CSC 151 INTRODUCTION TO PROGRAMMING LANGUAGES

KEY - SPRING 2020 FINAL WRITTEN ASSESSMENT - KEY

Vocabulary

Categorize each of the four main languages we have worked with (Python, OCaml, C, and Java) according to the following distinctions.

a.) Statically typed vs. dynamically typed
Static: OCaml, C, Java. Dynamic: Python

b.) Object-oriented vs. non-object-oriented
Object-oriented: Python, OCaml, Java. Non-object-oriented: C

c.) Active memory management vs. passive management
Active: C. Passive: Python, OCaml, Java

d.) Primarily imperative vs. primarily functional
Imperative: Python, C, Java. Functional: OCaml

Type Inference

For each OCaml value below, fill in the blank for the type annotation or else write "ill typed" if there is a type error on that line. Your answer should be the *most generic* type for the value—i.e. if **`int list`** and **`bool list`** are both possible types of an expression, you should write **`'a list`**.

The first one is done for you.

```
let z : _________ 'a list list ________ = [[]]
let a : __________ill-typed_____________ = true::false
let b : __________'a list list_________ = [] :: [] :: []
let c : __________ill-typed_____________ = begin match [] with
                                              | [] -> "foo"
                                              | h::t -> h+3
                                           end
let d : ______int list -> bool list____ = transform (fun x -> x>2)
let e : _'a list -> 'a list -> 'a list_ = fold (fun x y -> x::y)
let f : ________'a -> int_______________ = (fun x -> fun y -> x) 42
let g : _____int list list_____________ = let f x = [x] in f (f 5)
let h : _int list list -> (int -> int) list list_ = let sum x y = x+y in
                                                    transform (transform sum)
```

Note: in the above, recall our definitions of transform and fold:

```
let rec transform (f : 'a -> 'b) (ls : 'a list) : 'b list =
  begin match ls with
    | [] -> []
    | h::t -> (f h) :: (transform f t)
  end

let rec fold (combine: 'a -> 'b -> 'b) (base: 'b) (l: 'a list): 'b =
  begin match l with
  | [] -> base
  | h :: t -> combine h (fold combine base t)
  end
```

Conditional Expressions

Consider the Java code below. Underline the calls to **`getVal()`** that will actually be executed when the following code runs.

```
public class Cond {
    private int value;
    public Cond(int v) {
        value = v;
    }
    public int getVal() {
        return value;
    }
    public static void main(String[] args) {
        Cond c = new Cond(7);
        if ((c.getVal()<8)&&(c.getVal()>6)) {
            System.out.println(c.getVal());
        }
        c = new Cond(5);
        if ((c.getVal()<8)||(c.getVal()>6)) {
            System.out.println(c.getVal());
        }
        c = new Cond(3);
        if ((c.getVal()>8)&&(c.getVal()<6)) {
            System.out.println(c.getVal());
        }
        c = new Cond(6);
        if ((c.getVal()>8)||(c.getVal()<6)) {
            System.out.println(c.getVal());
        }
        c = new Cond(2);
        if (((c.getVal()>8)||(c.getVal()<6))&&((c.getVal()<5)||(c.getVal()<9))) {
            System.out.println(c.getVal());
        }
        c = new Cond(8);
        if (((c.getVal()>2)&&(c.getVal()<6))||(c.getVal()>4)||(c.getVal()<3)) {
            System.out.println(c.getVal());
        }
    }
}
```

Iteration

Consider the pseudocode below in answering the questions that follow. Assume that the value of **n** has been set previously. It may have any integer value.

```
i = 0
print i
while i < n do
    i = i+1
    print i
end
```

This turned out to be the most difficult question on the exam. Most people correctly figured out the ending condition, making sure that their loops printed numbers up to and including n. However, you also need to pay attention to the beginning of the loop. The code given will print only 0 when n = 0. Many of the responses to this question had two print statements before the first continuation test, meaning that they would always print at least two numbers regardless of the value of n.

