12th Oct 2020

Studio 9
Env Model, Arrays and Loops

CS1101S AY20/21 SEM 1
Studio 03A

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Studio X

Agenda

- Admin
- Recap:
  - Arrays
  - Loops
  - Environment models
- Studio sheet
- In-class studio sheet

Recap

Recap: Arrays

Recap
Arrays

- What are arrays?
  - A data structure that stores a sequence of elements
    - Elements can be of different types
  - Similar to lists, but do not have idea of head or tail
  - Accessed using integer index, in O(1) time (random access)
    - 0 <= index <= length - 1

Recap

Arrays

- `const arr = [1, 2, 3];  // declare a new array of 3 elements`
- Accessing arrays:
  - `arr[0];    // 1`
  - `arr[100];  // undefined`
- Finding the size of array:
  - `array_length(arr);  // 3`

Recap

Arrays

- `const arr = [1, 2, 3];  // declare a new array of 3 elements`
- Mutating array elements:
  - `arr[1] = 4;  // [1, 4, 3];`
  - `arr[1];      // 4`

Recap
Arrays

- `const arr = [1, 2, 3];  // declare a new array of 3 elements`
- Appending to end of array:
  - `arr[3] = 999;`
  - `arr;  // [1, 4, 3, 999]`
  - `trick: ` `arr[array_length(arr)] = newElement;` `  // how does this work?`
- What if we want to append to position 50?
  - `arr[50] = 999;  // [1, 2, 3, , , , …, 999]`

Recap

Arrays

- `const arr = [1, 2, 3];  // declare a new array of 3 elements`
- Note: index starts at 0 !!!!!!!!!!
  - if we have an array `[1, 2, 3]`
    - number 1 is at index 0
    - number 2 is at index 1
    - number 3 is at index 2
  - be careful of “off-by-one” errors!

Recap

Arrays - Matrices

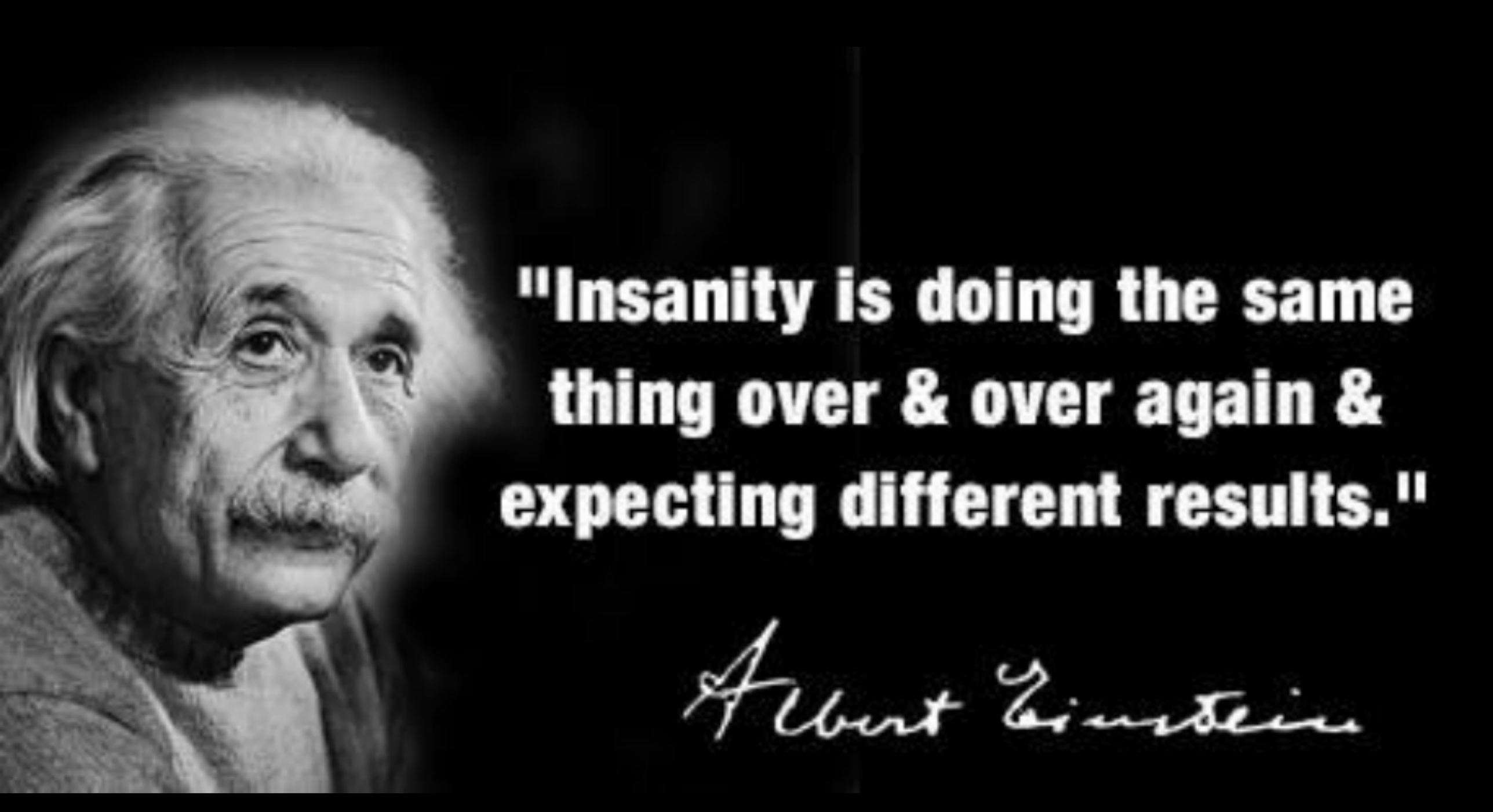
- Matrices:
  - an array of arrays (extension: array of matrices, matrices of matrices)
  - recall: list of lists!
- `const matrix = [ [1, 2, 3], [4, 5, 6], [7, 8, 9] ];`
- `matrix[0];     // [1, 2, 3]`
- `matrix[0][1];  // 2`
  - recall: applicative order reduction

Any questions?

