OMeta
an OO Language for Pattern Matching

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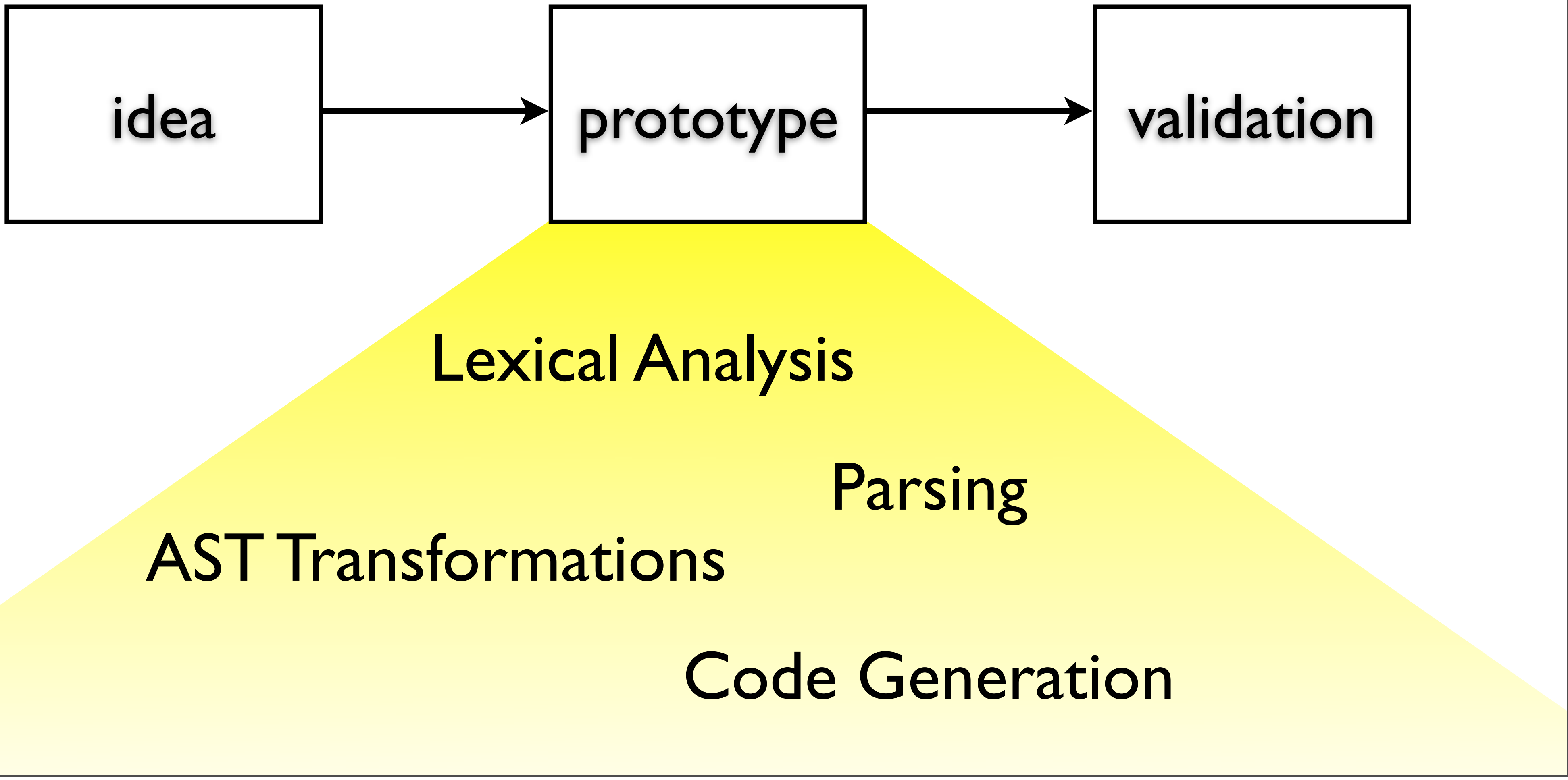
Programming language research



