1. Consider the following piece of ML code:

```
let val x = 1
 in let fun f y = y + x;
   in  let val q = 2
        in let fun h z = (f z ) * q;
           in let val w = h 3 in w
               end
           end
        end
   end
end
```

   (a) What is the value of w?

   (b) Fill in the missing parts in the following diagram of the run-time structures for execution of this code up to the point where the call inside h(3) is about to return. The activation records are numbered $1-7$, from the top.

Activation Records

(1)		access link	(0)
		x	
(2)		access link	( )
		f	•
(3)		access link	( )
		q	
(4)		access link	( )
		h	•
(5)		access link	( )
		w	
(6)	h(3)	access link	( )
		z	
(7)	f(3)	access link	( )
		y	

Closures

⟨( ), • ⟩

⟨( ), • ⟩

Compiled Code

code for f
...

code for h

2. Consider the following ML program:

```
fun foo x =  let fun bar f = fn x =>  f ( f x);
             in   bar (fn y => y + x)
             end ;
```

   (a) what is the value of "foo 3 2" according to the standard (statically scoped) semantics of ML?

   Now, suppose we try to optimize the above function by first inlining the bar function

   ```
   fun foo x = fn x => (fn y => y + x) ((fn y => y + x) x);
   ```

   Substituting x for y

   ```
   fun foo x = fn x => (fn y => y + x) (x + x);
   ```

   Substituting (x + x) for y.

   ```
   fun foo x = fn x => x + x + x;
   ```

   (b) What does "foo 3 2" evaluate to using the "optimized" version of foo?

   (c) What was the mistake we made in our attempted optimization?

3. Do Exercise 7.12 from Mitchell using the following SML code:

```
let val x = 5
    in let val f = fn y => (x+y)-2
        in let val g = fn h => let val x = 7 in h x end
            in let val x = 10 in
                g f
            end
        end
    end
end
```

4. Do Exercises 7.13(b) and 7.13(c) from Mitchell using the following SML code:

```
let val x = 5
 in let fun f y =  let val z =[1,2,3]
                       fun g w = w+x+y
                         in g
                       end
    in let val h =  let val x = 7 in f 3 end
        in  h 2
        end
    end
end
```

5. (4 points) Do Exercise 7.15 from Mitchell.