequence may still change if it *contains* a mutable value as an element

```
>>> s = ([1, 2], 3)
>>> s[0] = 4
ERROR
```

```
>>> s = ([1, 2], 3)
>>> s[0][0] = 4
>>> s
([4, 2], 3)
```

Mutation

Sameness and Change

- As long as we never modify objects, a compound object is just the totality of its pieces
- A rational number is just its numerator and denominator
- This view is no longer valid in the presence of change
- A compound data object has an "identity" in addition to the pieces of which it is composed
- A list is still "the same" list even if we change its contents
- Conversely, we could have two lists that happen to have the same contents, but are different

```
>>> a = [10]
>>> b = a
>>> a == b
True
>>> a.append(20)
>>> a
[10, 20]
>>> b
[10, 20]
>>> a == b
True
```

```
>>> a = [10]
>>> b = [10]
>>> a == b
True
>>> b.append(20)
>>> a
[10]
>>> b
[10, 20]
>>> a == b
False
```

Identity Operators

Identity

`<exp0> is <exp1>`

evaluates to True if both <exp0> and <exp1> evaluate to the same object

Equality

`<exp0> == <exp1>`

evaluates to True if both <exp0> and <exp1> evaluate to equal values

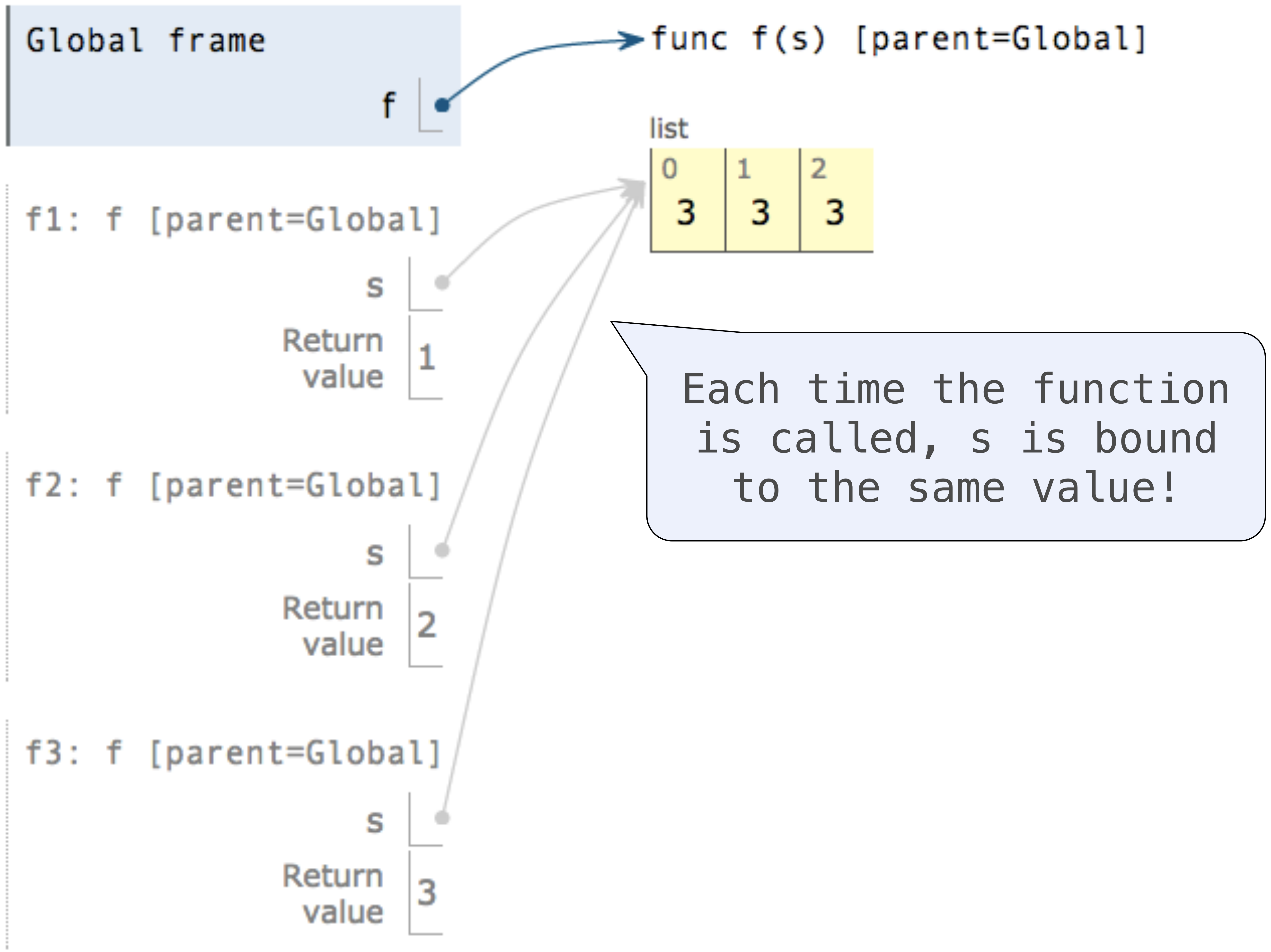
Identical objects are always equal values

