CS 135 Fall 2016
Graham, Holtby, Petrick, Sakhnini

Assignment: 8

Due:	Tuesday, November 15, 2016 9:00pm
Language level:	Intermediate Student
Allowed recursion:	Pure structural recursion only
Files to submit:	`chart.rkt`, `funabst.rkt`
Warmup exercises:	HtDP 17.3.1, 17.6.4, 19.1.5, 20.1.1, 20.1.2, 24.0.7, 24.0.8
Practise exercises:	HtDP 17.6.5, 17.6.6, 19.1.6, 20.1.3, 21.2.3, 24.0.9

- All helper functions must be **local** definitions, unless you are using a helper function defined in a previous part of the same question.
- You are not required to provide examples or tests for **local** function definitions. You are still encouraged to do informal testing of your helper functions outside of your main function to ensure they are working properly. Functions defined at the "top level" must include the complete design recipe.
- You may define global constants if they are used for more than one part of a question. This includes defining constants for examples and tests. Constants that are only used by one top level function should be included in the **local** definitions.
- In this assignment your *Code Complexity/Quality* grade will be determined both by how clear your approach to solving the problem is, and how effectively you use local constant and function definitions. You should include local definitions to avoid repetition of common subexpressions, to improve readability of expressions and to improve efficiency of code.
- You may only use the list functions that have been discussed in the notes up to the end of Module 9, unless explicitly allowed in the question.
- You may reuse the provided examples, but you should ensure you have an appropriate number of examples and tests.
- Your solutions must be entirely your own work.
- Solutions will be marked for both correctness and good style as outlined in the Style Guide.

Here are the assignment questions you need to submit.

1. Perform the Assignment 8 questions using the online evaluation "Stepping Problems" tool linked to the course web page and available at

   https://www.student.cs.uwaterloo.ca/~cs135/stepping

   The instructions are the same as A03 and A04; check there for more information, if necessary. Reminder: You should not use DrRacket's Stepper to help you with this question, for a few reasons. First, as mentioned in class, DrRacket's evaluation rules are slightly different from the ones presented in class; you are to use the ones presented in class. Second, in an exam situation, of course, you will not have the Stepper to help you. Third, you can re-enter steps as many times as necessary to get them correct, so you might as well maximize the educational benefit.

2. This question deals with functional abstraction (except part c). Place your solution in the file `funabst.rkt`.

   (a) Write a function *and-pred* that consumes a predicate (boolean function which takes one argument) and a list, and produces *false* if the application of the consumed predicate on any element of lst produces *false*, otherwise the function produces *true*. For *empty* consumed list the function should produce *true*. For example:

   (*and-pred even? empty*) $\Rightarrow$ *true*
   (*and-pred odd?* (*list* 5 9 3)) $\Rightarrow$ *true*
   (*and-pred string?* (*list* 5 "wow")) $\Rightarrow$ *false*

   (b) In class, we have seen that we are now able to put functions into lists. What can we do with lists of functions? One thing is to apply each function in the list to a common set of inputs. Write a function *map2argfn* which consumes a list of functions (each of which takes two numbers as arguments) and a list containing two numbers. It should produce the list of the results of applying each function in turn to the given two numbers. For example,

   (*map2argfn* (*list* + - * / *list*) '(3 2)) $\Rightarrow$ '(5 1 6 1.5 (3 2))

   Note that the above list being passed to *map2argfn* has five elements, each of which is a function that can take two numbers as input. The resulting list is also of length five.

   Pay close attention to the contract for your function. Hint: you will probably discover you need to use **local** to give a function a name at one point. However, do not use either global or local helper functions in this question.

(c) Consider the data definition below.

```
;; An ASExp is one of:
;; * a Num
;; * a Sym (compliant with Racket rules for identifier)
;; * (cons Sym ASEXplist) (where Sym is either '+ or '*)

;; An ASExplist is one of:
;; * empty
;; * (cons ASExp ASExplist)

;; Association List (AL) is one of
;; * empty
;; * (cons (list Sym Num) AL)
;; All Symbols are unique.
```

By allowing ASExp to be symbol, we can construct arithmetic expression lists that contain constants. For example: '(+ 3 x (∗ y y)). Write the function *evaluate* to compute the value of an ASExp. The function consumes an ASExp and an AL, and produces the value of the expression. The AL (from symbols to numbers, where the key is Sym and the value is Num) will act as a dictionary, indicating the numeric value of each constant (matching constants names to values). Example: (*evaluate* '(+ x 4) '((x 5) (y 7))) should produce the value 9.
You may assume that each constant in the ASExp is present in the association list.
Note that apply is a defined function in Intermediate Student that does not do what you want.
You should develop your own version with your own name. Restrict your use of built-in functions to primitives such as mathematical functions, basic list functions (such as *cons*, *list*, *first*, etc. but not *append*, *reverse*, *apply*, etc.).