idea

prototype

validation

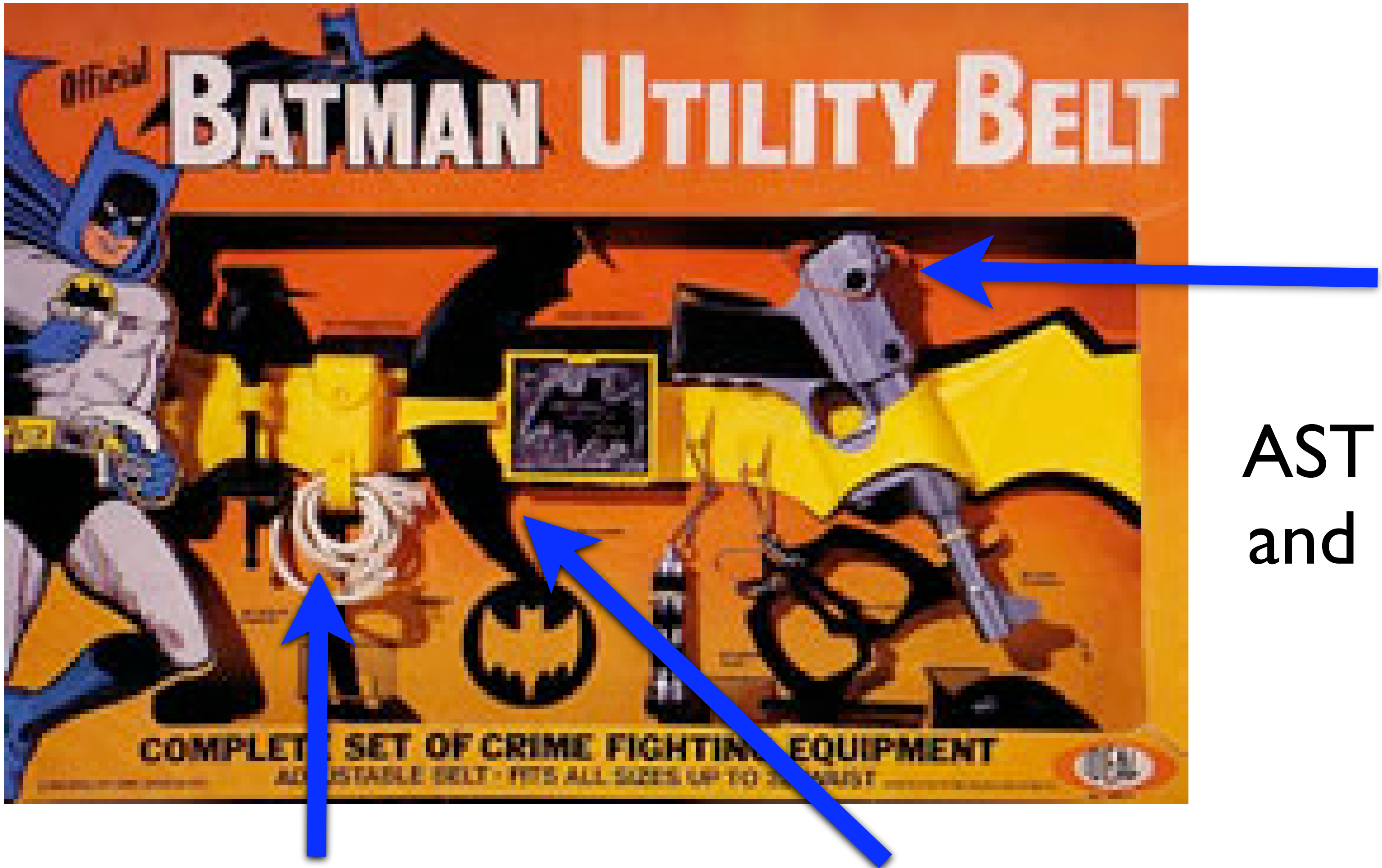
Lexical Analysis

Parsing

AST Transformations

Code Generation

We have special weapons...

