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But we have to have repetition to have useful programs

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Recursion

So we use *recursion*

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One is that it leads naturally to having functions as *first class objects*

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So we are going to need functions that manipulate functions: these are called *higher order* functions

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Other languages might do

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Again, a trivial (and contrived) example of a much bigger idea

Functional Style

Recursion

Exercise. Investigate

```
double foo(double x) {
  return (x > 0.0 ? sin : cos)(3.0);
}
```

in C

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List: do the current value; recurse on the rest of the list

Tree: do the current value; recurse on the left subtree; recurse on the right subtree

We will find that the idea of separating the action of traversal of a datastructure from the operation on the elements of the datastructure is prominent in the functional style

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Some were designed from scratch as functional

Functional Style

Just a few names

- Lisp/Scheme (1959)
- APL (1964) “A Programming Language”
- ISWIM (1966) “If you See What I Mean”
- SASL (1972) “St. Andrews Static Language”
- ML/SML (1973) “Meta Language”
- Hope (1980)
- KRC (1981) “Kent Recursive Calculator”
- Miranda (1985)
- Erlang (1987)
- Haskell (1990)
- OCaml (1996)

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Java has just introduced first class functions (lambdas)

Though there have been many previous attempts to add functional style to Java, e.g., Pizza

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If you don't like the way methods are chosen, or the way slots are accessed in an object, change it

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Two languages that look and feel very different, but both embrace the functional idea

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- Really a *family* of languages

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- Standardised as "Haskell 98"

Functional Languages

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So Lisp will look strange but act as you might expect

And Haskell will look relatively normal but act quite weirdly

Lisp

We start with Lisp

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> *“Lisp is worth learning for the profound enlightenment experience you will have when you finally get it; that experience will make you a better programmer for the rest of your days, even if you never actually use Lisp itself a lot.”*

Eric Raymond, “How to Become a Hacker”

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We shall spend more time on Lisp than Haskell as they share many ideas

By the time we get to Haskell we should be able to say “and such-and-such is just like Lisp” and just concentrate on their differences

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History

Lisp is a **lis**t **p**rocessing language

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Not designed for numerical processing (Fortran did that), but manipulation of symbols

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We could do an entire unit on it

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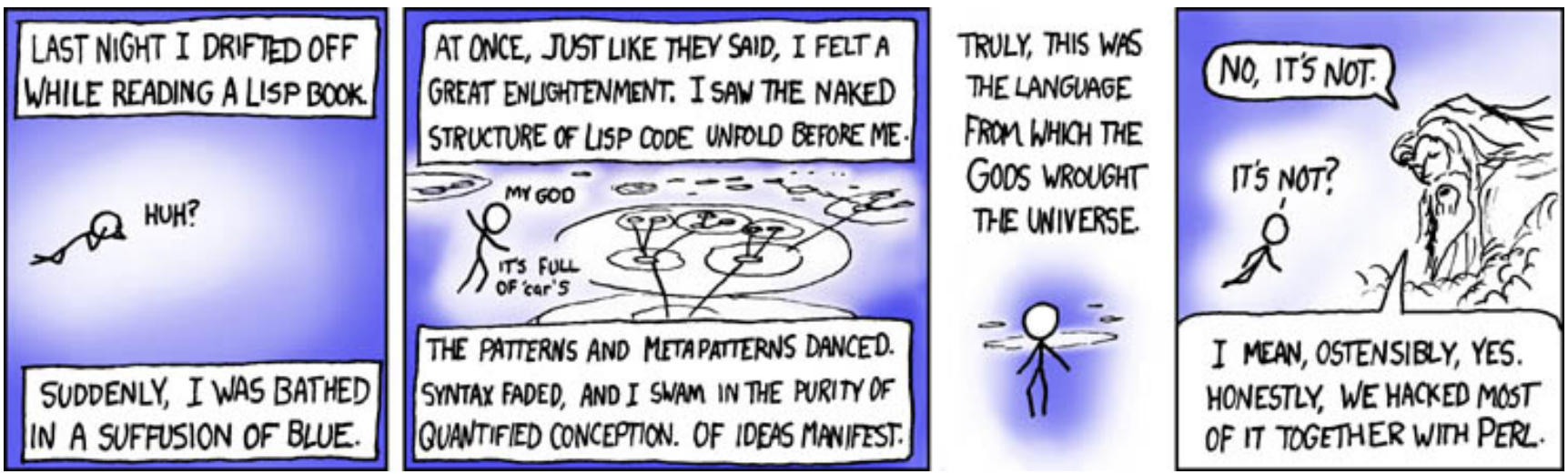

