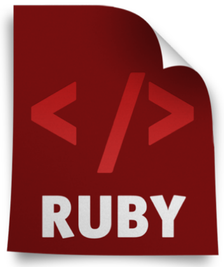
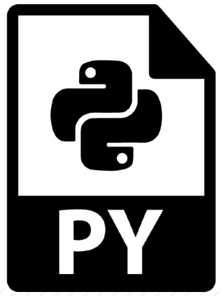
Tree-sitter

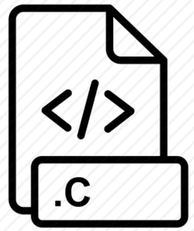
@maxbrunsfeld

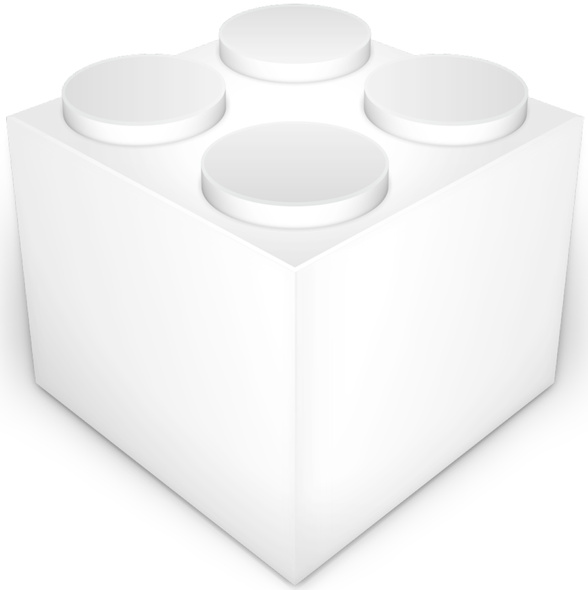
- What is Tree-sitter?
- Why I wrote Tree-sitter
- What we're building with Tree-sitter at GitHub
- Algorithms behind Tree-sitter

What is Tree-sitter?