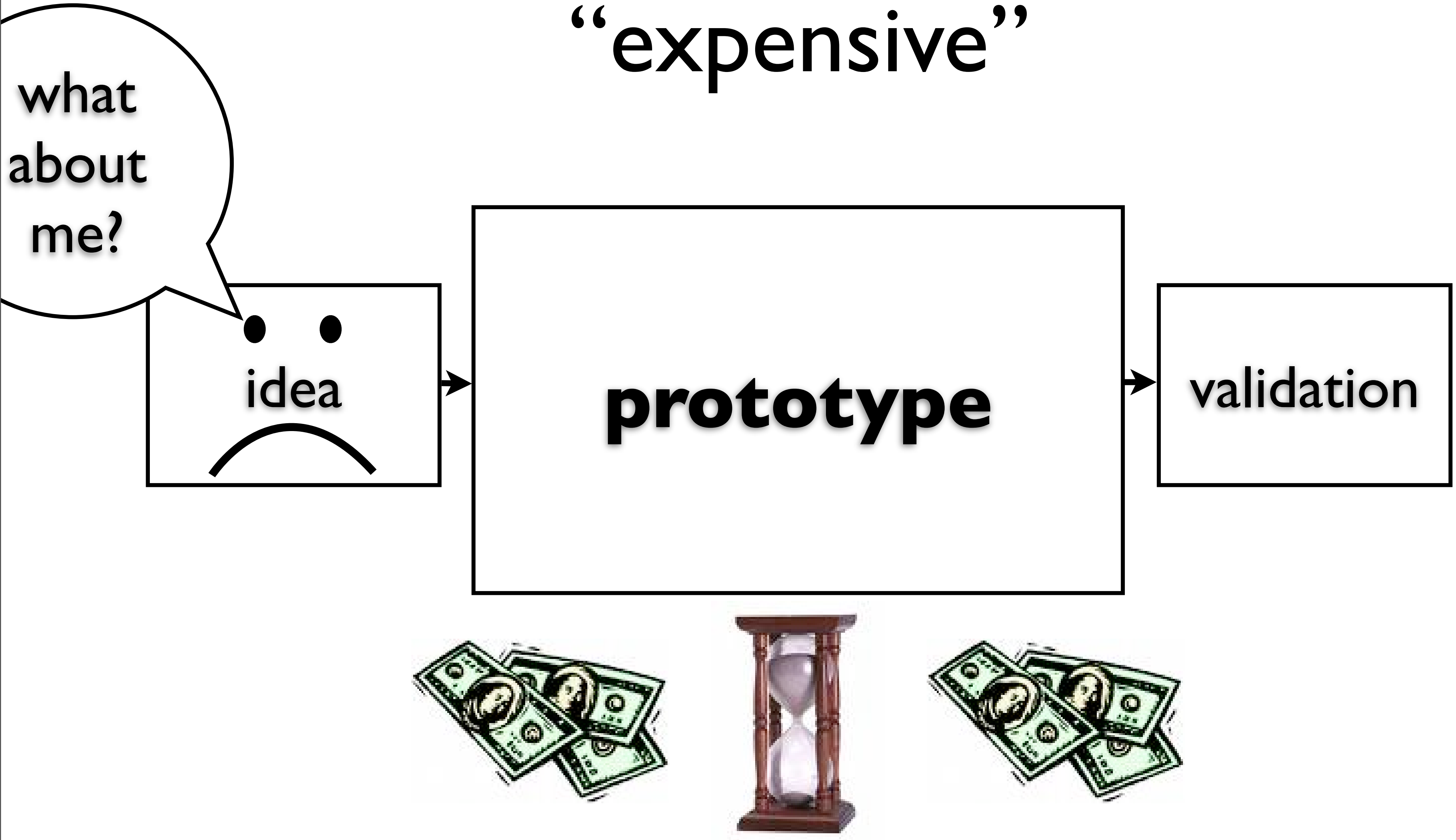


visitors,
for
AST transformations
and code generation

lex,
for lexical analysis

yacc,
for parsing

... but prototypes are still "expensive"



what about me?

idea

prototype

validation

Why do we care?

- PL researchers have lots of ideas...
- ... but can only afford to prototype a few of the "more promising" ones

The ideal prototype

- ... should be
  - quick to implement
  - easy to change
  - extensible
  - “efficient enough”

OMeta

- An Object-Oriented language for Pattern Matching
- Intended for rapid language prototyping (but not limited to that domain)
- OO: extend your prototypes using familiar mechanisms
    - inheritance, overriding, ...