a.) Rewrite to get the same behavior using **repeat…until**

```
i = 0
repeat
    print i
    i = i+1
until i >= n
```

b.) Rewrite to get the same behavior using **do…while**

```
i = 0
do
    print i
    i = i+1
while i < n
```

c.) Rewrite to get the same behavior using a Python-style **range** loop

```
for i in range(0,6):
    print i
```

d.) Rewrite to get the same behavior using a **while true do…** loop with a mid-loop **break** to exit.

```
i = 0
while true do
    print i
    if i >= n then break
    i = i+1
end
```

Subtypes

Consider the code on the following page in answering the questions below.

a.) What are the subtypes of Alpha? *Epsilon, Lambda*
b.) What are the subtypes of Beta? *Zeta, Iota, Theta, Kappa*
c.) What are the subtypes of Gamma? *Zeta, Theta, Lambda*
d.) What are the subtypes of Delta? *Eta, Iota, Theta, Lambda, Kappa*
e.) What are the supertypes of Theta? *Beta, Gamma, Delta, Zeta*
f.) What are the supertypes of Lambda? *Alpha, Gamma, Delta, Epsilon*

```
class Alpha {
    // details omitted
}

class Beta {
    // details omitted
}

interface Gamma {
    // details omitted
}

interface Delta {
    // details omitted
}

class Epsilon extends Alpha {
    // details omitted
}

class Zeta extends Beta implements Gamma {
    // details omitted
}

class Eta implements Delta {
    // details omitted
}

class Theta extends Zeta implements Delta {
    // details omitted
}

class Iota extends Beta implements Delta {
    // details omitted
}

class Kappa extends Iota {
    // details omitted
}

class Lambda extends Epsilon implements Gamma, Delta {
    // details omitted
}
```

Computational Models

a.) The diagram below shows one state of the abstract stack machine during execution of some OCaml code. Circle all the bindings that are accessible in the current scope.

Workspace

```
let rec factTR (n: int) (a: int) :int =
    if (n == 0) then a else factTR (n-1) (n*a)
```

In OCaml, all bindings in the stack are accessible as long as they are not shadowed by a more recent binding of the same name. Only the most recent bindings for n and a (at the bottom) are accessible.

The code:

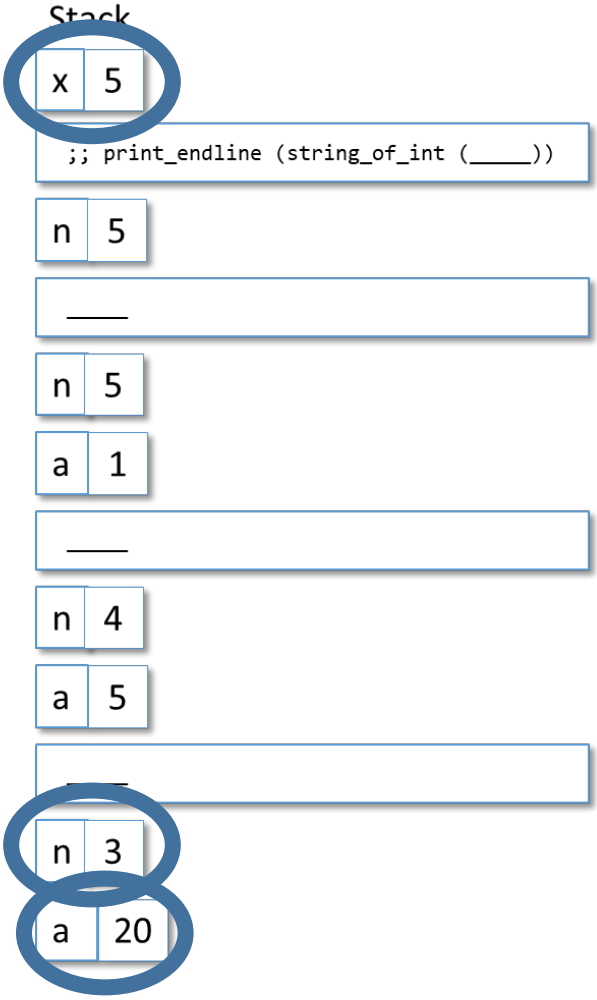
```
let x = 5

(* A function to calculate factorial *)
let rec factTR (n: int) (a: int) :int =
    if (n == 0) then a else factTR (n-1) (n*a)

(* A wrapper over factTR *)
let fact(n: int) :int =
    factTR n 1

;; print_endline (string_of_int (fact x))
```

