Lisp
Functional Programming

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Outline

Course and lecture formalia

Lisp introduction

- Linguistics

Lisp

- Installation
- Lisp syntax
- Variables in Lisp

Lambda calculus 1/2

- Functions in Lisp

Lists in Lisp

- Linked lists

Lambda calculus 2/2

Lisp syntax

Knowledge of:

- Functional programming paradigm
- Building blocks of a functional programming language
- How to support parallelism using a functional language
- Where to find additional information

Skills:

- Write basic web applications in Elm
- Understand and write programs in Lisp
- Understand and write simple programs in Haskell

Before we begin...

- Lecture format
- Learning to learn
- Metacognition

Lectures

- You have one job, and one job only

Lectures

- You have one job, and one job only
- Practical part - use your computer

Lectures

- You have one job, and one job only
- Practical part - use your computer
- Theoretical part - do *not* use your computer

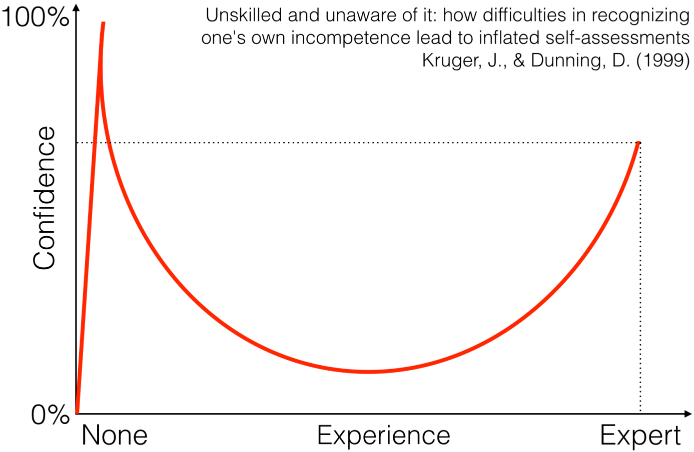
Memory is formed when you pay attention.

Learning to learn

Memory is formed when you pay attention.

- Computers and phones *seriously* distractions
- Take notes (internalisation)
- Try to understand and *relate* (Bloom's taxonomy)

Dunning-Kruger Effect



Metacognition

- Cognition $\approx$ thinking

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- *Meta*cognition $\approx$ thinking about thinking

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- Could you change something?

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- Could you change something?

- *Please* experiment. And *please* be critical

Agenda for today

- Lisp and linguistics
- Lambda calculus 1/2
- Functions in Lisp
- Exercise
- Lists in Lisp
- Lambda calculus 2/2
- Exercise 2

Lisp

- Specified in 1958
- One of the oldest high-level programming languages
- Prefix notation
- First language to use lambda calculus

Programming language

- Low versus high abstraction
- *Computer think* are not for humans
- Can it be generalised?

Linguistics: Language science
Traditionally occupied with human language.

Noam Chomsky: Chomsky hierarchy

Type-3 grammar	Regular language (state automata)
Type-2 grammar	Context-free (no ambiguity)
Type-1 grammar	Context-sensitive (ambiguity)
Type-0 grammar	Unrestricted grammar (no restrictions on I/O)

One of the first higher-level programming languages

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"The most intelligent way to misuse a computer" - Edgar W. Dijkstra

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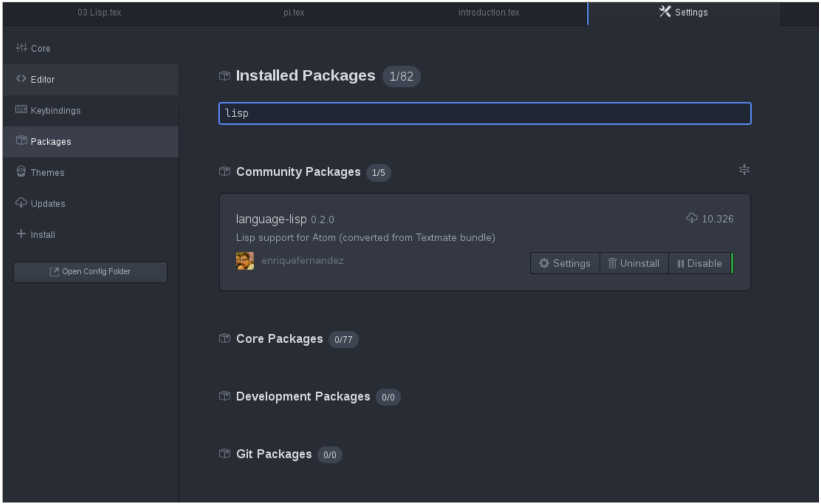
Many (!) dialects: `Scheme`, `Common Lisp`, `Emacs Lisp`, `AutoLisp`, `Racket`, `Clojure` (JVM), **`CLisp`**