- OMeta compiler
- JavaScript compiler
  - “almost” ECMA-262 compliant
- Some JS extensions
- *Toylog* interface to Prolog for children

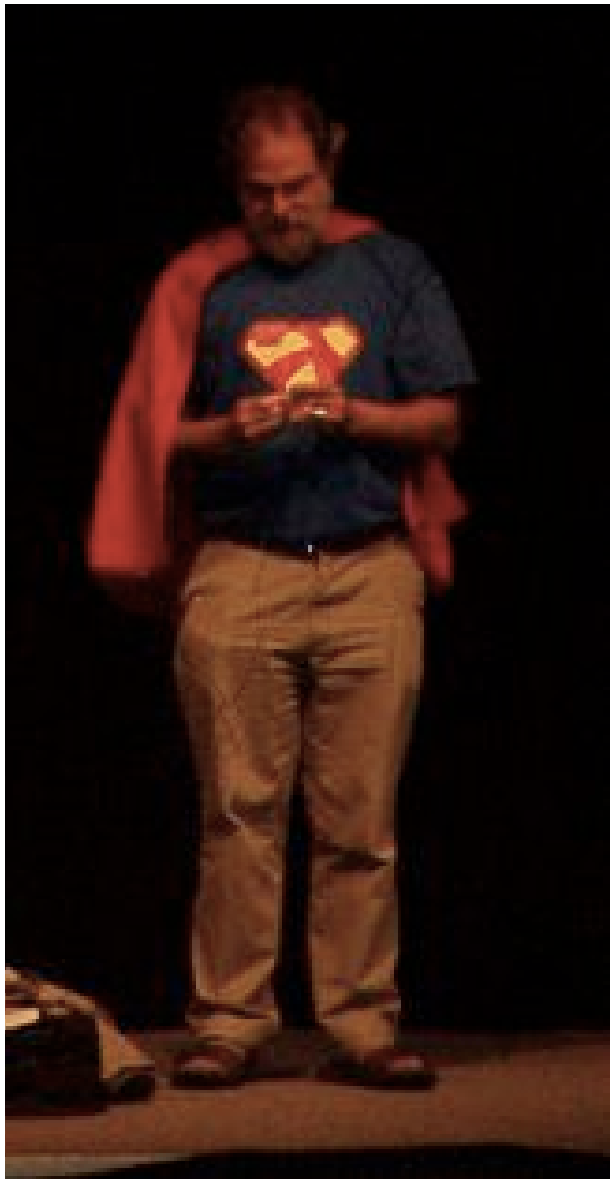
Roadmap

- OMeta’s pattern matching
- Object-Oriented features
- Other interesting features
- Experience

Why Pattern Matching?

It’s a unifying idea!

- **lexical analysis:** characters → tokens
- **parsing:** tokens → parse trees
- **constant folding and other optimizations:** parse trees → parse trees
- **(naive) code generation:** parse trees → code



Pattern Matching

- ML-style pattern matching
  - Can you write a lexer / parser with it?
  - Yes, but...
  - “That’s what ML-lex and ML-yacc are for!”
- OMeta is based on PEGs

Parsing Expression Grammars (PEGs) [Ford, '04]

- Recognition-based foundation for describing syntax
- Only **prioritized choice**
  - no ambiguities
  - easy to understand
- Backtracking, unlimited lookahead
- Semantic predicates, e.g., `?[x == y]`

About the examples

- 2 versions of OMeta:
    - OMeta/Squeak
    - OMeta/COLA
- Slightly different syntaxes
- Use different languages for semantic actions and predicates

PEGs, OMeta style

```
dig  ::= (“0” | ... | “9”):d  => [d digitValue]

num  ::= <num>:n <dig>:d      => [n * 10 + d]
       | <dig>

expr ::= <expr>:e “+” <num>:n => [{#plus. e. n}]
       | <num>
```

Increasing Generality

- PEGs operate on streams of characters
- OMeta operates on streams of *objects*
  - `<anything>` matches any one object
  - characters, e.g,. `$x`
  - strings, e.g., `‘hello’`
  - numbers, e.g., `42`
  - symbols, e.g, `#answer`
  - lists, e.g., `{‘hello’ 42 #answer {}}`