Recap: Loops

Recap
Loops

- What are loops?
  - An expression (more accurately its an instruction)
  - Repeats itself for a certain number of iterations
  - Ends when some condition is reached
    - Checks for this condition at every iteration


"Insanity is doing the same thing over & over again & expecting different results."
Albert Einstein

Recap
Loops - While

- While loops:
  - Loops that repeat itself as long as the conditional expression is true
- Structure:

```
while (<condition>) {
    // do stuff
}
```

Recap
Loops - While

- An example:

```
let i = 0;

while (i < 10) {

    display(i);

    i = i + 1;  // recall: re-assignment

}


// displays 0, 1, 2, … 9
```

Recap
Loops - While

- Another example:

```
while (true) {
    display(“hello”);
}


// runs forever (at least theoretically)
```

credits:
r/ProgrammerHumor

Recap
Loops - for

- For loops:
  - A loop that repeats for a preset number of times
- Structure:

```
for (<initialisation>; <condition>; <re-assignment>) {
    // do stuff
}
```

Recap
Loops - for

- An example:

```
for (let i = 0; i < 10; i = i + 1) {
    display(i);
}


// displays 0, 1, 2, … 9
```

Recap

Loops - for

```
for (let i = 0; i < 10; i = i + 1) {
    display(i);
}
```

- How this works:
  1. declare i = 0
  2. check if i is less than 10
  3. execute body (displays value of i)
  4. re-assign i
  5. repeat steps 2 to 4

Recap
Loops - for

- Discussion:
  - Write this in terms of a while loop.

```
let x = 0;

for (let i = 10; i > 0; i = i - 1) {

    x = x * x;

}
```

Recap
Loops - for

- Answer:

```
let x = 0;

let i = 10;

while (i > 0) {

    x = x * x;

    i = i - 1;

}
```

```
let x = 0;

for (let i = 10; i > 0; i = i - 1) {

    x = x * x;

}
```

`for (let i = 0; i < 5; i = i + 1)`

credits:
r/ProgrammerHumor

Recap
Loops

- Cautions:
  - The loop will NOT run when the condition fails
  - Be careful of “off-by-one” errors… (again)
  - Do NOT try to assign the control variable in the loop body
    - `for (let i = 0; i < 10; i = i + 1) { i = i - 1; }`

Recap
Loops

- What are the differences?
  - While loops state explicitly the conditions for the loop to run
    - You can use compound conditions using `| |` and `&&`
  - For loops usually specify the number of iterations

Recap
Loops

- When to use which?
  - Intuitively:
    - For - when we know how many iterations we need to do
    - While - when we are unsure of how many iterations we need to do
  - If you are advanced:

```
function list_length_loop(xs) {
    let count = 0;
    for (let p = xs; !is_null(p); p = tail(p)) {
        count = count + 1;
    }
    return count;
}
```

Recap

Loops - Keywords

- We can use certain keywords to control the logic flow of loops:
  - `break` and `continue`
  - Can be used for both for-loops and while-loops

Recap

Loops - Keywords - Continue

- Continue - what does it do?
  - Continue… to the next iteration
  - Skips whatever’s below this statement

Recap

Loops - Keywords - Continue

- An example:

```
for (let i = 0; i < 10; i++) {
    if (i == 7) {
        continue;
    } else {
        display(i);
    }
}
```

Result:

1
2
3
4
5
6
8
9

Recap

Loops - Keywords - Break

- Break - what does it do?
  - Break… out of the loop
  - Terminates the loop entirely, no matter which iteration it is
- A personal note from me:
  - I don’t like to use breaks since you can add conditions into the while loop header
  - Also it kind of disrupts the flow of logic

Recap

Loops - Keywords - Break

- An example:

```
for (let i = 0; i < 10; i++) {
    if (i == 7) {
        break;
    } else {
        display(i);
    }
}
```

Result:

1
2
3
4
5
6

Recap
Loops - Keywords

- A personal note from me:
  - I don’t like to use breaks since you can add conditions into the while loop header
  - I also don’t like to use continue since you can always add an if-else with an empty else block
  - Also they kind of disrupt the flow of logic :’)
- Should you use?
  - If you know how they work then go ahead!

Recap
Loops - Keywords

- Should you use?
  - If you know how they work then go ahead!
  - But make sure you can trace and debug your programme

Recap
Loops

- Question: How long should a loop last?
- Answer: for a while!

Any questions?

Recap: Arrays and Loops

Recap
Arrays and Loops

- With loops, we can traverse an array
  - Wait… what's traverse?
  - Basically: visiting a specific sub-set of the array
    - Entire array, or
    - From index 0 to 2, or
    - Just index 1

Recap
Arrays and Loops

- An example:

```
const arr = [0, 1, 2, 3];

for (let i = 0; i < array_length(arr); i = i + 1) {

    display( arr[i] );

}


// prints 0, 1, 2, 3 each on a new line
```

Recap
Arrays and Loops

- Another example:

```
const arr = [[0, 1, 2, 3], [4, 5];
for (let i = 0; i < array_length(arr); i = i + 1) {
    for (let j = 0; j < array_length(arr[i]); j = j + 1) {
        display( arr[i][j] );
    }
}
// visiting nested arrays using nested loops
// prints 0, 1, 2, 3, 4, 5 each on a new line
```