Installing Lisp package in Atom



Installing CLisp

Go to `http://clisp.org/` and:

On Windows Download the Cygwin package by running the Cygwin installer

On Unix Download the package for your system or build it from source

Integration in Atom

The `atom-slime` Atom package provides compilation functionality

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See: `https://atom.io/packages/atom-slime`

Lisp syntax

- Prefix notation: *Function first* then arguments
- Function call surrounded by parenthesis

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```
(+ 1 1)
```

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(+ 1 1)

(* 1 (+ 2 3))
```

Lisp syntax

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- Prefix notation: *Function first* then arguments
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```
(+ 1 1)

(* 1 (+ 2 3))

(write (- 5 2))
```

Exercise 1

1.1: Divide $5 + 3$ with $4 - 2$

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1.2: Write $9 * 2 - 3 + 5$ to the console

Basic Lisp syntax

- Arithmetic: `* + /`
- Function call: `(name [arg1 [arg2 [arg3...]]])`
- Comments (`;;`): `(+ 3 1) ;; 4`

Procedural programming

`(setf variable 10)` ← mutable

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Functional programming

Local variables: `let`-binding

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Functional programming

Local variables: `let`-binding

```
(let ((a 10)) (write a) )
```

Procedural programming

`(setf variable 10)` ← mutable

Functional programming

Local variables: `let`-binding

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(let ((a 10)) (write a) )
```

Why is the `let`-binding preferred in functional programming?

Introduction exercise

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Clone the `lisp-exercises` from `cphbus-functional-programming`

`https://github.com/cphbus-functional-programming/lisp-exercises`

Work on the `variables.lisp` file

A computer is a thing that follows an algorithm = computation.

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Imagine living in 1900; How do you 'compute'?

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What do you have to work with?

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Imagine living in 1900; How do you 'compute'?
What do you have to work with?
Mathematics!

Lambda calculus

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$sum(x, y) = x + y$

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$f(5)(2) =$

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Lisp functions

- Functions defined with `defun`
- Takes three expressions: name, arguments and function body

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```
(defun test (a) (write a))
```

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```
(defun test (a) (write a))

(test 10)
```

```
(lambda () ())
```

Lambdas in Lisp

```
(lambda () ())
```

```
(lambda (x) (* x x))
```

Lambdas in Lisp

```
(lambda () ())

(lambda (x) (* x x))

((lambda (x) (* x x)) 5)
```

What do you need to know in an `if` statement?

`if` statements

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```
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eq: Equality function

```
(eq 1 2) ;; false
```

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```
(if condition then else)
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`eq`: Equality function

```
(eq 1 2) ;; false
```

```
(if (= a 0) 0 1)
```