(Demo)

Mutable Default Arguments are Dangerous

A default argument value is part of a function value, not generated by a call

```
>>> def f(s=[]):
...     s.append(3)
...     return len(s)
...
>>> f()
1
>>> f()
2
>>> f()
3
```



Each time the function is called, s is bound to the same value!

pythontutor.com/composingprograms.html#code=def%20f%28s%3D[]%29%3A%0A%20%20%20%20s.append%283%29%0A%20%20%20%20return%20len%28s%29%0A%20%20%20%20%0Af%28%29%0Af%28%29%0Af%28%29&mode=display&origin=composingprograms.js&cumulative=true&py=3&rawInputLstJSON=[]&curInstr=0

Lists

Lists in Environment Diagrams

Assume that before each example below we execute:

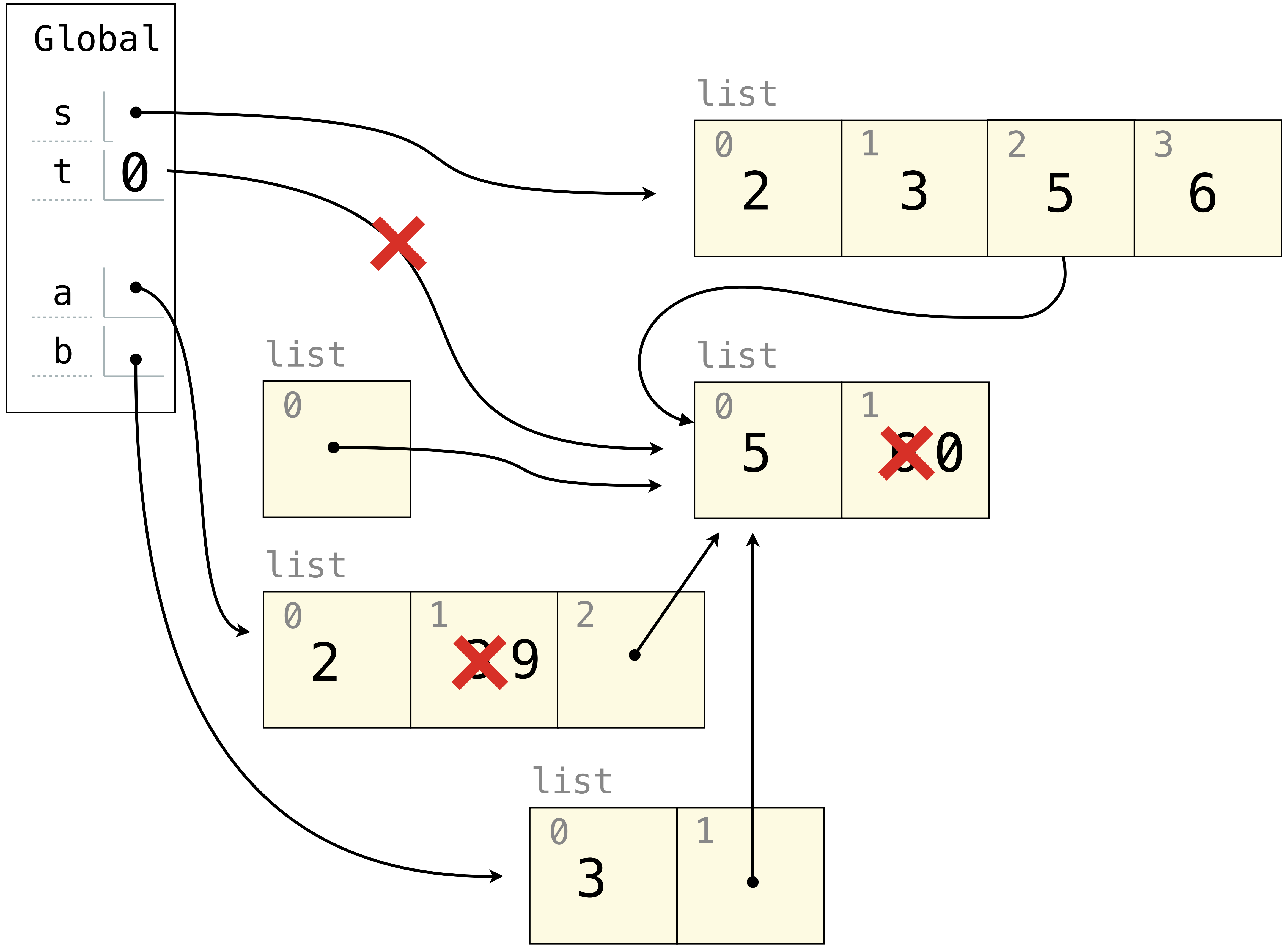
```
s = [2, 3]
t = [5, 6]
```

Operation	Example	Result

append adds one element to a list	s.append(t)
	t = 0
		s → [2, 3, [5, 6]]
		t → 0

extend adds all elements in one list to another list	s.extend(t)
	t[1] = 0
		s → [2, 3, 5, 6]
		t → [5, 0]

addition & **slicing** create new lists containing existing elements	a = s + [t]
	b = a[1:]
	a[1] = 9
	b[1][1] = 0
		s → [2, 3]
		t → [5, 0]
		a → [2, 9, [5, 0]]
		b → [3, [5, 0]]



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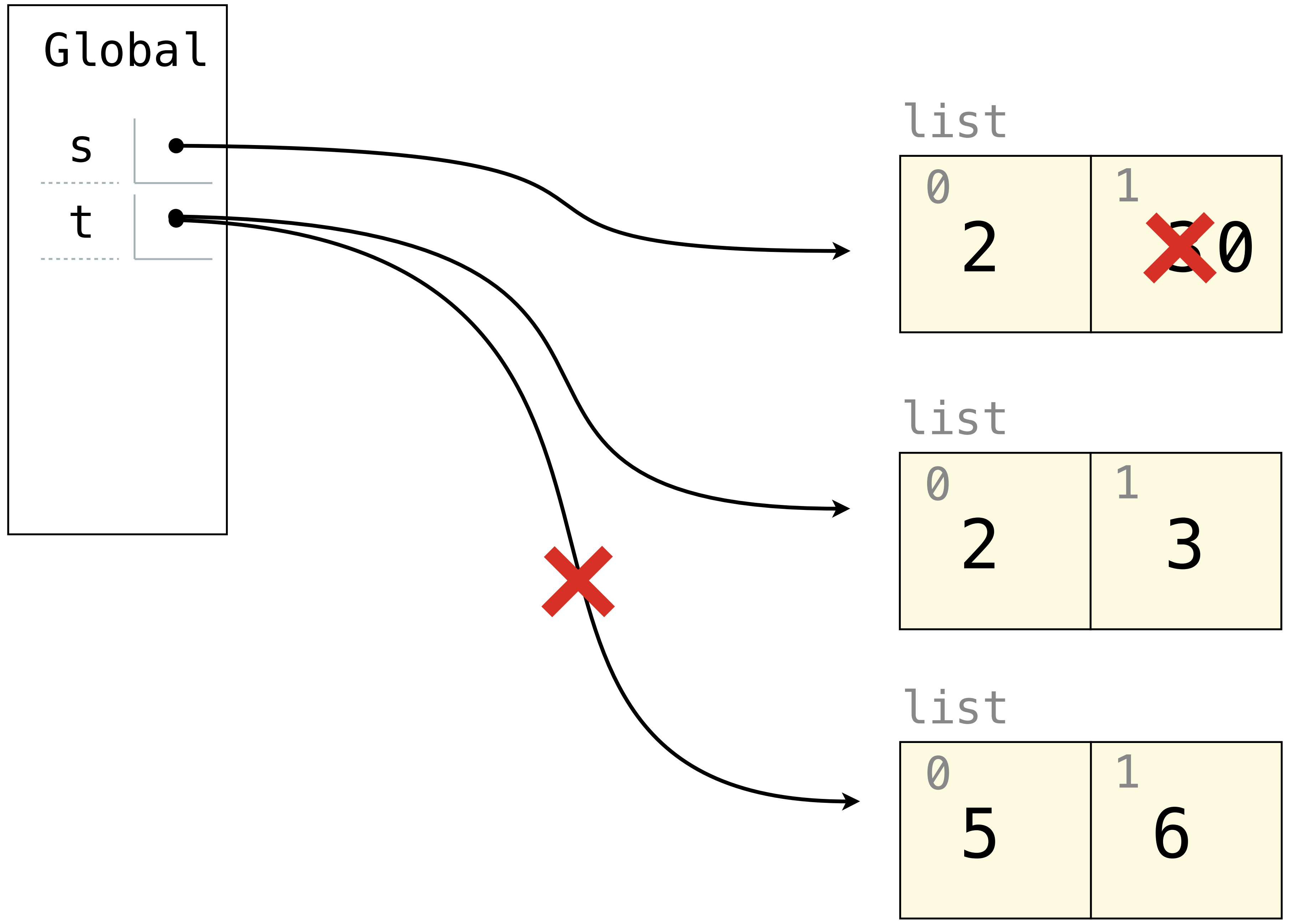
		`t → [5, 0]`
		`a → [2, 9, [5, 0]]`
		`b → [3, [5, 0]]`