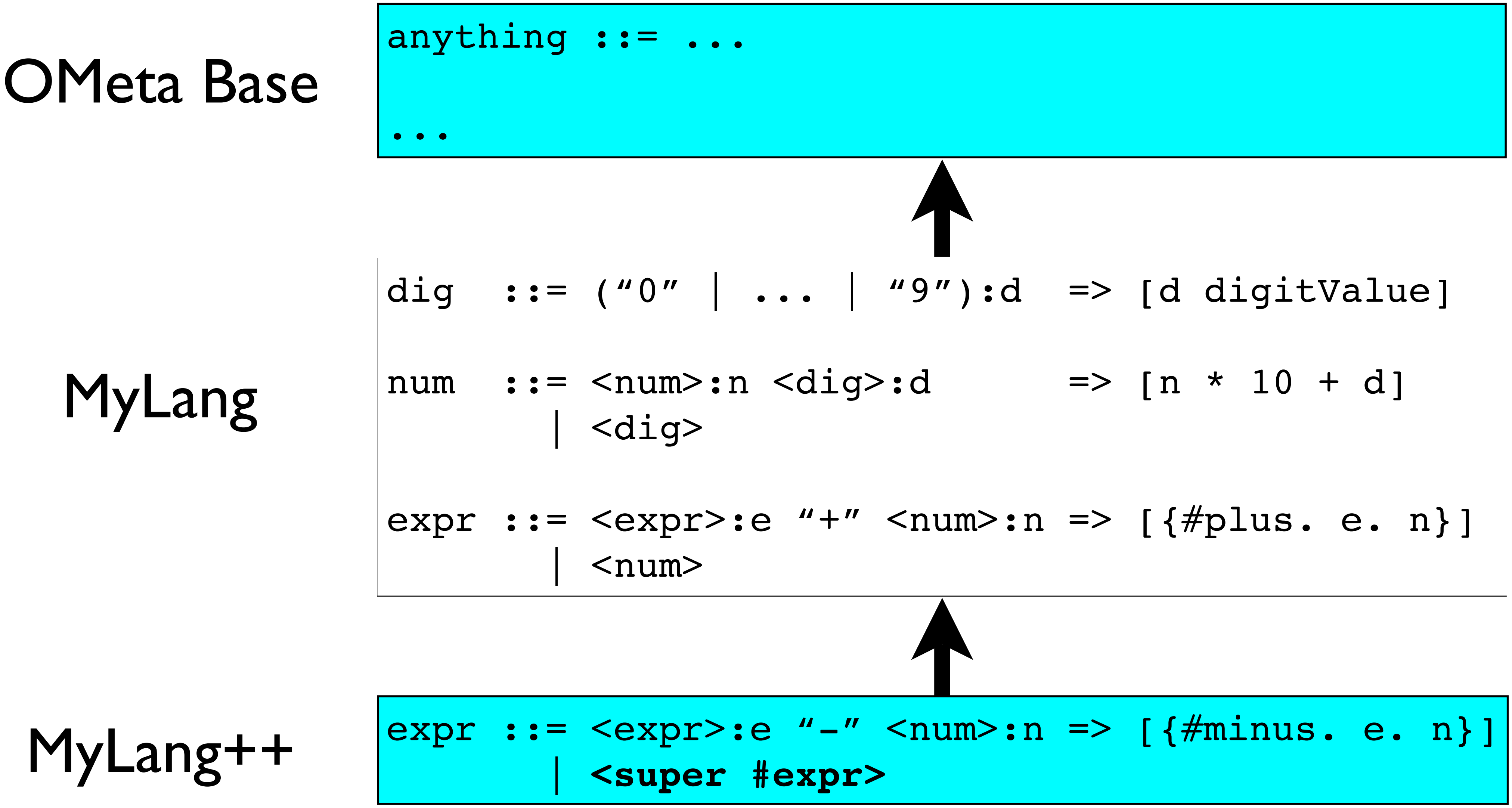
Example: evaluating parse trees

```
num  ::= <anything>:n ?[n isNumber] => [n]

eval ::= {#plus <eval>:x <eval>:y}  => [x + y]
       | <num>
```

