Functional Programming
Exercises Week 6
(for November 22, 2013)

Numbers in parentheses refer to the 6th edition of the course notes.
Exercises marked with $\star$ are optional and can be ignored.

1. Read Chapter 5 of the lecture notes.

2. (Exercise 5.12) Use the following type for λ-terms

```
type var  = Strng.t
type term = Var of var
          | App of (term * term)
          | Abs of (var  * term)
```

to implement the functions:

```
subterms : term -> term list
vars     : term -> var list
fvars    : term -> var list
bvars    : term -> var list
```

3. (Exercise 5.13) Which of the following terms are in normal form (NF), which are in weak head normal form (WHNF)?

a) $\lambda x.x$

b) $(\lambda x.x)\ y$

c) $(\lambda x.x)\ y\ x$

d) $x\ x$

e) $\lambda x.(\lambda y.y)\ x$

4. (Exercise 5.14) Reduce $\mathsf{add}\ \overline{2}\ \overline{3}$ to WHNF, applying

a) leftmost innermost and

b) leftmost outermost

reduction.

5. (Exercise 5.23) Reduce the λ-term $\mathsf{hd}\ (\mathsf{cons}\ \overline{1}\ \mathsf{nil})$ to WHNF using the leftmost outermost strategy.

$\star$. (Exercise 5.24) Consider the infinite list of natural numbers `nats`, defined by

```
let rec from n = n :: from(n+1)
let nats       = from 0
```

Give the computation steps of `hd nats` using call-by-name. What happens using call-by-value?