(d) Write a predicate function *arranged?* that consumes a (list predicate-function binary-relational-operator) pair and a list of values (operands). The predicate function in the first list is to determine the data type of the values in the second list and the binary relational operator consumes the same data type (see contract below). Note that the first list is of length 2 and the second list may be empty.
Here is a contract for *arranged?* which you may type it into your solutions (Hooray! free mark).

```
;; arranged?: (list(Any → Bool) (X X → Bool)) (listof Any) → Bool
```

The predicate *arranged?*

- produces *true* if the list of operands is *empty* or has one value and applying the predicate on it produces true.

(*arranged?* (*list integer?* <) (*list*)) ⇒ *true*
(*arranged?* (*list integer?* >) (*list* 1)) ⇒ *true*
(*arranged?* (*list integer?* >)(*list* 'red)) ⇒ *false*

- produces *false* if applying the predicate on any of the operands produces *false*

(*arranged?* (*list string? >*) (*list* "wow" 'red)) ⇒ *false*

- produces *true* if applying the predicate on every operand produces true and applying the binary relational operator on all consecutive elements of the list of operands produces true, otherwise the function produces *false*.

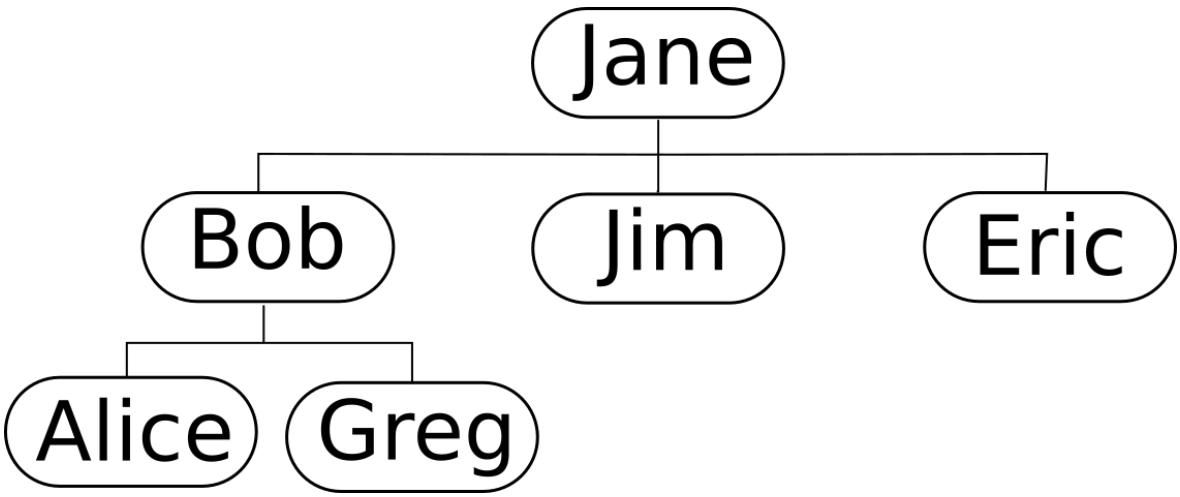
(*arranged?* (*list string? string>?*)(*list* "wow" "cs135" "amazing")) ⇒ *true*

3. Recall question 2 from A07. Here is the question specification again for your convenience. Remember that All your helper functions must be local definitions. Place your solution in the file *chart.rkt*.
   Now that the inventory has been taken care of, you must now write some functions for dealing with the bakery's growing list of employees. An organizational chart or "org chart" can be represented with a general tree. Use the following data definition:

```
(define-struct orgnode (name employees))
;; An OrgChart is a (make-orgnode Str (listof OrgChart))
;; requires: name is unique

(define my-orgchart (make-orgnode "Jane"
                                  (list (make-orgnode "Bob"
                                                      (list (make-orgnode "Alice" empty)
                                                            (make-orgnode "Greg" empty)))
                                        (make-orgnode "Jim" empty)
                                        (make-orgnode "Eric" empty))))
```

my-orgchart looks like:



Every employee **supervises** the employees directly below them in the tree, and this person is called a **supervisor** . In the example tree, Bob supervises Alice and Greg, while Jim doesn't

supervise anybody. Put differently, Bob is the supervisor of both Alice and Greg, and Jim isn't anybody's supervisor.

Every employee is **responsible** for all employees below them in the tree (directly or not). In the example tree, Jane is responsible for all other employees, while Greg is responsible for nobody.

(a) Write the function *supervised-employees* that consumes a string (an employee's name) and an OrgChart, and produces a list of the names of the employees that the consumed employee directly supervises. The produced list of strings must be in the the same order as the *employees* field.

If the consumed name is not found in the chart, the function produces *false*.

Example: (*supervised-employees* `"Bob"` *my-orgchart*) ⇒ (*list* `"Alice"` `"Greg"`)

(b) Write the function *bottom-rung* that consumes an OrgChart, and produces a list of employees that do not supervise anybody (the leaves in the OrgChart tree). The produced list can be in any order.

