Mutability and advanced control structures

Jia Xiaodong

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  - A machine he devised to abstract "computation through a purely mechanical process".

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- Church, 1936: λ-calculus.
  - Functions can be defined.
  - Functions can be called.
- Turing, 1936 (later): Turing machines.
  - A machine he devised to abstract "computation through a purely mechanical process".
  - Consists of a memory tape, a head, a machine state, and a function that makes decisions.

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- Computers nowadays mostly are in the style of the von Neumann architecture.
- Most programming languages have a way to mutate data.
- Most data structures and algorithms also mutate data.
- We would also like to mutate data, then.

Mutability

- `const` constant declaration.

[1] See lecture notes for pitfalls.

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- `let` *variable* declaration.

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Mutability

- `const` constant declaration.
- `let` *variable* declaration.
- Mutability leads to more complicated reasoning.[1]. Yet if done right, is more "natural" to work with.

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Arrays

The Array

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Q: `arr[0] = ?, arr[1] = ?, arr[2] = ?`

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

Q: `arr[4] = ?`

Arrays

The Array

The array is initialized with a list of comma delimited items within square brackets. The items are 0-indexed. Elements can be accessed with the dereference operator `[]`.

Example

```
let arr = [1, 2, 3, 4];
arr[0] = 1, arr[1] = 2, arr[2] = 3
arr[4] = undefined
```

Arrays

Insertion

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Example

```
let arr = [1, 2, 3, 4];
arr[3] = 3; arr[4] = 4; arr[6] = 6;
```

Q: `arr = ?`

Arrays

Insertion

We can insert or modify any element by simply dereferencing it and setting it.

Example

```
let arr = [1, 2, 3, 4];
arr[3] = 3; arr[4] = 4; arr[6] = 6;
```

```
[1, 2, 3, 3, 4, undefined, 6]
```

While loops

Definition

A while loop is made as such:

```
while (expression) {
    statements
}
```

This is something like `expression ? statements : undefined`, over and over again.

For loops

Definition

A for loop is made as such:

```
for (expr a; expr b; expr c) {
    statements
}
```

This is like

```
expr a;
while(expr b;) {
    expr c;
    statements;
}
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}
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This is like

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expr a;
while(expr b;) {
    expr c;
    statements;
}
```

Traversing arrays

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

Loop controls

Control statements

If you wish to escape the closest loop prematurely, use `break`. If you wish to skip one iteration immediately, use `continue`.

Question

Two nested loops:

```
while(...) {
    while(...) {
        //I am here
    }
}
```

How to break out of both loops?

Crisis

Substitution model does not work any more. We need a new way to keep track of our names!

Remember that time...

- Every new context creates a new *scope*.
- The most common context are blocks: ....
- Names in an inner scope inherit those defined outside of it.
- Names can be overridden by definitions in the current scope.
- You cannot go "into" an inner scope from an outer scope to retrieve definitions!
- **In conclusion:** To find what a name refers to, look at the current scope, and then outwards. Take the first one you come across.

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  - All whole program resides in the program environment.
  - The parent is the closest *enclosing environment*.
- Duplicate names in the same environment cannot exist.
  - However, they can be overwritten depending on the statement.
- Environments are never destroyed.
- When evaluating a name, search outwards starting from the current environment. First match is returned. Otherwise, invalid name.

S9 Q1

```
function change(x, new_value) {
    x = new_value;
}
let x = 0;
change(x, 1);
```

What is the value of `x` after evaluation?

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}
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```
function d_filter(pred, xs) {
    if (is_null(xs)) {
        return xs;
    }




}
```

S9 Q2

Write `d_filter(xs)` that acts like `filter` but modifies the list `xs` in place.