http://xkcd.com/224/

Lisp

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Everything in Lisp is either

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- or an *atom*

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`(1 x "hello")` is a list of three atoms: a number, a symbol and a string

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Symbols look like variables in other languages, but are objects in their own right

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There's not much you can do with symbols by default (in comparison, you can, e.g., add numbers or concatenate strings), they just *are*

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The original intent of Lisp was to make manipulation of symbols easy

That is, pushing symbols about, just like in mathematics

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It is the only object that is both a list and an atom

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Thus Lisp can easily be used to represent non-numeric data

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With a Lisp program you can't tell

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All functions are like this, even things like + that are treated specially by other languages

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People complain about the syntax of Lisp saying it has too many parentheses

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And has exactly the right number of parentheses!

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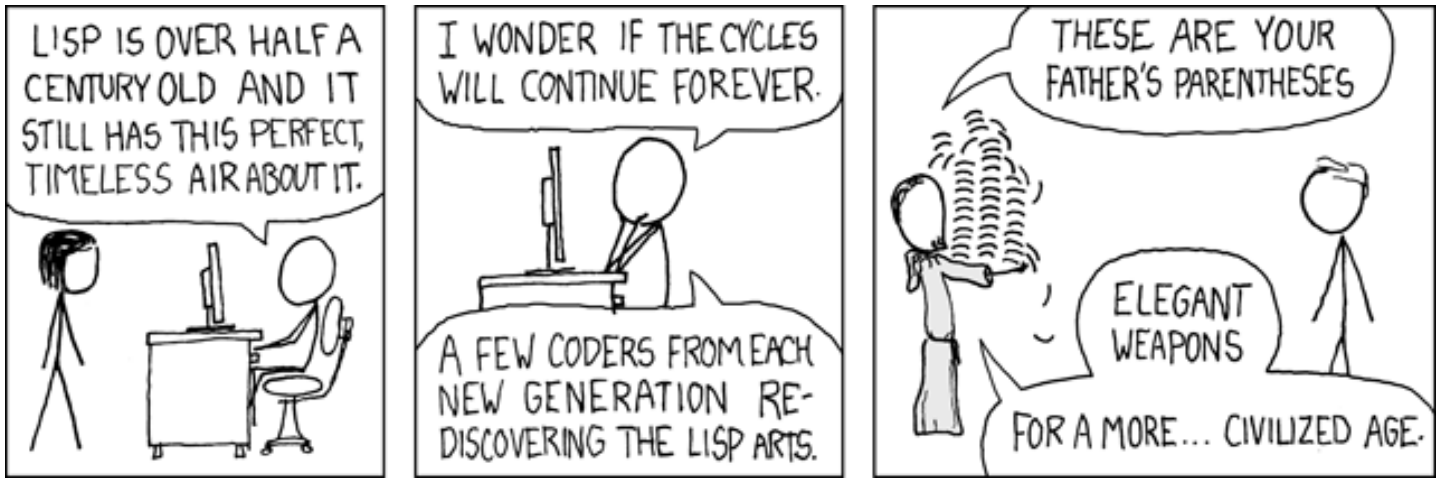

http://xkcd.com/297/

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(+ (pow (sin x) 2) (pow (cos x) 2))
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for $\sin^2 x + \cos^2 x$

Lisp

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(+ (pow (sin x) 2) (pow (cos x) 2))
```

for $\sin^2 x + \cos^2 x$

The *reason* for this syntax is very important