Recap

Arrays and Loops

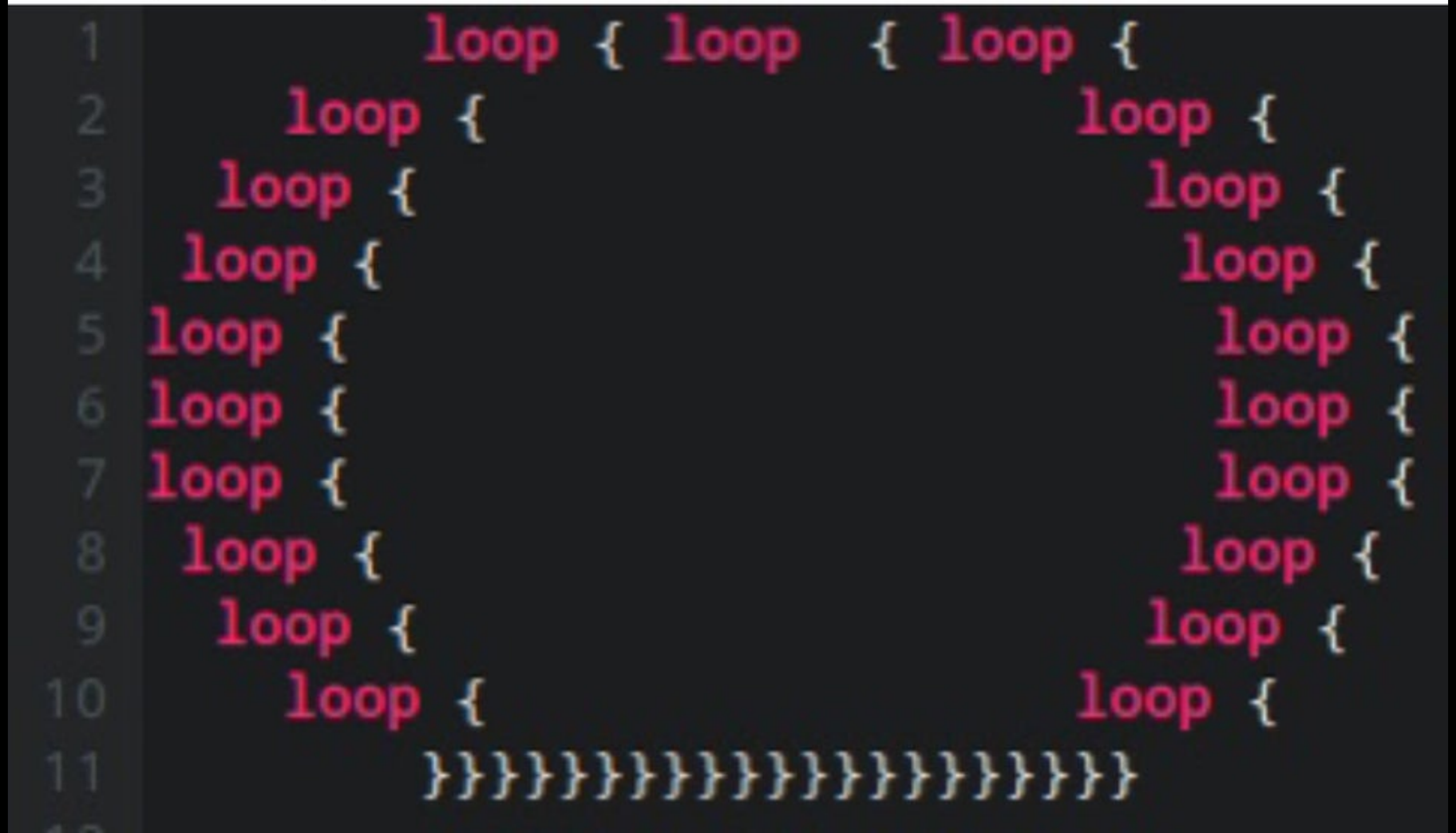
- Takeaway:
  - We can visit every element in an array of some size with loops
  - We can nest arrays in arrays
  - We can also nest loops in loops

Recap
Arrays and Loops

- Thinking question:
  - Recall binary search on lists and quick sort on lists
  - Now, try to implement:
    - Binary search for arrays
    - Quick sort on arrays
- Hand-write your programme and NO GOOGLING!

Therapist: loop loops aren't real, they can't hurt you.

Loop loops:



credits:
r/ProgrammerHumor

Any questions?

Recap: Environment Model

Recap
Environment Model

- Why?
  - With states, the substitution model breaks down
- What’s an environment?
  - A sequence of frames that store name bindings

Recap

Environment Model - Frames

- What are frames:
  - A table of bindings
    - Associate variable names and the corresponding values
    - aka: shows key-value pairs

Recap
Environment Model - Frames

- An example:

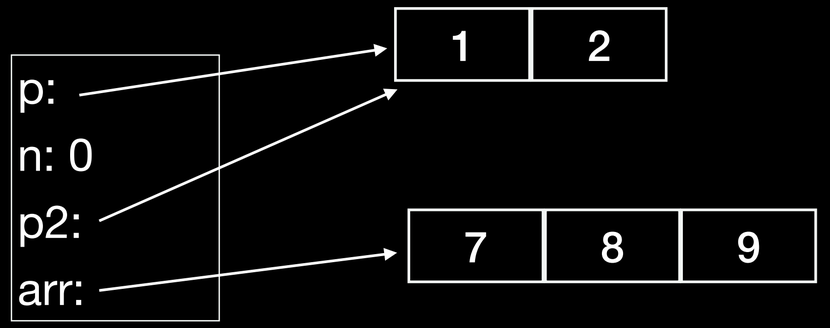
```
{
  let a_number = 0;
  const a_bool = true;
  let a_str = “hello world!”;
}
```

a_number: 0
a_bool := true
a_str: “hello world!”

Recap
Environment Model - Frames

- Another example

```
{
  let p = pair(1, 2);
  let n = 0;
  let p2 = p;
  let arr = [7, 8, 9]
}
```



Recap

Environment Model - Frames

- Note:
  - For variables, use ` : `
  - For constants: use ` := `

Recap

Environment Model - Environment

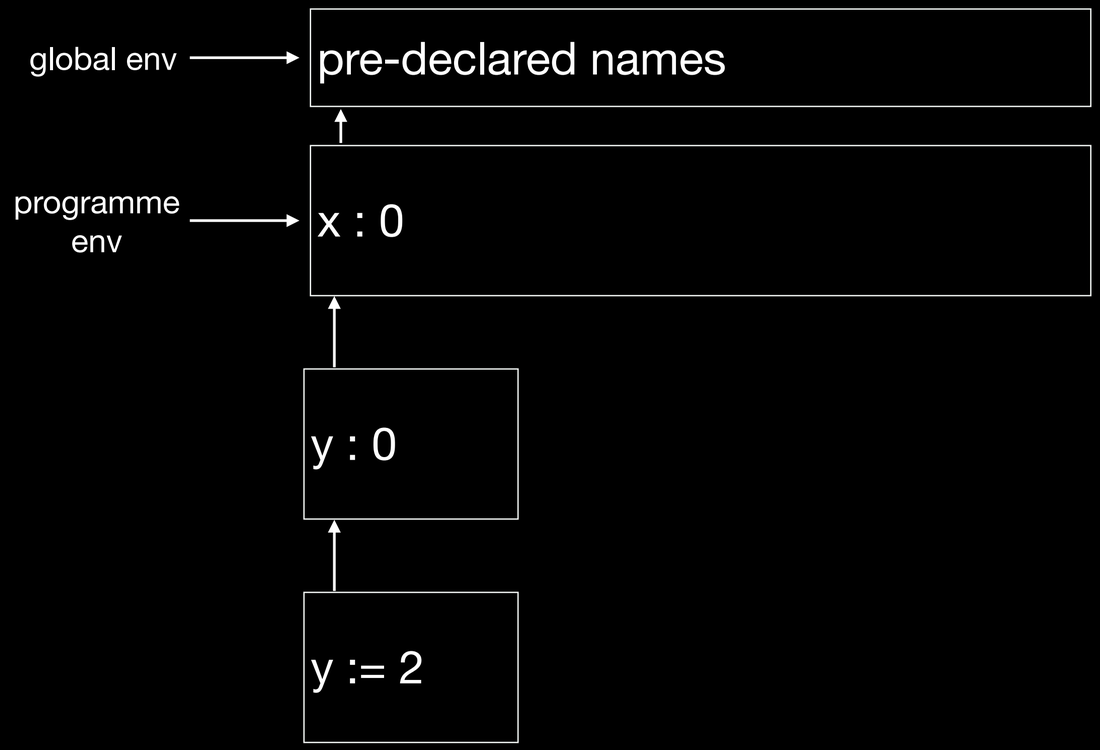
- What’s an environment:
  - A sequence of frames
  - Each frame has a pointer to its enclosing environment (except the global frame)
  - Two special frames:
    - global: contains all pre-declared stuff (primitive values and functions)
    - programme: top level declarations

