**Exercises**

We're going to do the following exercises a bit differently than what you'll see in the rest of the book, as we will be providing some answers and explanations for the questions below.

**Combinators** Determine if each of the following are combinators or not.

1. $\lambda x.xxx$
2. $\lambda xy.zx$
3. $\lambda xyz.xy(zx)$
4. $\lambda xyz.xy(zxy)$
5. $\lambda xy.xy(zxy)$

**Normal form or diverge?**

Determine if each of the following can be reduced to a normal form or if they diverge.

1. $\lambda x.xxx$

2. $(\lambda z.zz)(\lambda y.yy)$

3. $(\lambda x.xxx)z$

**Beta reduce** Evaluate (that is, beta reduce) each of the following expressions to normal form. We *strongly* recommend writing out the steps on paper with a pencil or pen.

1. $(\lambda abc.cba)zz(\lambda wv.w)$

2. $(\lambda x.\lambda y.xyy)(\lambda a.a)b$

3. $(\lambda y.y)(\lambda x.xx)(\lambda z.zq)$

4. $(\lambda z.z)(\lambda z.zz)(\lambda z.zy)$

Hint: alpha equivalence.

5. $(\lambda x.\lambda y.xyy)(\lambda y.y)y$
6. $(\lambda a.aa)(\lambda b.ba)c$

7. $(\lambda xyz.xz(yz))(\lambda x.z)(\lambda x.a)$