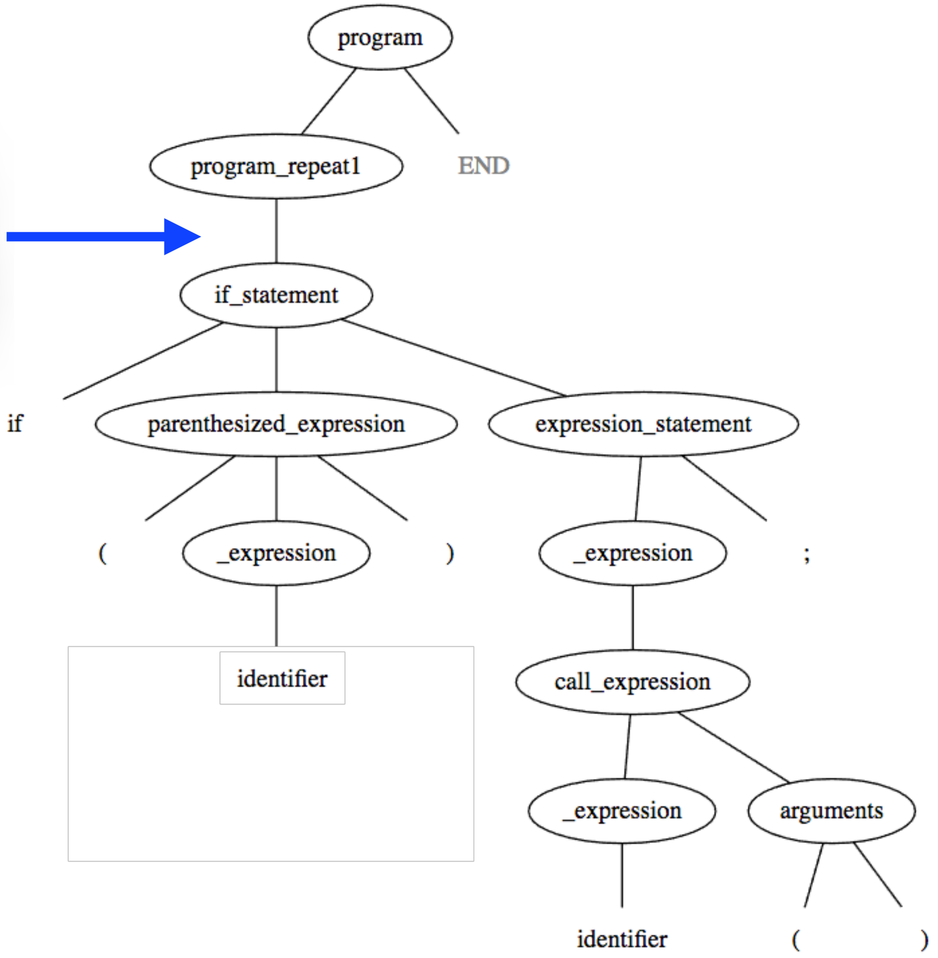




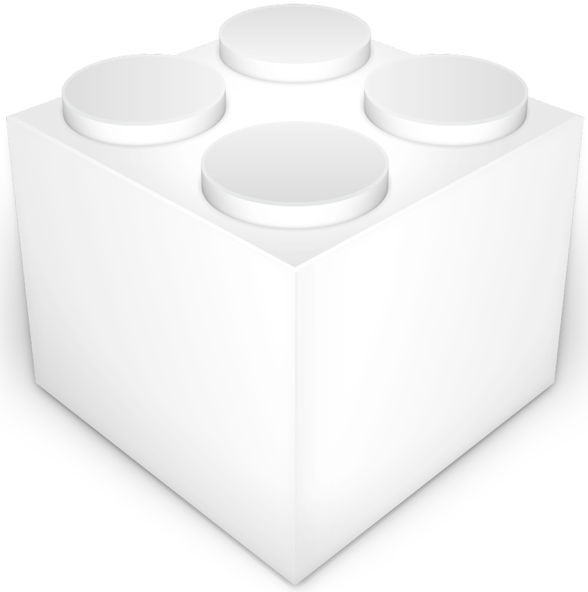


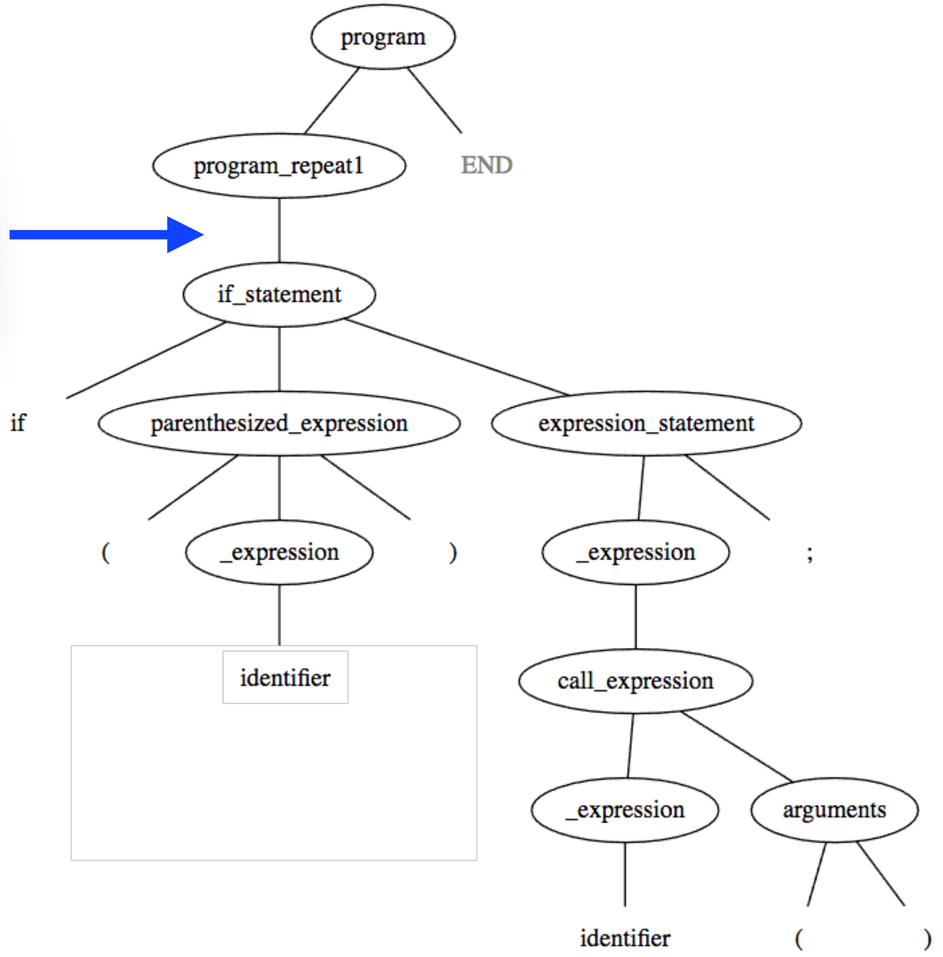


Uniform parsing of different languages



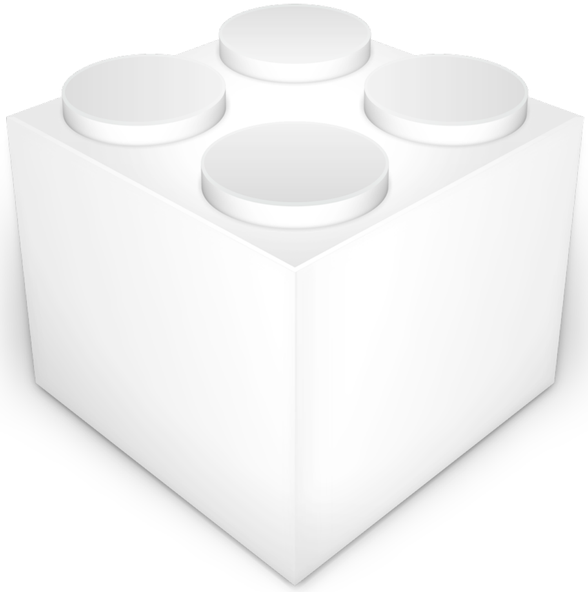
```
if (a) c();
```

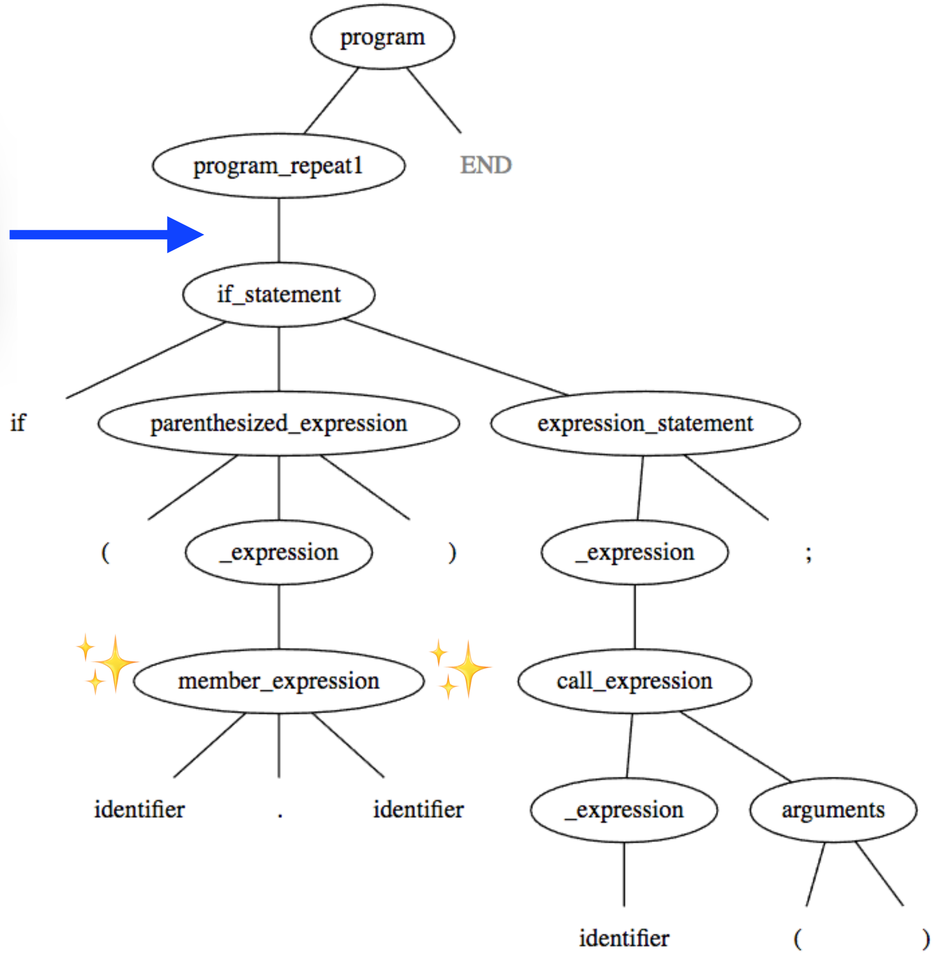




Incremental parsing

```
if (a.b) c();
```

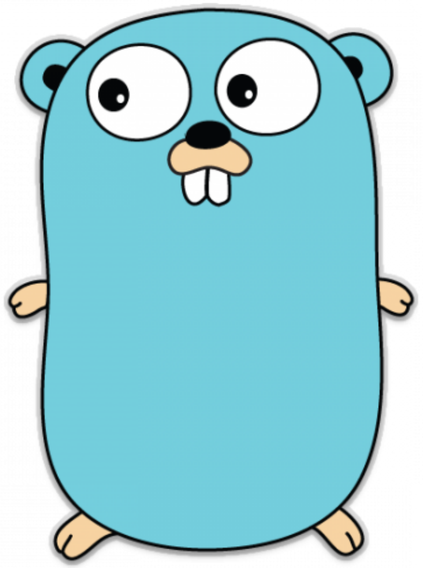




Incremental parsing

Why I wrote Tree-sitter

Single-language code analysis tools



Syntax Highlighting Today

```
type Person struct {
    name string
    mom *Person
}

func NewPerson(name string, mom *Person) Person {
    return Person{name: name, mom: mom}
}

func (self *Person) GetName() string {
    return self.name
}

func (self *Person) GetMom() *Person {
    return self.mom
}
```

Syntax Highlighting Today

```
3   type Person struct {
4       name string
5       mom *Person
6   }
7
8   func NewPerson(name string, mom *Person) Person {
