National University of Singapore
School of Computing
CS1101S: Programming Methodology
Semester I, 2013/2014

Recitation 4
Data Abstraction

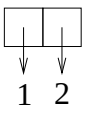
JavaScript

1. `pair(a,b)`: makes a pair from `a` and `b`
2. `head(c)`: extracts the value of the first part of the pair `c`
3. `tail(c)`: extracts the value of the second part of the pair `c`
4. `list(a, b, c, ...)`: builds a list of the arguments to the function
5. `length(list)`: returns the number of elements in `list`
6. `list_ref(lst,n)`: returns the *n*th element of `lst`
7. `append(list1,list2)`: returns a new list consisting of the elements of the first list followed by the elements of the second list. The new list is made from new pairs for the first argument; the second argument (which need not actually be a list) is merely placed at the end of the new structure.
8. `reverse(lst)`: returns new list containing the elements of `lst` in reverse order

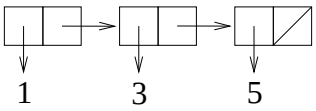
Problems:

1. Draw the box-and-pointer diagram for the values of the following expressions. Also give the representation that the JediScript Console uses.

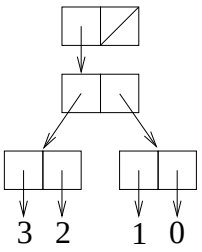
   (a) `pair(1,2) => [1, 2]`

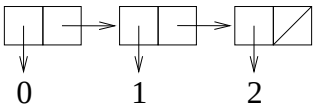
   (b) `pair(1,pair(3,pair(5,[]))) => [1, [3, [5, []]]]`

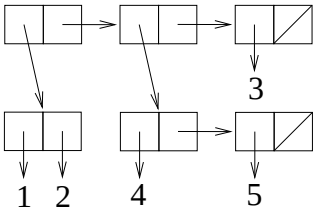
(c) `pair(pair(pair(3,2),pair(1,0)),[]) => [[[3, 2], [1, 0]], []]`



(d) `pair(0,list(1,2)) => [0, [1, [2, []]]]`



(e) `list(pair(1,2),list(4,5),3) => [[1, 2], [[4, [5, []]], [3, []]]]`



2. Write JediScript Week 5 expressions that do not use the array syntax `[...]`, whose values will print out like the following.

```
[1, [2, [3, []]]] => list(1,2,3)
[1, [2, 3]] => pair(1,pair(2,3))
[[1, [2, []]], [[3, [4, []]], [[5, [6, []]], []]]] => list(list(1,2),list(3,4),list(5,6))
```

3. Write expressions using `head` and `tail` that will return 4 when the `lst` is bound to the following values:

(a) `list(7,6,5,4,3,2,1)`

Answer:

```
head(tail(tail(tail(lst))))
```

(b) `list(list(7),list(6,5,4),list(3,2),1)`

Answer:

```
head(tail(tail(head(tail(lst)))))
```

(c)
```
list(7,
     list(6,
          list(5,
           list(4,
                list(3,
                 list(2,
                  list(1)))))))
```

Answer:

```
head(head(tail(head(tail(head(tail(lst)))))))
```

(d)
```
list(7,
     list(list(list(6,5,
                    list(list(4)),
                    3),
               2)
          ),
     1)
```

Answer:

```
head(head(head(tail(tail(head(head(head(tail(lst)))))))))
```

Note: The key idea in this question is that you have to understand how to translate an expression into a box and pointer diagram and to systematically traverse the box and pointer structure.

4. You found a holiday assignment at the Registar's Office. Your job is to write a program to help students with their scheduling of classes. You are provided with an implementation of the records for each class as follows:

```
function make_class(number,units) {
    return list(number,units);
}
var get_class_number = head;
function get_class_units(cl) {
    return head(tail(cl));
}
function make_units(lecture,tutorial,lab,homework,prep) {
    return list(lecture,tutorial,lab,homework,prep);
}
var get_units_lecture = head;
function get_units_tutorial(units) {
    return head(tail(units));
}
function get_units_lab(units) {
    return head(tail(tail(units)));
}
function get_units_homework(units) {
    return head(tail(tail(tail(units))));
}
function get_units_prep(units) {
    return head(tail(tail(tail(tail(units)))));
}
function get_class_total_units(cl) {
    var units = get_class_units(cl);
    return get_units_lecture(units) +
           get_units_tutorial(units) +
           get_units_lab(units) +
           get_units_homework(units) +
           get_units_prep(units);
}
function is_same_class(c1,c2) {
    return get_class_number(c1) ===
           get_class_number(c2);
}
```

Each class has a course code and an associated number of credit unit, e.g. for CS1101S, that's 3-2-1-3-3. Your job is now to write a schedule object to represent the sets of classes taken by a student.

(a) Write a constructor that returns an empty schedule.
Answer:

```
function empty_schedule() { return list(); }
```

It does not make sense to talk about an order of "growth" for this function because there are no arguments that may grow in size.

(b) Write a function that when given a class and a schedule, returns a new schedule including the new class.
Answer:

```
function add_class(class, schedule) {
    return pair(class, schedule);
}
```

Order of growth in time: $O(1)$, space: $O(1)$.

(c) Write a function that computes the total number of units in a schedule.
Answer:

```
function total_scheduled_units(sched) {
    if(is_empty_list(sched)) {
        return 0;
    } else {
         return get_class_total_units(head(sched)) +
                total_scheduled_units(tail(sched));
    }
}
```

Order of growth in time: $O(n)$, space: $O(n)$.

(d) Write a function that drops a particular class from a schedule.
Answer:

```
function drop_class(sched, class) {
    if(is_empty_list(sched)) {
        return sched;
    } else {
        if (get_class_number(head(sched)) ===
            get_class_number(class)) {
        return drop_class(tail(sched), class);
        } else {
            return pair(head(sched),
                        drop_class(tail(sched),
                        class));
        }
    }
}
```

Order of growth in time: $O(n)$, space: $O(n)$.

(e) Implement a credit limit by taking in a schedule, and removing classes until the total number of units is less than max_credits.
Answer:

```
function credit_limit(sched, max_credits) {
    if(total_scheduled_units(sched) > max_credits) {
        return credit_limit(tail(sched), max_credits);
    } else {
        return sched;
    };
}
```

Order of growth in time: $O(n^2)$, space: $O(n)$.

The following is an alternate solution:

```
function credit_limit(sched, max_credits) {
    function helper(s,e) {
        if(e <= 0) {
            return s;
        } else {
            return helper(tail(s),
                          e - get_class_total_units(head(s)));
        }
    }
    var total = total_scheduled_units(sched);
    var extra = total - max_credits;
    return helper(sched, extra);
}
```

Order of growth in time: $O(n)$, space: $O(n)$.

(f) **Homework 1:** Implement `total_scheduled_units` using higher-order functions `accumulate` and `map`.

(g) **Homework 2:** Implement an improved version of `credit_limit` that will return a schedule with a total number of units is less than `max_credits`, but with the maximal number of classes. What is the order of growth of your solution? Is that the best you can do?