Example: (*bottom-rung* (*make-orgnode* `"a"` (*list* (*make-orgnode* `"b"` *empty*)))) ⇒ (*list* `"b"`)

(c) Sometimes, personal issues can get in the way of good business. These might be positive (e.g. two employees who start dating) or negative (two employees who hold strong but differing opinions in the Kirk v. Picard debate). Regardless of the source, the business has an interest in avoiding potential conflicts of interest

Write the function *conflict?* that consumes two strings (the names of two employees with a potential conflict) and an OrgChart, and produces *true* if there is a conflict of interest, and *false* otherwise. There is a conflict of interest if either both employees have the same supervisor, or if one employee is responsible for the other (one employee is below the other in the tree). You may assume that both names are in the consumed chart, and that the two names are different.

For example, in the sample tree there is a conflict between Jane and Greg (because Jane is responsible for Greg) and also between Alice and Greg (because both are supervised by Bob). There is no conflict between Jim and Greg.

This concludes the list of questions for which you need to submit solutions. Don't forget to always check your email for the public test results after making a submission.

Enhancements: *Reminder—enhancements are for your interest and are not to be handed in.*

Professor Temple does not trust the built-in functions in Racket. In fact, Professor Temple does not trust constants, either. Here is the grammar for the programs Professor Temple trusts.

⟨exp⟩ = ⟨var⟩|(**lambda** (⟨var⟩) ⟨exp⟩) | (⟨exp⟩⟨exp⟩)

Although Professor Temple does not trust **define**, we can use it ourselves as a shorthand for describing particular expressions constructed using this grammar.

It doesn't look as if Professor Temple believes in functions with more than one argument, but in fact Professor Temple is fine with this concept; it's just expressed in a different way. We can create a function with two arguments in the above grammar by creating a function which consumes the first argument and returns a function which, when applied to the second argument, returns the answer we want (this should be familiar from the *addgen* example from class, slide 09-39). This generalizes to multiple arguments.

But what can Professor Temple do without constants? Quite a lot, actually. To start with, here is Professor Temple's definition of zero. It is the function which ignores its argument and returns the identity function.

(**define** *my-zero* (**lambda** (*f*) (**lambda** (*x*) *x*)))

Another way of describing this representation of zero is that it is the function which takes a function f as its argument and returns a function which applies f to its argument zero times. Then "one" would be the function which takes a function f as its argument and returns a function which applies f to its argument once.

(**define** *my-one* (**lambda** (*f*) (**lambda** (*x*) (*f x*))))

Work out the definition of "two". How might Professor Temple define the function *add1*? Show that your definition of *add1* applied to the above representation of zero yields one, and applied to one yields two. Can you give a definition of the function which performs addition on its two arguments in this representation? What about multiplication?

Now we see that Professor Temple's representation can handle natural numbers. Can Professor Temple handle Boolean values? Sure. Here are Professor Temple's definitions of true and false.

(**define** *my-true* (**lambda** (*x*) (**lambda** (*y*) *x*)))
(**define** *my-false* (**lambda** (*x*) (**lambda** (*y*) *y*)))

Show that the expression ((*c a*) *b*), where *c* is one of the values *my-true* or *my-false* defined above, evaluates to *a* and *b*, respectively. Use this idea to define the functions *my-and*, *my-or*, and *my-not*.

What about *my-cons*, *my-first*, and *my-rest*? We can define the value of *my-cons* to be the function which, when applied to *my-true*, returns the first argument *my-cons* was called with, and when applied to the argument *my-false*, returns the second. Give precise definitions of *my-cons*, *my-first*, and *my-rest*, and verify that they satisfy the algebraic equations that the regular Scheme versions do. What should *my-empty* be?

The function *my-sub1* is quite tricky. What we need to do is create the pair $(0,0)$ by using *my-cons*. Then we consider the operation on such a pair of taking the "rest" and making it the "first", and making the "rest" be the old "rest" plus one (which we know how to do). So the tuple $(0,0)$ becomes

$(0,1)$, then $(1,2)$, and so on. If we repeat this operation n times, we get $(n-1,n)$. We can then pick out the "first" of this tuple to be $n-1$. Since our representation of n has something to do with repeating things n times, this gives us a way of defining *my-sub1*. Make this more precise, and then figure out *my-zero?*.

If we don't have **define**, how can we do recursion, which we use in just about every function involving lists and many involving natural numbers? It is still possible, but this is beyond even the scope of this challenge; it involves a very ingenious (and difficult to understand) construction called the Y combinator. You can read more about it at the following URL (PostScript document):

`http://www.ccs.neu.edu/home/matthias/BTLS/tls-sample.ps`

Be warned that this is truly mindbending.

Professor Temple has been possessed by the spirit of Alonzo Church (1903–1995), who used this idea to define a model of computation based on the definition of functions and nothing else. This is called the lambda calculus, and he used it in 1936 to show a function which was definable but not computable (whether two lambda calculus expressions define the same function). Alan Turing later gave a simpler proof which we discussed in the enhancement to Assignment 7. The lambda calculus was the inspiration for LISP, a predecessor of Racket, and is the reason that the teaching languages retain the keyword **lambda** for use in defining anonymous functions.