```
function d_filter(pred, xs) {
    if (is_null(xs)) {
        return xs;
    }
    else if (pred(head(xs))) {
        set_tail(xs, d_filter(pred, tail(xs)));
        return xs;
    }



}
```

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    }
    else if (pred(head(xs))) {
        set_tail(xs, d_filter(pred, tail(xs)));
        return xs;
    }
    else {
        return d_filter(pred, tail(xs));
    }
}
```

S9 Q3

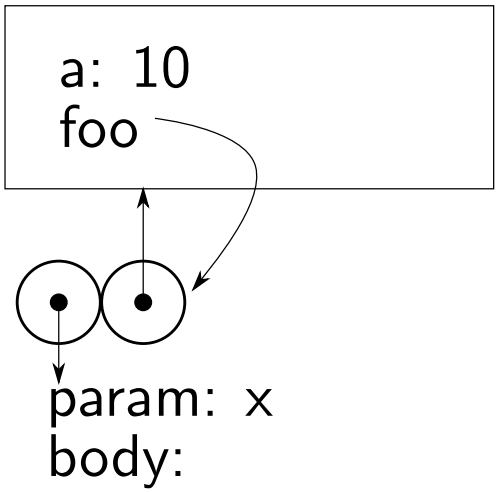
Draw the environment at the breakpoints.

```
let a = 10;
function foo(x) {
    let b = 0;
    function goo(x) {
        let a = 30;
    }
    if (x <= 2) {
        a = a + x;
        b = b + x;
        // Breakpoint #4
    } else {
        // Breakpoint #3
        goo(x - 1);
    }
    a = a + x;
    b = b + x;
    // Breakpoint #2
    goo(3);
}
// Breakpoint #1
foo(1);
// Breakpoint #5
```

S9 Q3

Breakpoint 1

```
let a = 10;
function foo(x) {
    let b = 0;
    function goo(x) {
        let a = 30;
    }
    if (x <= 2) {
        a = a + x;
        b = b + x;
    } else {
        goo(x - 1);
    }
    a = a + x;
    b = b + x;
    goo(3);
}
// Breakpoint #1
foo(1);
```



S9 Q3

Breakpoint 2

```
let a = 10;
function foo(x) {
    let b = 0;
    function goo(x) {
        let a = 30;
    }
    if (x <= 2) {
        a = a + x;
        b = b + x;
    } else {
        goo(x - 1);
    }
    a = a + x;
    b = b + x;
    // Breakpoint #2
    goo(3);
}
foo(1);
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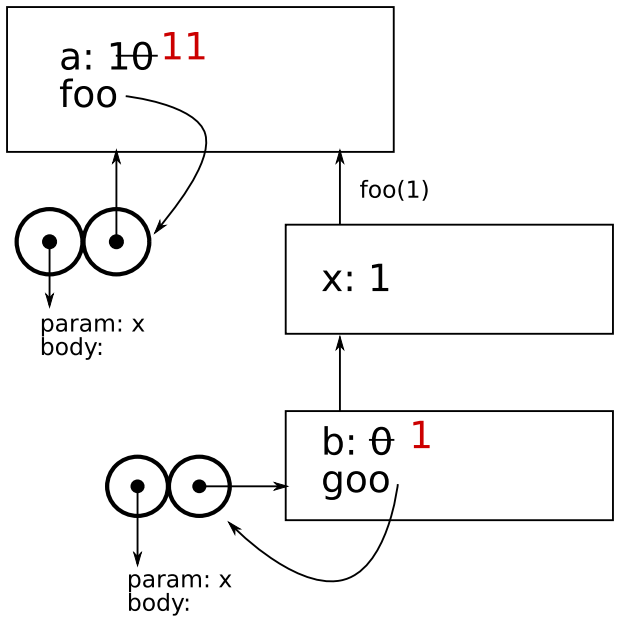

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Breakpoint 3

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let a = 10;
function foo(x) {
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    } else {
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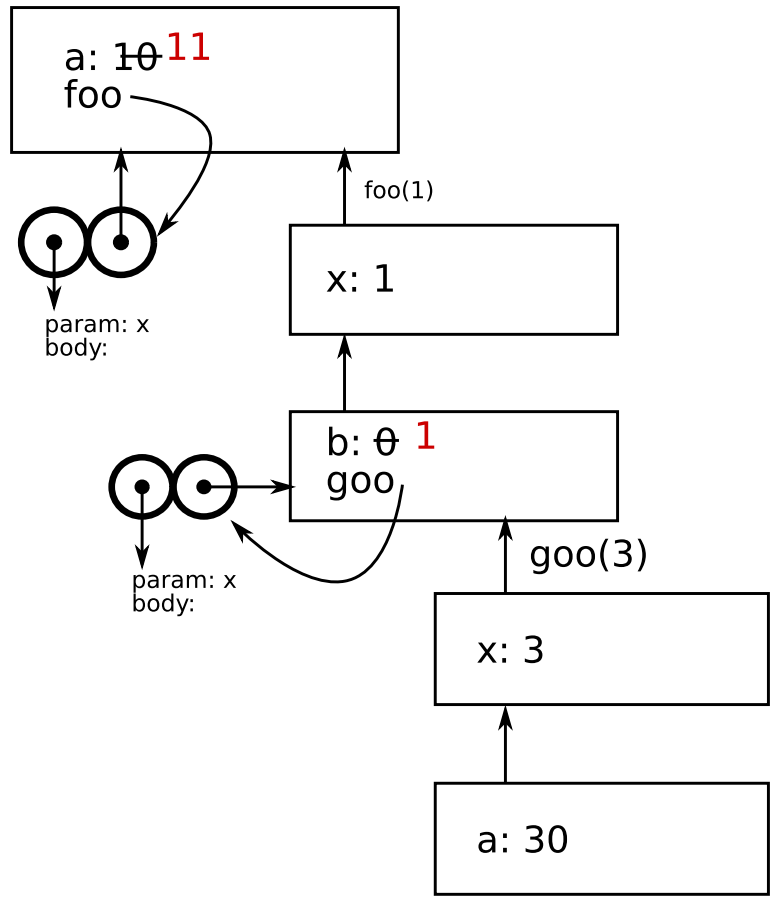

S9 Q3

Breakpoint 4