Recap

Environment Model - Environment

- An example:

```
const x = 0;
{
    let y = 0;
    {
        const y = 2;
    }
}
```

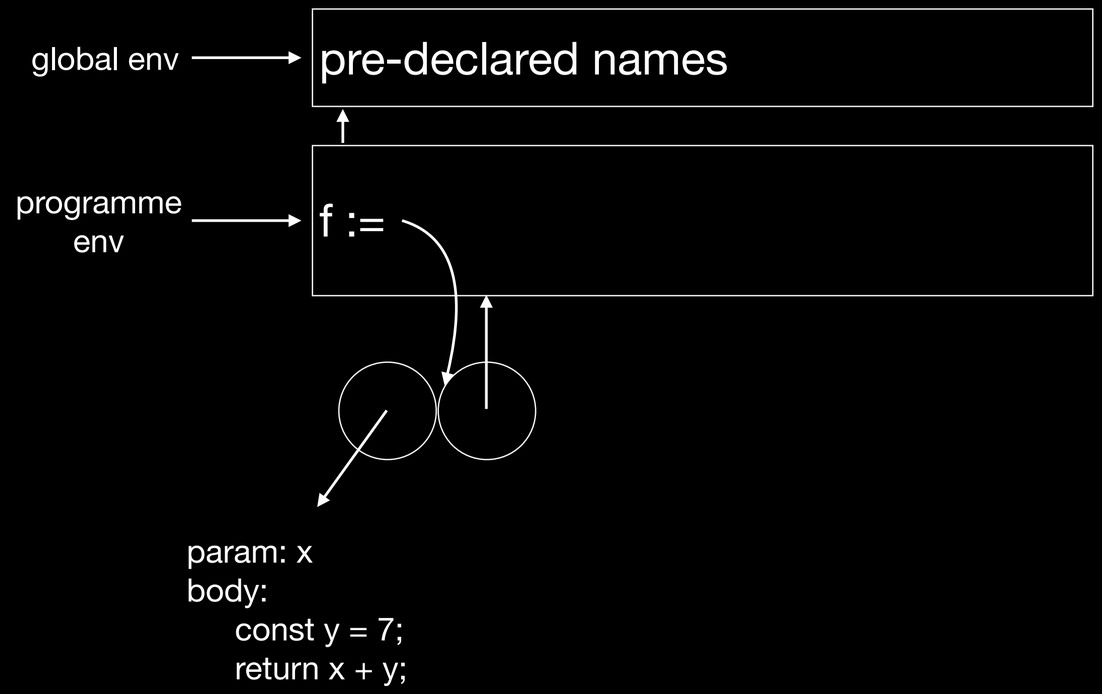


Recap

Environment Model - Environment

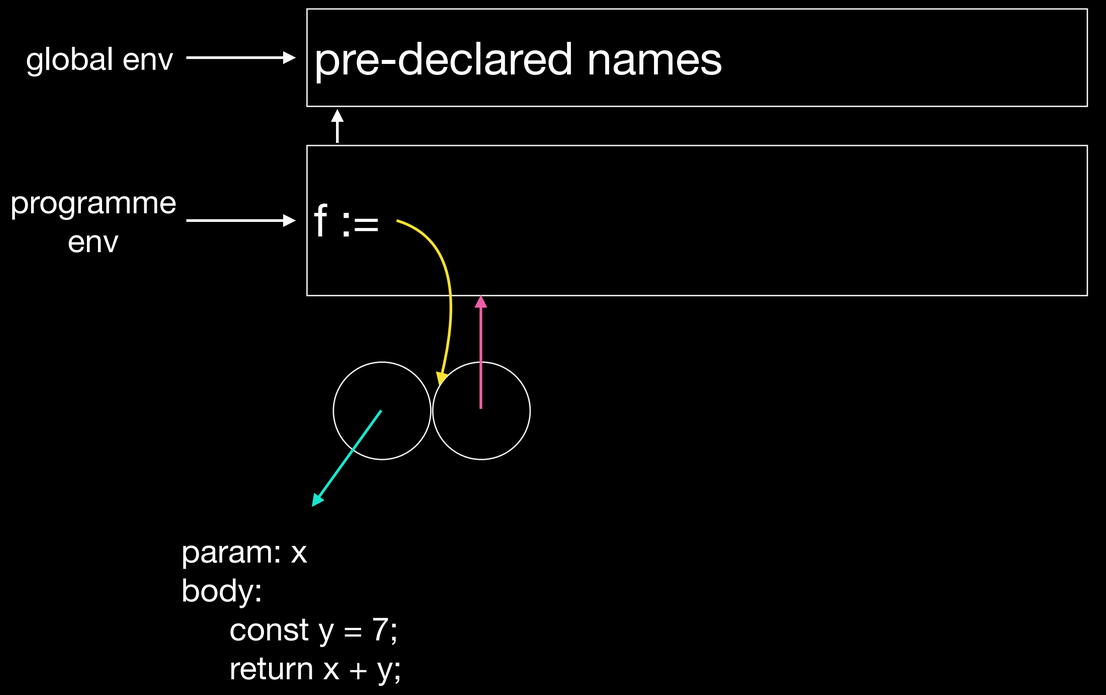
- Another example:

```
function f(x) {
    const y = 7;
    return x + y;
}
```



Recap

Environment Model - Functions



- Function declarations: “googly eyes”
  - yellow arrow:
    - reference to function obj
  - cyan arrow:
    - param and body
  - magenta arrow:
    - environment in which the function is declared and should be evaluated
- Note: cyan and magenta arrows may not be from the same frame!