9       return Person{name: name, mom: mom}
10  }
11
12  func (self *Person) GetName() string {
13      return self.name
14  }
15
16  func (self *Person) GetMom() *Person {
17      return self.mom
18  }
```

Why three different colors for types?

Syntax Highlighting Today

```
 3  type Person struct {
 4      name string
 5      mom *Person
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 8  func NewPerson(name string, mom *Person) Person {
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15
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17      return self.mom
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```

Why three different colors for types?

Syntax Highlighting Today

```
3   type Person struct {
4       name string
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8   func NewPerson(name string, mom *Person) Person {
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11
12  func (self *Person) GetName() string {
13      return self.name
14  }
15
16  func (self *Person) GetMom() *Person {
17      return self.mom
18  }
```

Why three different colors for types?

Why not use standard parsers?

- Most are too slow for text editors
- Many require extra information that's not available
- Each has its own dependencies

Why use Tree-sitter

- It's fast
- It requires no extra information
- Parsers have no dependencies

What we're doing with Tree-sitter

Syntax Highlighting - Go

```go
type Person struct {
    name string
    mom *Person
}

func NewPerson(name string, mom *Person) Person {
    return Person{name: name, mom: mom}
}

func (self *Person) GetName() string {
    return self.name
}

func (self *Person) GetMom() *Person {
    return self.mom
}
```

Syntax Highlighting - C

```c
typedef struct {
  char *name;
  Person *mom;
} Person;