The **list** function also creates a new list containing existing elements	`t = list(s)`
	`s[1] = 0`
		`s → [2, 0]`
		`t → [2, 3]`



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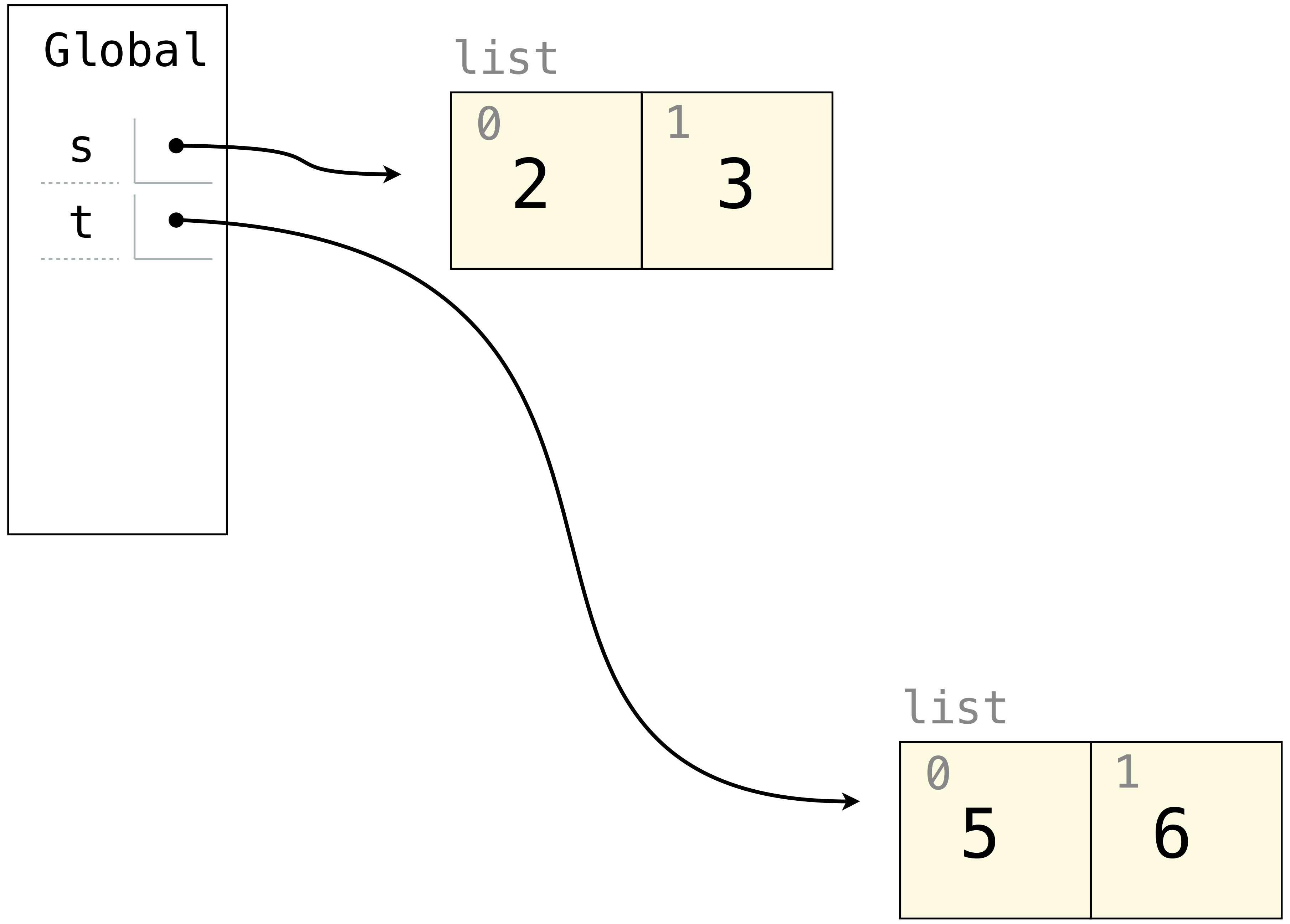
		t → [2, 3]