Recap

Environment Model - Functions

- Function declarations:
  - Do not draw boxes for declarations!
- Differentiate between function declarations and applications
  - Declarations: googly eyes
  - Applications: create new frames
- Tip:
  - Write “…” for param and body during exam as long as it’s not ambiguous

Recap
Environment Model - Functions

- Function applications:
    1. Evaluate argument expressions (applicative order reduction)
    2. Identify environment where function should be evaluated from (the right eyeball arrow)
    3. Extend from that environment and create a new frame (A)
    4. In the new frame (A), bind the parameter name to argument value
    5. If there are declarations in the function body, extend from frame A and bind the declarations
    6. Evaluate the function and update parent frames if necessary

Recap
Environment Model - Functions

- An example:

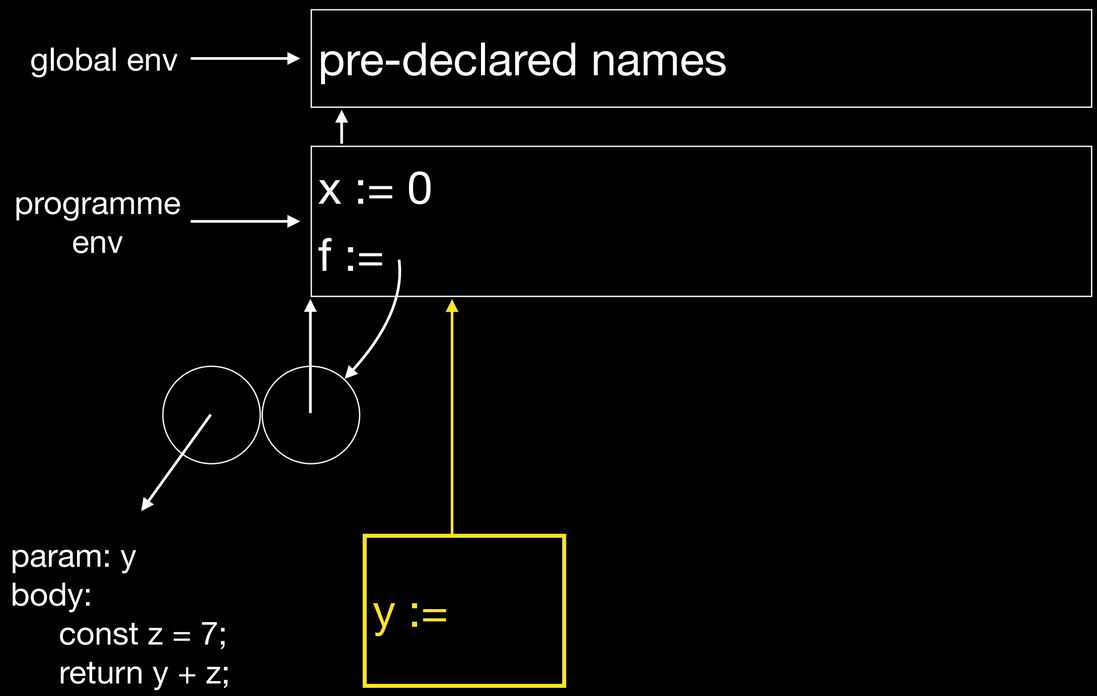
```
const x = 0;

function f(y) {
    let z = 7;
    return y + z;
}

if (x < 10) {
    const y = f(x);
} else {}
```

Recap

Environment Model - Functions

- An example:

```
const x = 0;

function f(y) {
    let z = 7;
    return y + z;
}
if (x < 10) {
    const y = f(x);
} else {}
```



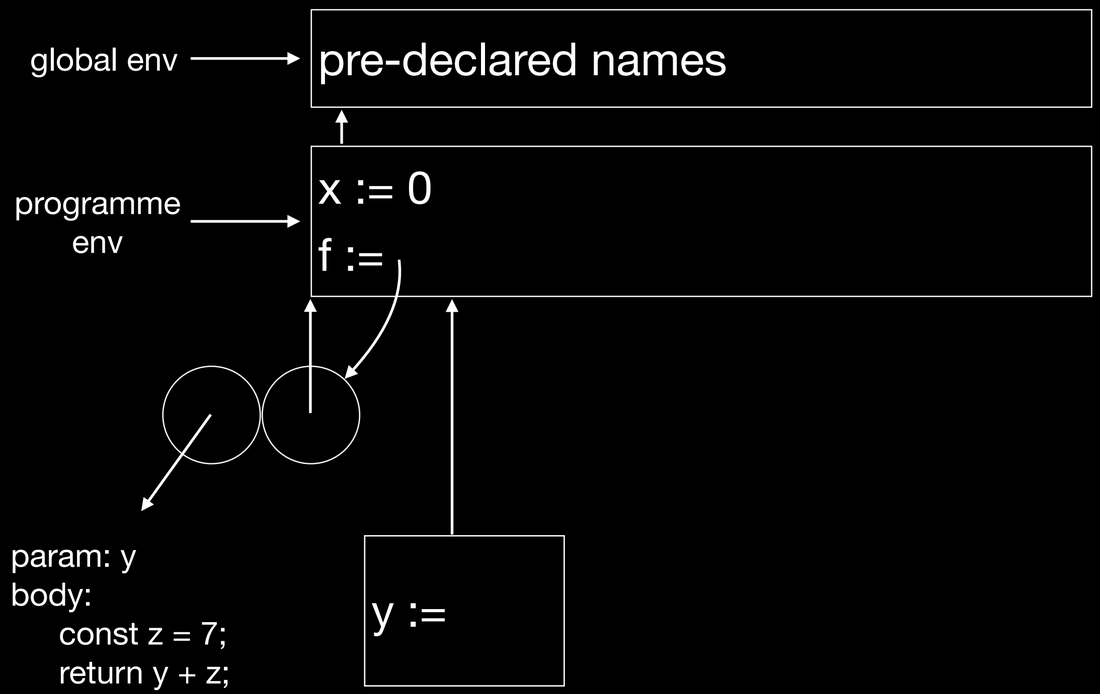
Step 0: create new frame for block with declaration of `y`