Person new_person(char *name, Person *mom) {
  return (Person){.name = name, .mom = mom};
}

const char *get_name(Person *self) {
  return self->name;
}

const Person *get_mom(Person *self) {
  return self->mom;
}
```

Syntax Highlighting - C++

```
class Person {
  const std::string name;
  const Person *mom;

 public:
  Person(std::string name, const Person *mom)
    : name(name), mom(mom) {}

  const std::string &get_name() {
    return this->name;
  }

  const Person *get_mom() {
    return this->mom;
  }
};
```

Syntax Highlighting - TypeScript

```typescript
class Person {
  name: string
  mom: Person

  constructor(name: string, mom: Person) {
    this.name = name;
    this.mom = mom;
  }

  getName() : string {
    return this.name;
  }

  getMom() : Person {
    return this.mom;
  }
};
```

Syntax Highlighting - Python

```python
class Person:
    def __init__(self, name: string, mom: Person):
        self.name = name
        self.mom = mom

    def get_name(self):
        return self.name

    def get_mom(self):
        return self.mom

```

Syntax Highlighting - Ruby

```ruby
class Person
  def initialize(name, mom)
    @name = name
    @mom = mom
  end

  def name
    @name
  end

  def mom
    @mom
  end
end
```

Syntax Highlighting - Rust

```rust
struct Person<'a> {
    name: String,
    mom: &'a Person<'a>,
}

impl<'a> Person<'a> {
    pub fn get_name(&self) -> &String {
        &self.name
    }

    pub fn get_mom(&self) -> &'a Person {
        self.mom
    }
}
```

Syntax Highlighting - Long Lines

```
/*! jQuery v3.1.1 | (c) jQuery Foundation | jquery.org/license */
!function(a,b){"use strict";"object"==typeof module&&"object"==typeof module.exports?module.exports=a.document?b(a,!0):fu
  c=b.createElement("script");c.text=a,b.head.appendChild(c).parentNode.removeChild(c)}var q="3.1.1",r=function(a,b){retu
  b.prevObject=this,b},each:function(a){return r.each(this,a)},map:function(a){return this.pushStack(r.map(this,function(
  this.prevObject||this.constructor()},push:h,sort:c.sort,splice:c.splice},r.extend=r.fn.extend=function(){var a,b,c,d,e,
  0!==d&&(g[b]=d));return g},r.extend({expando:"jQuery"+(q+Math.random()).replace(/\D/g,""),isReady:!0,error:function(a){
  Object]"!==k.call(a))&&(!(b=e(a))||(c=l.call(b,"constructor")&&b.constructor,"function"==typeof c&&m.call(c)===n))},isE
  c,d=0;if(w(a)){for(c=a.length;d<c;d++)if(b.call(a[d],d,a[d])===!1)break}else for(d in a)if(b.call(a[d],d,a[d])===!1)bre