slice assignment replaces a slice with new values	s[0:0] = t s[3:] = t t[1] = 0	



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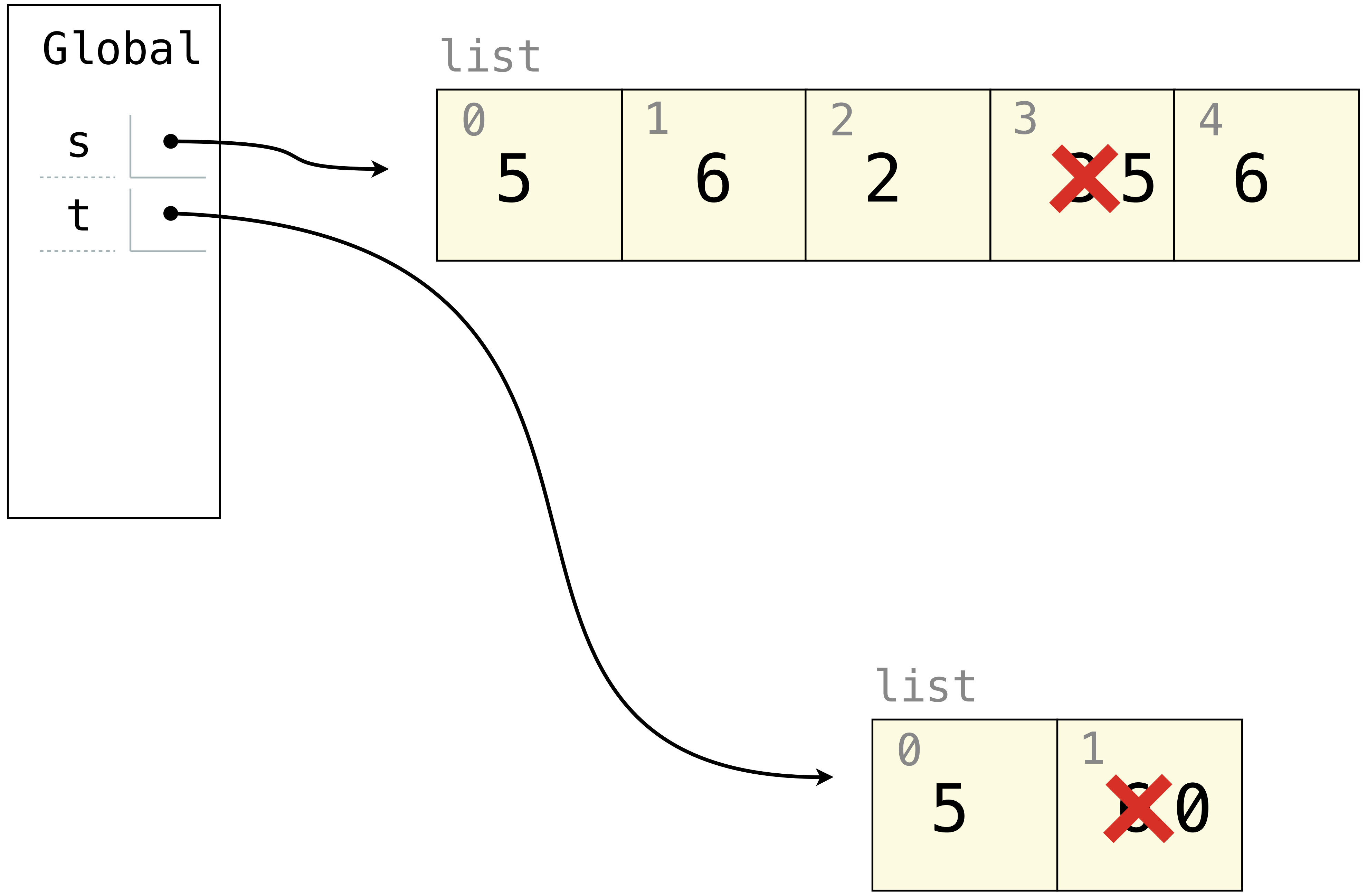
		s → [2, 0]
		t → [2, 3]