Recap

Environment Model - Functions

- An example:

```
const x = 0;

function f(y) {
    let z = 7;
    return y + z;
}

if (x < 10) {
    const y = f(x);
} else {}
```



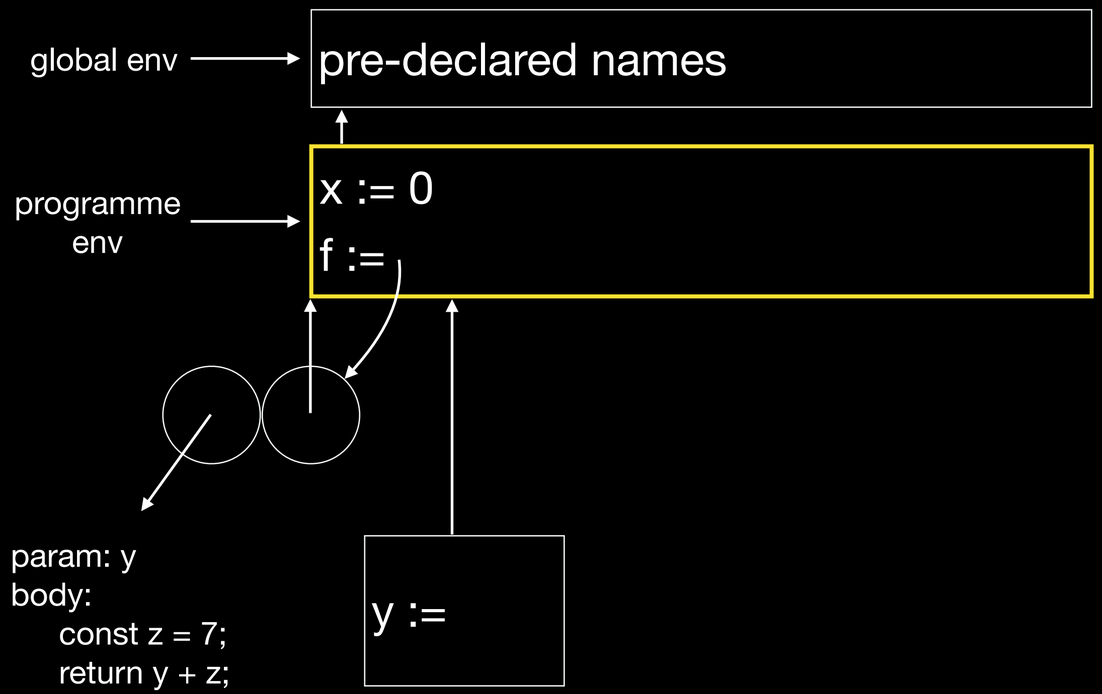
Step 1: evaluate function arguments: x = 0
(this is not shown here)

Recap

Environment Model - Functions

- An example:

```
const x = 0;

function f(y) {

    let z = 7;

    return y + z;

}

if (x < 10) {

    const y = f(x);

} else {}
```



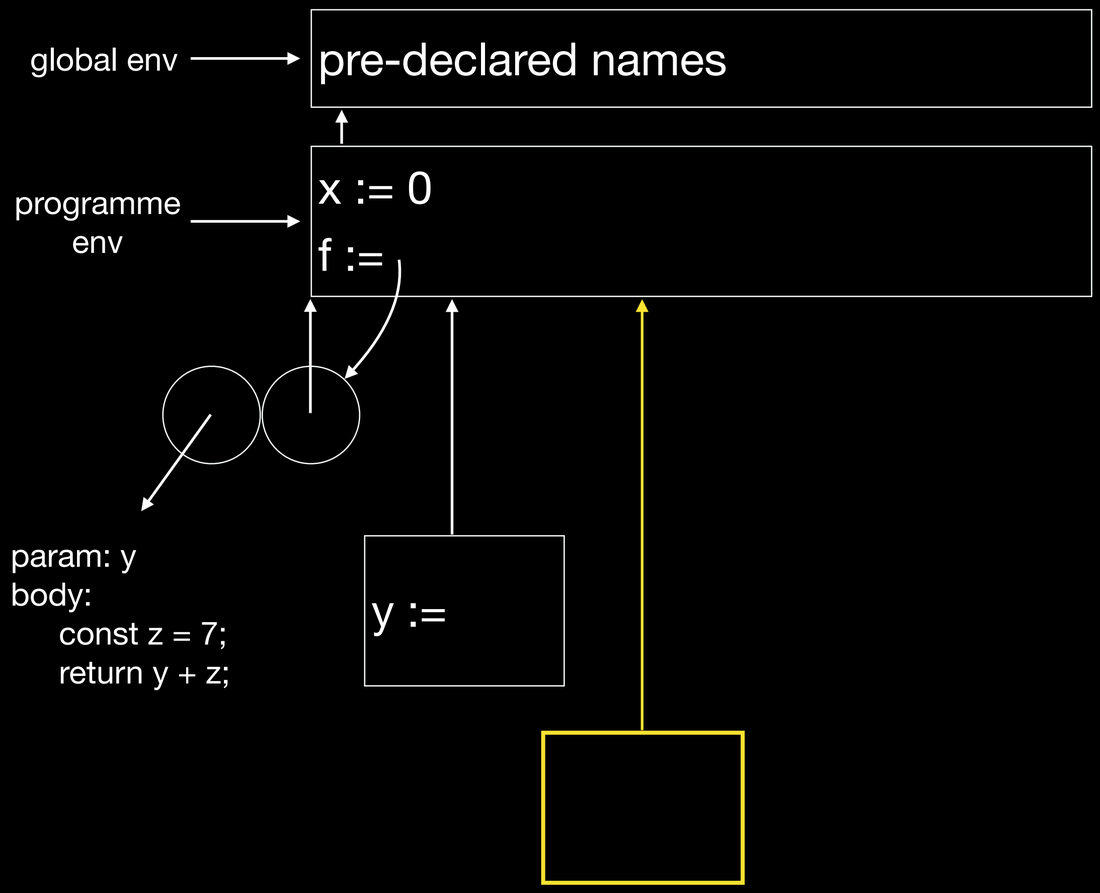
Step 2: identify frame that f was declared in (programme env)