Stack



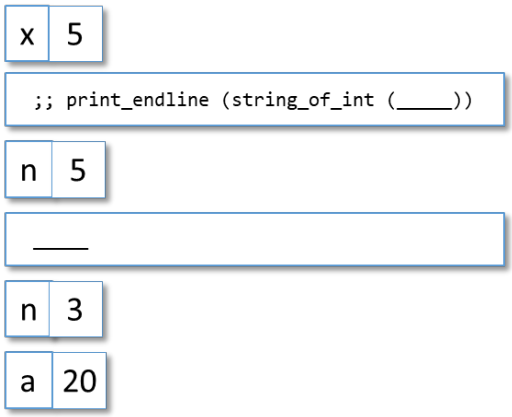
b.) If the compiler emplys a tail recursion optimization, the stack would look different. Draw the state of the stack under this assumption.

Workspace

```
let rec factTR (n: int) (a: int) :int =
    if (n == 0) then a else factTR (n-1) (n*a)
```

Under tail recursion, the stack frames for recursive calls are reused. Thus instead of three frames for factTR we have just one, the most recently called.

Stack



c.) The diagram below shows one state of the abstract stack machine during execution of some C code. The current line is underlined. Circle all the bindings that are accessible in the current scope.

Workspace

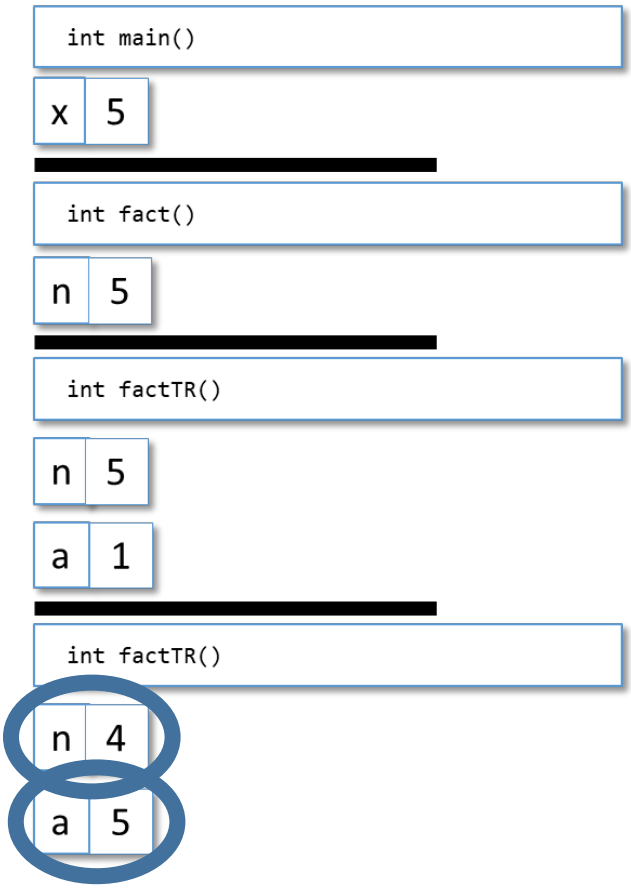
```
#include<stdio.h>

// calculate factorial
int factTR(int n, int a) {
    if (n == 0)  return a;
    return factTR(n-1, n*a);
}

// A wrapper over factTR
int fact(int n) {
   return factTR(n, 1);
}

// Driver program to test
int main() {
    int x = 5;
    printf("%d\n",fact(x));
    return 0;
}
```

Stack



In C, only the current function is in scope. Any previous bindings are inaccessible (this it the intended meaning of the thick black bar).