Lists are made by calling the function `list` followed by the list content

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```
(list 10 5 2)
```

Lists

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Lists are made by calling the function `list` followed by the list content

`(list 10 5 2)` $\mapsto$ `[10, 5, 2]`

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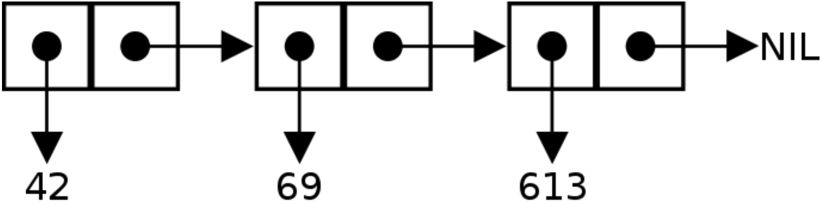
`(list 10 (list 5 2))` $\mapsto$ `[10, [5, 2]]` Lists in lisp is built using *linked lists*



Linked lists

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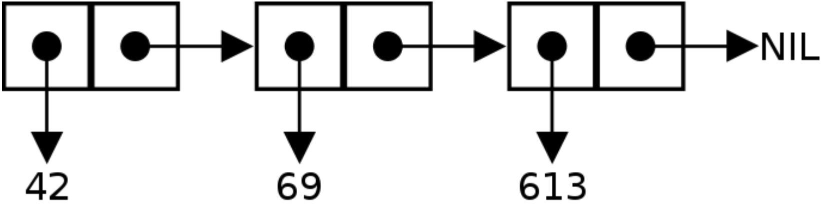

An empty list is called `nil`

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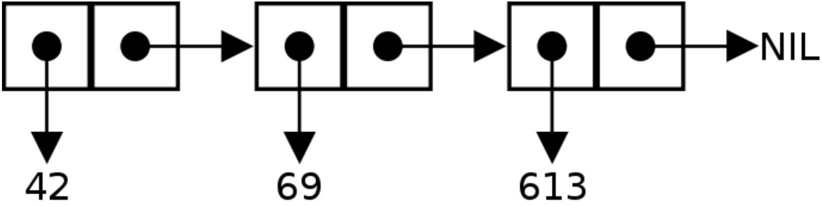

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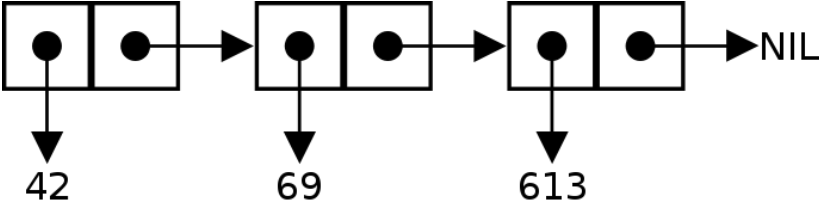

An empty list is called `nil`

A cell is called a *cons*

The two pointers is called `car` and `cdr`

Cons, car and cdr

A list can be constructed using `cons`: `(cons 4 nil)`

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What is `(car (cons 4 nil))`?

Cons, car and cdr

A list can be constructed using `cons`: `(cons 4 nil)`

What is `(car (cons 4 nil))`?

What is `(cdr (cons 4 nil))`?

append and reverse

Append appends a list on another

```
(append (list 1 2) (list 3 4))
```

append and reverse

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(append (list 1 2) (list 3 4))
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Reverse a list with `nreverse`

```
(nreverse (list 1 2 3))
```

List exercises

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Application as data

A computer is a thing that follows an algorithm = computation.

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What can be computed?

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What can be computed? Memory!

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If we can treat functions as memory, they simply become data

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$f(5)(2) =$

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$f(5)(2) = 29$

$f(5) = y \mapsto y^2 + 25$

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$f(5)(2) = 29$

$f(5) = y \mapsto y^2 + 25 \quad = \lambda y.y^2 + 25$

Boolean `T` and `nil`

Lisp syntax

Boolean	`T` and `nil`	
Conditional	`(if expr then else)`	`(if (= 0 0) x y)`

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Conditional	`(if expr then else)`	`(if (= 0 0) x y)`
Lists	`(list elements)` or	
	`(cons tail)`	`(list 1 2)` or
		`(cons 1 (cons 2 nil)))`

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Conditional	`(if expr then else)`	`(if (= 0 0) x y)`
Lists	`(list elements)` or `(cons tail)`	`(list 1 2)` or `(cons 1 (cons 2 nil)))`
Let binding	`(let ((variables))` `  (body))`	`(let ((a 10)) a)`

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Let binding	`(let ((variables)) (body))`	`(let ((a 10)) a)`
Functions	`(defun name (arguments) body)`	`(defun sum (a b) (+ a b))`

Lisp syntax

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Conditional	`(if expr then else)`	`(if (= 0 0) x y)`
Lists	`(list elements)` or `(cons tail)`	`(list 1 2)` or `(cons 1 (cons 2 nil)))`
Let binding	`(let ((variables)) (body))`	`(let ((a 10)) a)`
Functions	`(defun name (arguments) body)`	`(defun sum (a b) (+ a b))`
Lambda	`(lambda (arguments) body)`	`(lambda (a b) (+ a b))`

Lisp syntax: Lambda

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Lambdas are defined as `(lambda (arguments) body)`

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To avoid confusing them with normal functions, use `funcall` to call them

Lisp syntax: Lambda

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Lambdas are defined as `(lambda (arguments) body)` `(lambda (a) (+ a 2))`

To avoid confusing them with normal functions, use `funcall` to call them

```
(funcall (lambda a (+ a 2)) 5)
```

Lambda exercise

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Work on the `lambda.lisp` file