slice assignment replaces a slice with new values	s[0:0] = t s[3:] = t t[1] = 0	s → [5, 6, 2, 5, 6] t → [5, 0]



Lists in Environment Diagrams

Assume that before each example below we execute:

```
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t = [5, 6]
```

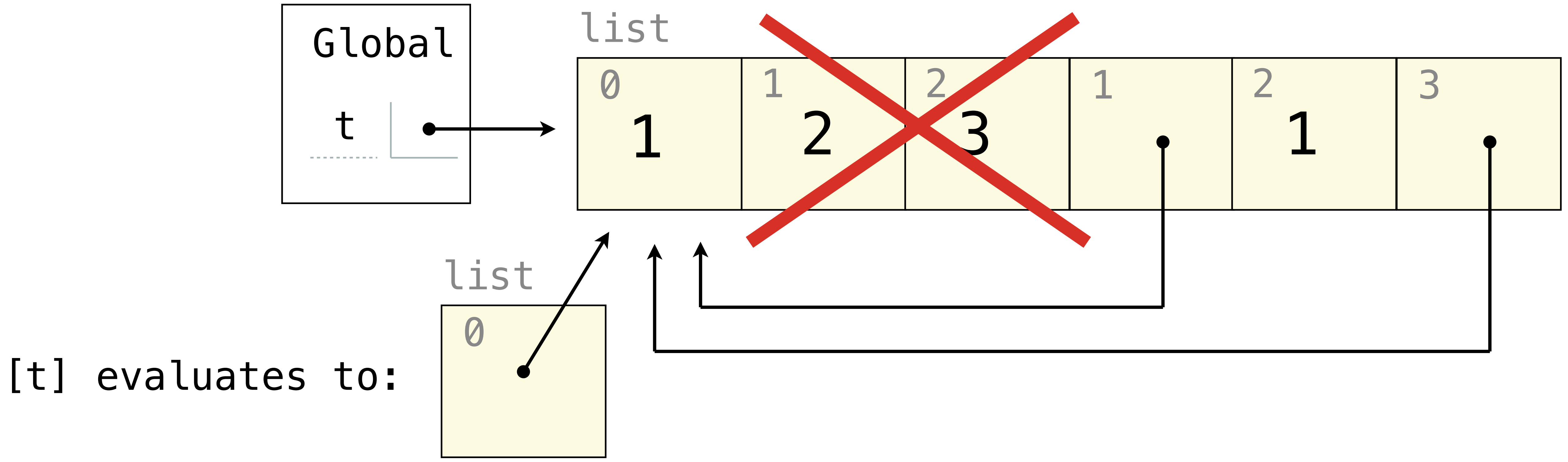
Operation	Example	Result
pop removes & returns the last element	t = s.pop()	s → [2] t → 3

remove removes the first element equal to the argument	t.extend(t)
	t.remove(5)
		s → [2, 3]
		t → [6, 5, 6]

slice assignment can remove elements from a list by assigning [] to a slice.	s[:1] = [] t[0:2] = []	s → [3] t → []

