Outline

recursion on nested lists

recursion with turtles

summing lists

```
L1 = [1, 9, 8, 15]
sum(L1) = ???
L2 = [[1, 5], [9, 8], [1, 2, 3, 4]]
sum([sum(row) for row in L2]) = ??
L3 = [[1, 5], 9, [8, [1, 2], 3, 4]]
```

How can we sum L3?

re-use built-in... recursion!

- a function `sum_list` that adds all the numbers in a nested list shouldn't ignore built-in `sum`
- ...except `sum` wouldn't work properly on the nested lists, so make a list-comprehension of their `sum_lists`
- but wait, some of the list elements are numbers, not lists!

write a definition of `sum_list` — don't look at next slide yet!

hey! don't peek!

```
def sum_list(L):
    """
    Return the sum of all ints in L.

    @param int|list[int|list[...]] L: possibly-nested list of ints, fin

    >>> sum_list([1, [2, 3], [4, 5, [6, 7], 8]])
    36
    >>> sum([])
    0
    """

    if isinstance(L, list):
        return sum([sum_list(x) for x in L])
    else:
        return L
```

tracing recursion

To understand recursion, trace from simple to complex:

- trace `sum_list(17)`
- trace `sum_list([1, 2, 3])`. Remember how the built-in `sum` works...
- trace `sum_list([1, [2, 3], 4, [5, 6]])`. Immediately replace calls you've already traced (or traced something equivalent) by their value
- trace `sum_list([1, [2, [3 ,4], 5], 6 [7, 8]])`. Immediately replace calls you've already traced by their value.

depth of a list

Define the `depth` of `L` as 1 plus the maximum depth of `L`'s elements if `L` is a list, otherwise 0.

- the definition is almost exactly the Python code you write!
- start by writing `return` and pythonese for the definition:

```
if isinstance(L, list):
    return 1 + max([depth(x) for x in L])
else: # L is not a list
    return 0
# find the bug! (then fix it...)
```

- deal with the special case of a non-list

trace to understand recursion

Trace in increasing complexity; at each step fill in values for recursive calls that have (basically) **already been traced**

- Trace `depth([])`
- Trace `depth(17)`
- Trace `depth([3, 17, 1])`
- Trace `depth([5, [3, 17, 1], [2, 4], 6])`
- Trace
  `depth([14, 7, [5, [3, 17, 1], [2, 4], 6], 9])`

maximum number in nested list

Use the built-in `max` much like `sum`

- how would you find the max of non-nested list?

  `max(...)`

- how would you build that list using a comprehension?

  `max([...])`

- what should you do with list items that were themselves lists?

  `max([rec_max(x) ...])`

- get some intuition by tracing through flat lists, lists nested one deep, then two deep...

code for rec_max

```
if isinstance(L, list):
    return max([rec_max(x) for x in L])
else:
    return L
```

trace the recursion

trace from simple to complex; fill in already-solved recursive calls

- trace `rec_max([3, 5, 1, 3, 4, 7])`
- trace `rec_max([4, 2, [3, 5, 1, 3, 4, 7], 8])`
- trace
  `rec_max([6, [4, 2, [3, 5, 1, 3, 4, 7], 8], 5])`

get some turtles to draw

Spawn some turtles, point them in different directions, get them to draw a little and then spawn again...

Try out tree_burst.py

Notice that **tree_burst** returns **NoneType**: we use it for its side-effect (drawing on a canvas) rather than returning some value.

nested_contains

Return whether a list, or any of its sublists, contain some non-list value.

- should return True if any element is equivalent to value
- should return True if any element is a list ultimately containing value
- Python **any** and functional **if** are useful

```
<expression 1> if <condition> else <expression 2>
```

If the condition is true, evaluates to the first expression, otherwise evaluates to the second expression.

base case, general case

You will have noticed that a recursive function has a conditional structure that specifies how to combine recursive subcalls (general case), and when/how to stop (the base case, or cases).

What happens if you leave out the base case?