```
let a = 10;
function foo(x) {
    let b = 0;
    function goo(x) {
        let a = 30;
    }
    if (x <= 2) {
        a = a + x;
        b = b + x;
        // Breakpoint #4
    } else {
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    }
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    b = b + x;
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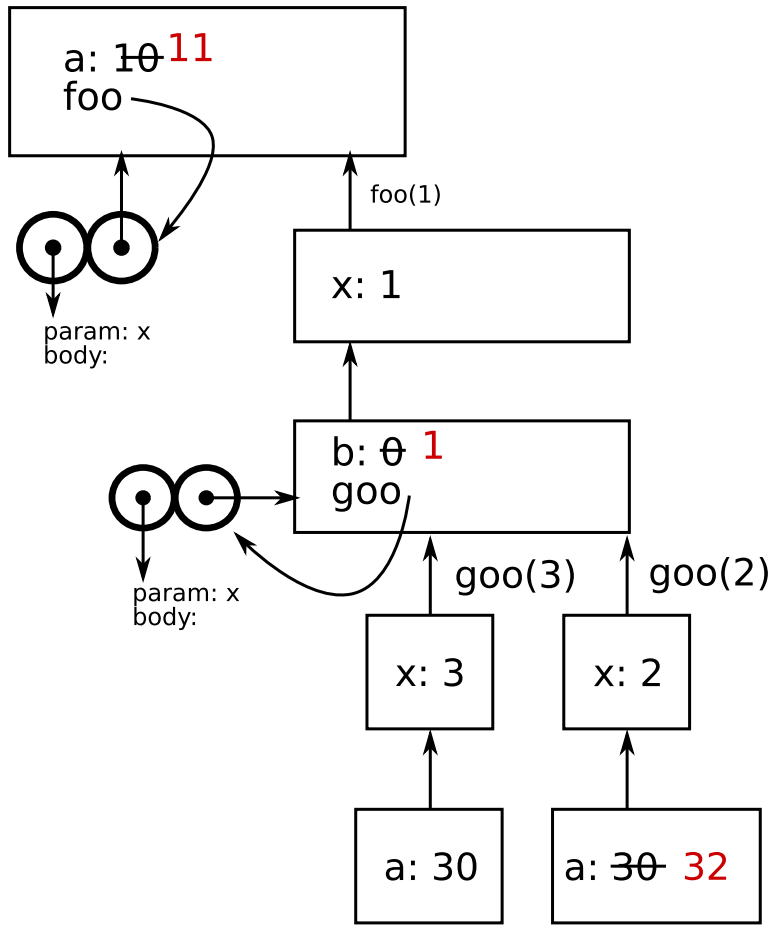

Q1

Write `d_reverse(xs)`, just like `d_filter` you did just now.

```
const L = list(1, 2, 3, 4, 5, 6);
d_reverse(L); // returns [6, [5, [4, [3, [2, [1, null]]]]]]
```