Recap

Environment Model - Functions

- An example:

```
const x = 0;

function f(y) {

    let z = 7;

    return y + z;

}

if (x < 10) {

    const y = f(x);

} else {}
```



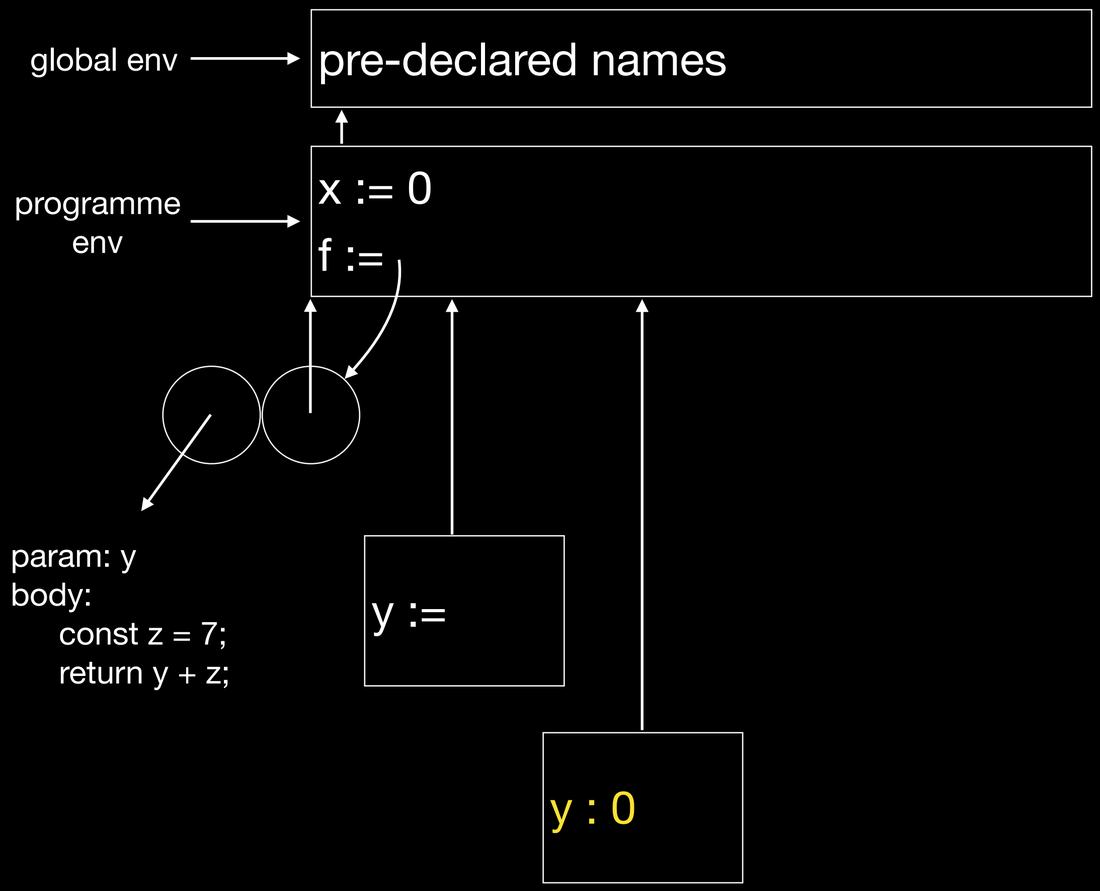
Step 3: extend environment and create a new frame

Recap

Environment Model - Functions

- An example:

```
const x = 0;

function f(y) {
    let z = 7;
    return y + z;
}

if (x < 10) {
    const y = f(x);
} else {}
```



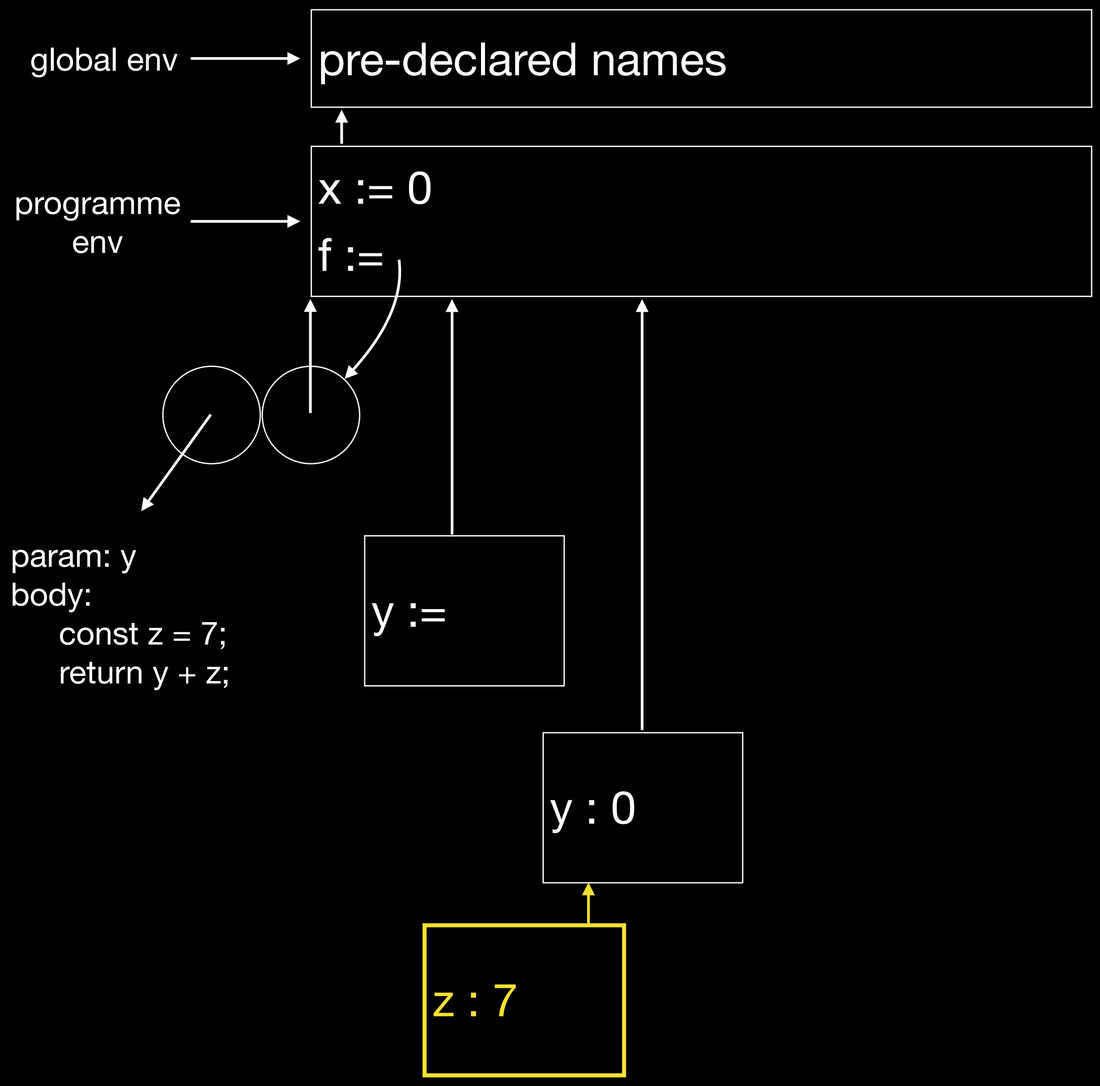
Step 4: bind parameter name to argument value