  d,e=[],f=0,g=a.length,h=!c;f<g;f++)d=!b(a[f],f),d!==h&&e.push(a[f]);return e},map:function(a,b,c){var d,e,f=0,h=[];if(w
  a.apply(b||this,d.concat(f.call(arguments)))},e.guid=a.guid=a.guid||r.guid++,e},now:Date.now,support:o}),"function"==ty
  b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u="sizzle"+1*new Date,v=a.document,w=0,x=0,y=ha(),z=ha(),A=ha(),B=function(a,b){r
  c;return-1},J="checked|selected|async|autofocus|autoplay|controls|defer|disabled|hidden|ismap|loop|multiple|open|reador
  RegExp("^"+K+"+|((?:^|[^\\\\])(?:\\\\.)*)"+K+"+$","g"),Q=new RegExp("^"+K+"*,"+K+"*"),R=new RegExp("^"+K+"*([>+~]|"+K+"
  RegExp("^:(only|first|last|nth|nth-last)-(child|of-type)(?:\\("+K+"*(even|odd|(([+-]|)(\\d*)n|)"+K+"*(?:([+-]|)"+K+"*(\
  RegExp("\\\\([\\da-f]{1,6}"+K+"?|("+K+")|.)","ig"),aa=function(a,b,c){var d="0x"+b-65536;return d!==d||c?b:d<0?String.f
  a)},{dir:"parentNode",next:"legend"});try{G.apply(D=H.call(v.childNodes),v.childNodes),D[v.childNodes.length].nodeType}
  d;if(!e&&((b?b.ownerDocument||b:v)!==n&&m(b),b=b||n,p)){if(11!==w&&(l=Z.exec(a)))if(f=l[1]){if(9===w){if(!(j=b.getEleme
  if("object"!==b.nodeName.toLowerCase()){(k=b.getAttribute("id"))?k=k.replace(ba,ca):b.setAttribute("id",k=u),o=g(a),h=c
  a[u]=!0,a}function ja(a){var b=n.createElement("fieldset");try{return!!a(b)}catch(c){return!1}finally{b.parentNode&&b.p
  c=b.nodeName.toLowerCase();return"input"===c&&b.type===a}}function na(a){return function(b){var c=b.nodeName.toLowerCas
  e,f=a([],c.length,b),g=f.length;while(g--)c[e=f[g]]&&(c[e]=!(d[e]=c[e]))})})}function qa(a){return a&&"undefined"!=type
  g!==n&&9===g.nodeType&&g.documentElement?(n=g,o=n.documentElement,p=!f(n),v!==n&&(e=n.defaultView)&&e.top!==e&&(e.addEv
  a.appendChild(n.createComment("")),!a.getElementsByTagName("*").length}),c.getElementsByClassName=Y.test(n.getElementsE
  b=a.replace(_,aa);return function(a){var c="undefined"!=typeof a.getAttributeNode&&a.getAttributeNode("id");return c&&c
  b.getElementsByTagName?b.getElementsByTagName(a):c.qsa?b.querySelectorAll(a):void 0}:function(a,b){var c,d=[],e=0,f=b.g
  msallowcapture=''><option selected=''></option></select>",a.querySelectorAll("[msallowcapture^='']").length&&q.push("[*
  disabled='disabled'><option/></select>";var
  b=n.createElement("input");b.setAttribute("type","hidden"),a.appendChild(b).setAttribute("name","D"),a.querySelectorAll
  ||o.msMatchesSelector))&&ja(function(a){c.disconnectedMatch=s.call(a,"*"),s.call(a,"[s!='']:x"),r.push("!=",N)}),q=q.le
```

Syntax Highlighting - Long Lines