`{#plus. {#plus. 1. 2}. 3}` → 6

OMeta is Object-Oriented



OMeta Base

```
anything ::= ...

...
```

MyLang

```
dig  ::= ("0" | ... | "9"):d  => [d digitValue]

num  ::= <num>:n <dig>:d      => [n * 10 + d]
       | <dig>

expr ::= <expr>:e "+" <num>:n => [{#plus. e. n}]
       | <num>
```

MyLang++

```
expr ::= <expr>:e "-" <num>:n => [{#minus. e. n}]
       | <super #expr>
```

Extensible pattern matching

```
meta NullOptimization {
  opt ::= (OR <opt>*:xs)                  => `(OR ,@xs)
        | (NOT <opt>:x)                   => `(NOT ,x)
        | (MANY <opt>:x)                  => `(MANY ,x)
        | (MANY1 <opt>:x)                 => `(MANY1 ,x)
        | (define <_>:n <opt>:v)          => `(define ,n ,v)
        | (AND <opt>*:xs)                 => `(AND ,@xs)
        | (FORM <opt>*:xs)                => `(FORM ,@xs)
        | <_>;
}

meta OROptimization <: NullOptimization {
  opt    ::= (OR <opt>:x)                 => x
           | (OR <inside>:xs)             => `(OR ,@xs)
           | <super opt>;
  inside ::= (OR <inside>:xs) <inside>:ys => (append xs ys)
           | <super opt>:x    <inside>:xs => (cons x xs)
           | <empty>                      => nil;
}
```

Parameterized productions

```
digit ::= “0” | “1” | “2” | “3” | “4”
        | “5” | “6” | “7” | “8” | “9”
```

```
range :a :b ::= <anything>:x ?[x >= a]
                             ?[x <= b] => [x]

digit ::= <range $0 $9>
```

More about parameterized productions

- The syntax

  ```
  range :a :b ::= …
  ```

  is really shorthand for

  ```
  range ::= <anything>:a <anything>:b (…)
  ```

- Arguments prepended to input stream
- Enables pattern matching on arguments

  ```
  fac 0                          => [1]
  fac :n ::= <fac (n - 1)>:m => [n * m]
  ```

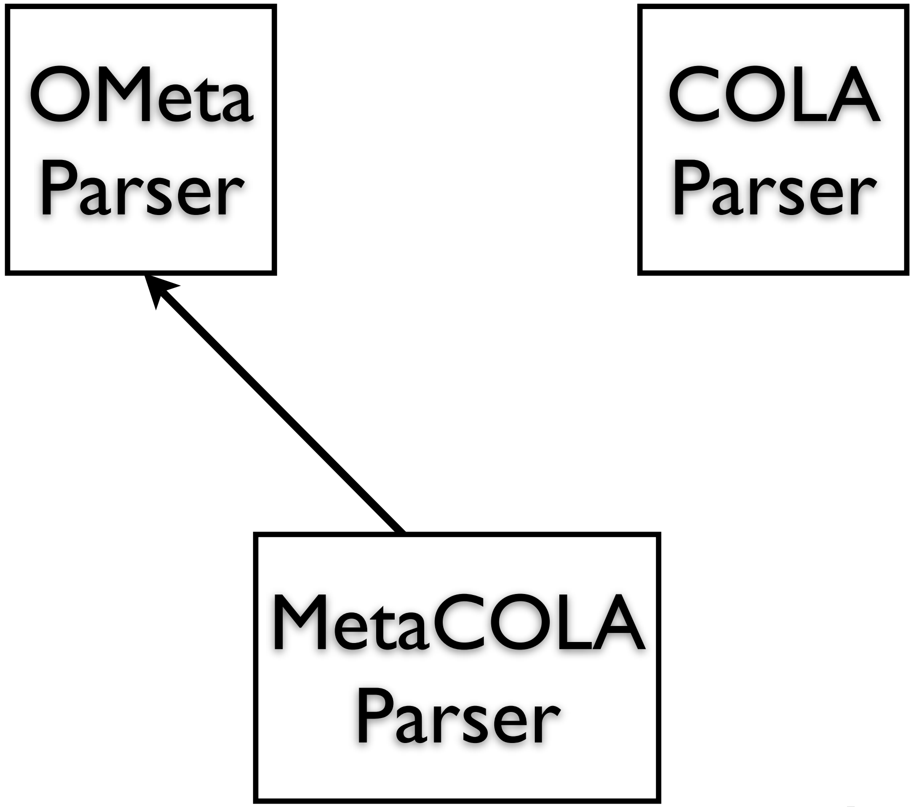
Higher-order productions

```
formals ::= <name> (“,” <name>)*
args    ::= <expr> (“,” <expr>)*
```

```
listOf :p ::= <apply p> (“,” <apply p>)*

formals ::= <listOf #name>
args    ::= <listOf #expr>
```