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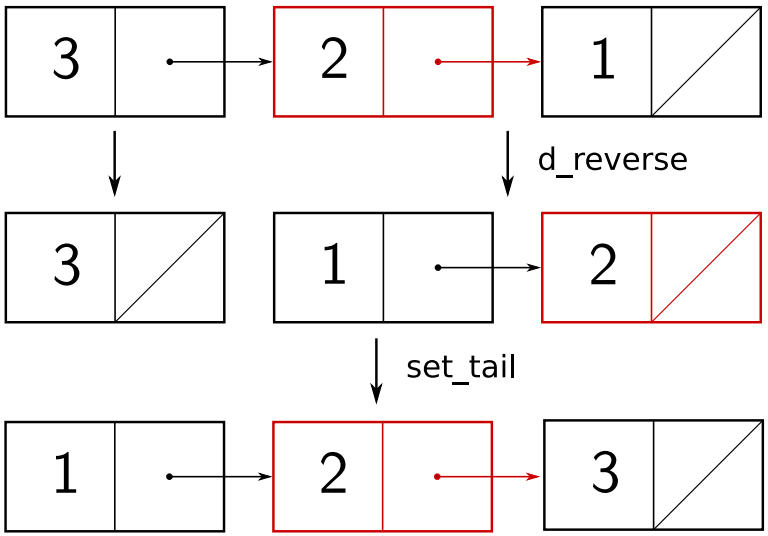

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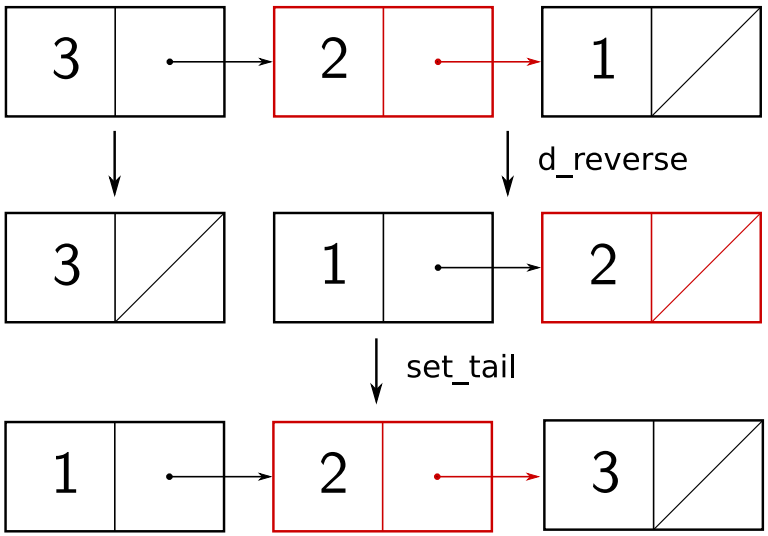


```
function d_reverse(xs) {
    if (is_null(xs) || is_null(tail(xs))) {
        return xs;
    }
    else {
        const temp = d_reverse(tail(xs));
        set_tail(tail(xs), xs);
        set_tail(xs, null);
        return temp;
    }
}
```

Q2

Ex. 3.16

Consider the following function that counts the number of pairs in a list. Give examples of lists made of 3 pairs that will cause the function to return 3, 4, 7, or never return at all.

```
function count_pairs(x) {
    if (!is_pair(x)) {
        return 0;
    } else {
        return 1 + count_pairs(head(x)) + count_pairs(tail(x));
    }
}
```

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```

```
// returns 3
const three = list(1, 2, 3);
count_pairs(three);
```

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}
```

```
// returns 3
const three = list(1, 2, 3);
count_pairs(three);

// infinite loop
const loop = list(1, 2, 3);
set_tail(tail(tail(loop)), loop);
count_pairs(loop);
```

```
// returns 4
const four_a = pair(null, null);
const four_b = pair(four_a, four_a);
const four = pair(four_b, null);
count_pairs(four);
```

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```

```
// returns 4
const four_a = pair(null, null);
const four_b = pair(four_a, four_a);
const four = pair(four_b, null);
count_pairs(four);

// returns 7
const seven_a = pair(null, null);
const seven_b = pair(seven_a, seven_a);
const seven = pair(seven_b, seven_b);
count_pairs(seven);
```