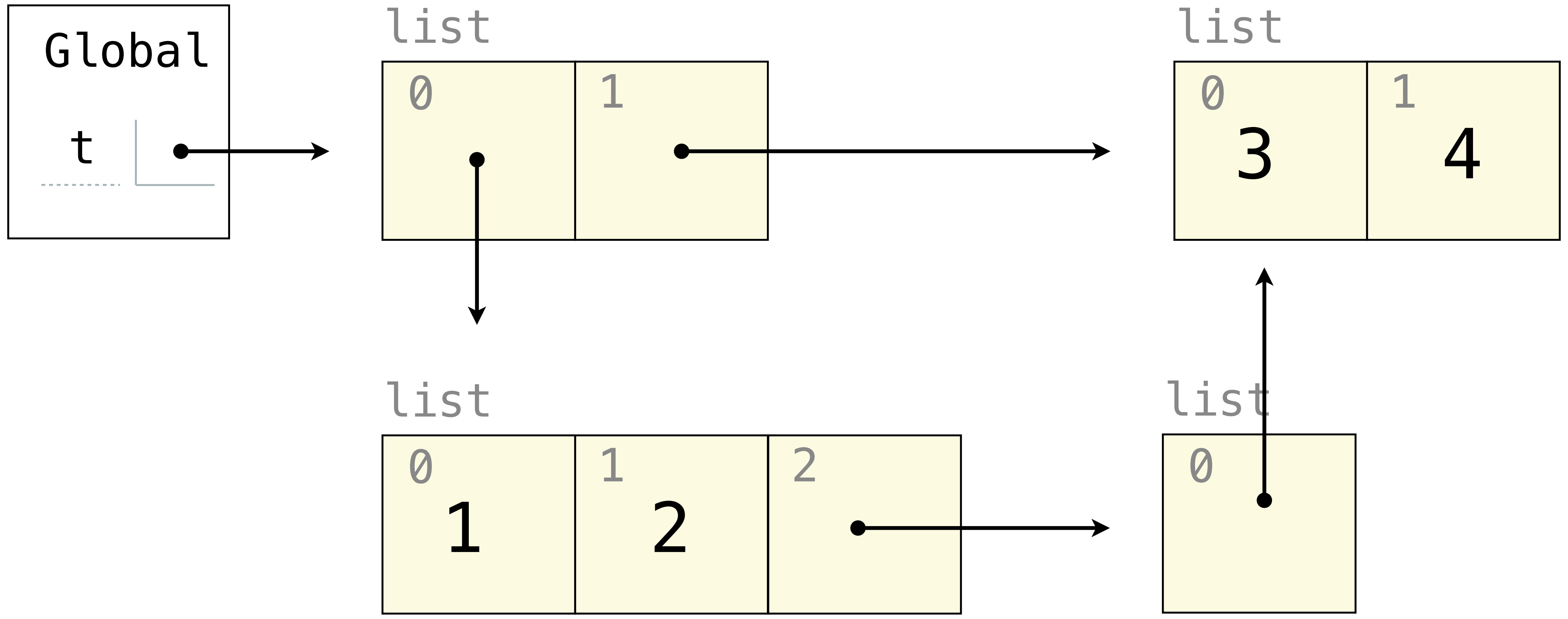
Lists in Lists in Lists in Environment Diagrams

```
t = [1, 2, 3]
t[1:3] = [t]
t.extend(t)
```



[1, [...], 1, [...]]

```
t = [[1, 2], [3, 4]]
t[0].append(t[1:2])
```



[[1, 2, [[3, 4]]], [3, 4]]