MetaCOLA = OMeta + COLA



- duplicated effort
- versioning problem

Foreign production invocation

- Lend input stream to another gramamar

```
meta MetaCOLA {
  mcola ::= <foreign OMeta ‘ometa>
          | <foreign COLA  ‘cola>;
}
```

- Compose multiple grammars w/o worrying about name clashes

Lexically-scoped syntax extensions

```
(define puts
  (lambda (s)
    (let ((idx 0))
      (while (!= (char@ s idx) 0)
        (putchar (char@ s idx))
        (set idx (+ idx 1)))
      (putchar 10))))
```

Lexically-scoped syntax extensions

```
(define puts
  (lambda (s)
    (let ((idx 0))
      (while (!= s[idx] 0)
        (putchar s[idx])
        (set idx (+ idx 1)))
      (putchar 10))))
```

Lexically-scoped syntax extensions

```
(define puts
  (lambda (s)
    (let ((idx 0))
      { cola ::= <cola>:a ’[’ <cola>:i ’]’ => `(char@ ,a ,i)
               | <super cola>; }
      (while (!= s[idx] 0)
        (putchar s[idx])
        (set idx (+ idx 1)))
      (putchar 10))))

(puts "this is a test")   ;; works
(printf "%d\n" "abcd"[0]) ;; parse error!
```

Experience

- The OMeta compiler
  - parser, optimizer passes, codegen
- JS compiler (OMeta/Squeak)
  - ~350 LOC (OMeta) for parser, "declaration visitor", codegen
  - ~1000 lines of JS for libraries
  - "almost" ECMA-262 compliant

Experience (cont’d)

- **MJavaScript** = Javascript + Macro support
- ~40 LOC, including additional syntax and macro expansion pass

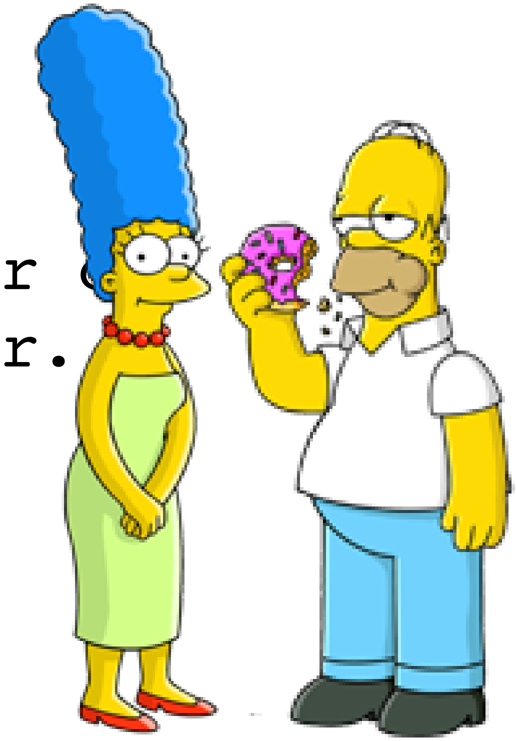
```
macro @repeat(numTimes, body) {
  var n = numTimes
  while (n-- > 0)
    body
}

@repeat(10 + 5, alert(“hello”))
```

Experience (cont’d)

- **Toylog** = Prolog front-end for children
- ~70 LOC

```
Homer is Bart’s father.
Marge is Bart’s mother.
x is y’s parent if x is y’s father
                   or x is y’s mother.
x is Bart’s parent?
```



Selected Related Work

- Parsing Expression Grammars [Ford, ‘04]
- LISP70 Pattern Matcher [Tesler et al., ‘73]
- Parser combinator libraries [Hutton, ‘92]
- “Modular Syntax” [Grimm, ’06]

http://www.cs.ucla.edu/~awarth/ometa

<questions>