Recap

Environment Model - Functions

- An example:

```
const x = 0;

function f(y) {
    let z = 7;
    return y + z;
}

if (x < 10) {
    const y = f(x);
} else {}
```



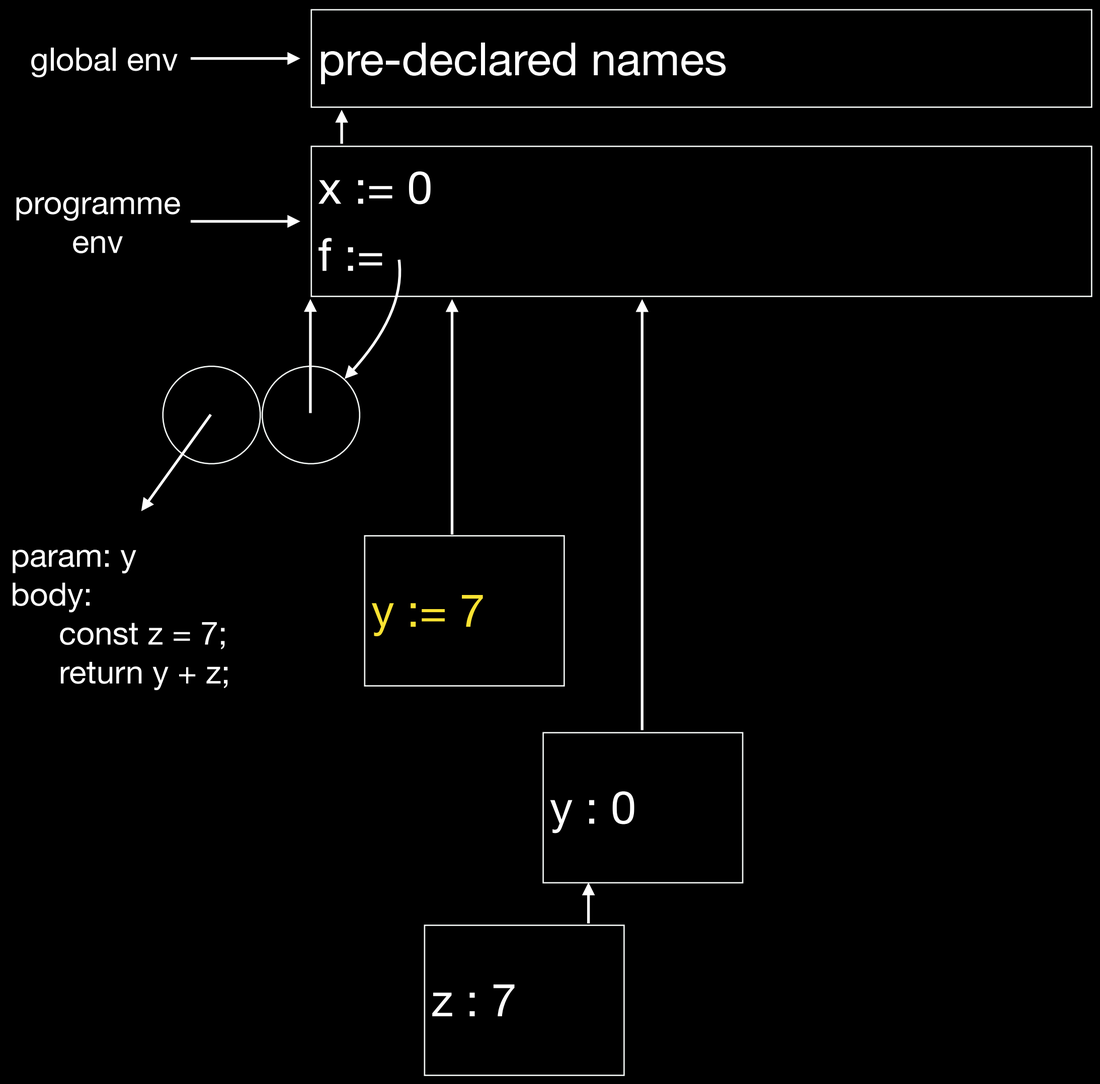
Step 5: bind declarations

Recap

Environment Model - Functions

- An example:

```
const x = 0;

function f(y) {
    let z = 7;
    return y + z;
}

if (x < 10) {
    const y = f(x);
} else {}
```



Step 6: evaluate and update

Recap

Environment Model - Functions

- When to create new frames?
  - Recall: frames are created to represent name-value bindings
  - Hence, we create frames when there are declarations!
    - If the block has a declaration, extend current environment and add a new frame containing those bindings
    - Else, don’t create frames
  - An example: if the programme has no declarations at all, the “programme env” will not be created at all!

Recap

Environment Model - Functions

- An example: if the programme has no declarations at all, the “programme env” will not be created at all!

```
{

    display(“hello world!”);

}



// does not create the programme env
```

Recap
Environment Model

- Shortcomings:
  - The environment model doesn’t tell us where the function is called from
    - Only where it should be evaluated in
  - We need to keep track of what the argument value is, and the return value of the function
  - The environment model can’t tell you whether a name is redeclared

Any questions?

End of Recap

End of File