```
/*! jQuery v3.1.1 | (c) jQuery Foundation | jquery.org/license */
!function(a,b){"use strict";"object"==typeof module&&"object"==typeof module.exports?module.exports=a.document?b(a,!0):fu
  c=b.createElement("script");c.text=a,b.head.appendChild(c).parentNode.removeChild(c)}var q="3.1.1",r=function(a,b){retu
  b.prevObject=this,b},each:function(a){return r.each(this,a)},map:function(a){return this.pushStack(r.map(this,function(
  this.prevObject||this.constructor()},push:h,sort:c.sort,splice:c.splice},r.extend=r.fn.extend=function(){var a,b,c,d,e,
  0!==d&&(g[b]=d));return g},r.extend({expando:"jQuery"+(q+Math.random()).replace(/\D/g,""),isReady:!0,error:function(a){
  Object]"!==k.call(a))&&(!(b=e(a))||(c=l.call(b,"constructor")&&b.constructor,"function"==typeof c&&m.call(c)===n))},isE
  c,d=0;if(w(a)){for(c=a.length;d<c;d++)if(b.call(a[d],d,a[d])===!1)break}else for(d in a)if(b.call(a[d],d,a[d])===!1)bre
  d,e=[],f=0,g=a.length,h=!c;f<g;f++)d=!b(a[f],f),d!==h&&e.push(a[f]);return e},map:function(a,b,c){var d,e,f=0,h=[];if(w
  a.apply(b||this,d.concat(f.call(arguments)))},e.guid=a.guid=a.guid||r.guid++,e},now:Date.now,support:o}),"function"==ty
  b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u="sizzle"+1*new Date,v=a.document,w=0,x=0,y=ha(),z=ha(),A=ha(),B=function(a,b){r
  c;return-1},J="checked|selected|async|autofocus|autoplay|controls|defer|disabled|hidden|ismap|loop|multiple|open|reador
  RegExp("^"+K+"+|((?:^|[^\\\\])(?:\\\\.)*)"+K+"+$","g"),Q=new RegExp("^"+K+"*,"+K+"*"),R=new RegExp("^"+K+"*([>+~]|"+K+"
  RegExp("^:(only|first|last|nth|nth-last)-(child|of-type)(?:\\("+K+"*(even|odd|(([+-]|)(\\d*)n|)"+K+"*(?:([+-]|)"+K+"*(\
  RegExp("\\\\([\\da-f]{1,6}"+K+"?|("+K+")|.)","ig"),aa=function(a,b,c){var d="0x"+b-65536;return d!==d||c?b:d<0?String.f
  a)},{dir:"parentNode",next:"legend"});try{G.apply(D=H.call(v.childNodes),v.childNodes),D[v.childNodes.length].nodeType}
  d;if(!e&&((b?b.ownerDocument||b:v)!==n&&m(b),b=b||n,p)){if(11!==w&&(l=Z.exec(a)))if(f=l[1]){if(9===w){if(!(j=b.getEleme
  if("object"!==b.nodeName.toLowerCase()){(k=b.getAttribute("id"))?k=k.replace(ba,ca):b.setAttribute("id",k=u),o=g(a),h=c
  a[u]=!0,a}function ja(a){var b=n.createElement("fieldset");try{return!!a(b)}catch(c){return!1}finally{b.parentNode&&b.p
  c=b.nodeName.toLowerCase();return"input"===c&&b.type===a}}function na(a){return function(b){var c=b.nodeName.toLowerCas
  e,f=a([],c.length,b),g=f.length;while(g--)c[e=f[g]]&&(c[e]=!(d[e]=c[e]))})})}function qa(a){return a&&"undefined"!=type
  g!==n&&9===g.nodeType&&g.documentElement?(n=g,o=n.documentElement,p=!f(n),v!==n&&(e=n.defaultView)&&e.top!==e&&(e.addEv
  a.appendChild(n.createComment("")),!a.getElementsByTagName("*").length}),c.getElementsByClassName=Y.test(n.getElementsB
  b=a.replace(_,aa);return function(a){var c="undefined"!=typeof a.getAttributeNode&&a.getAttributeNode("id");return c&&c
  b.getElementsByTagName?b.getElementsByTagName(a):c.qsa?b.querySelectorAll(a):void 0}:function(a,b){var c,d=[],e=0,f=b.g
  msallowcapture=''><option selected=''></option></select>",a.querySelectorAll("[msallowcapture^='']").length&&q.push("[*
  disabled='disabled'><option/></select>";var
  b=n.createElement("input");b.setAttribute("type","hidden"),a.appendChild(b).setAttribute("name","D"),a.querySelectorAll
  ||o.msMatchesSelector))&&ja(function(a){c.disconnectedMatch=s.call(a,"*"),s.call(a,"[s!='']:x"),r.push("!=",N)}),q=q.le
```

Syntax Highlighting - Performance

```
$ wc -l react.dev.js

20599 react.dev.js


$ tree-sitter parse react.dev.js --time

 react.dev.js 69ms
```

Code Folding

```
1 › typedef struct {⋯} Person;
5
6 › Person new_person(char *name, Person *mom) {⋯}
9
10 › const char *get_name(Person *self) {⋯}
13
14 › const Person *get_mom(Person *self) {⋯}
17
```

Code Folding

```
1  typedef struct {
2    char *name;
3    Person *mom;
4  } Person;
5
6  Person new_person(char *name,
7                    Person *mom) {
8    return (Person){.name = name, .mom = mom};
9  }
10
11 const char *get_name(Person *self) {
12   return self->name;
13 }
14
15 const Person *get_mom(Person *self) {
16   return self->mom;
17 }
```

Indentation doesn't always match syntax

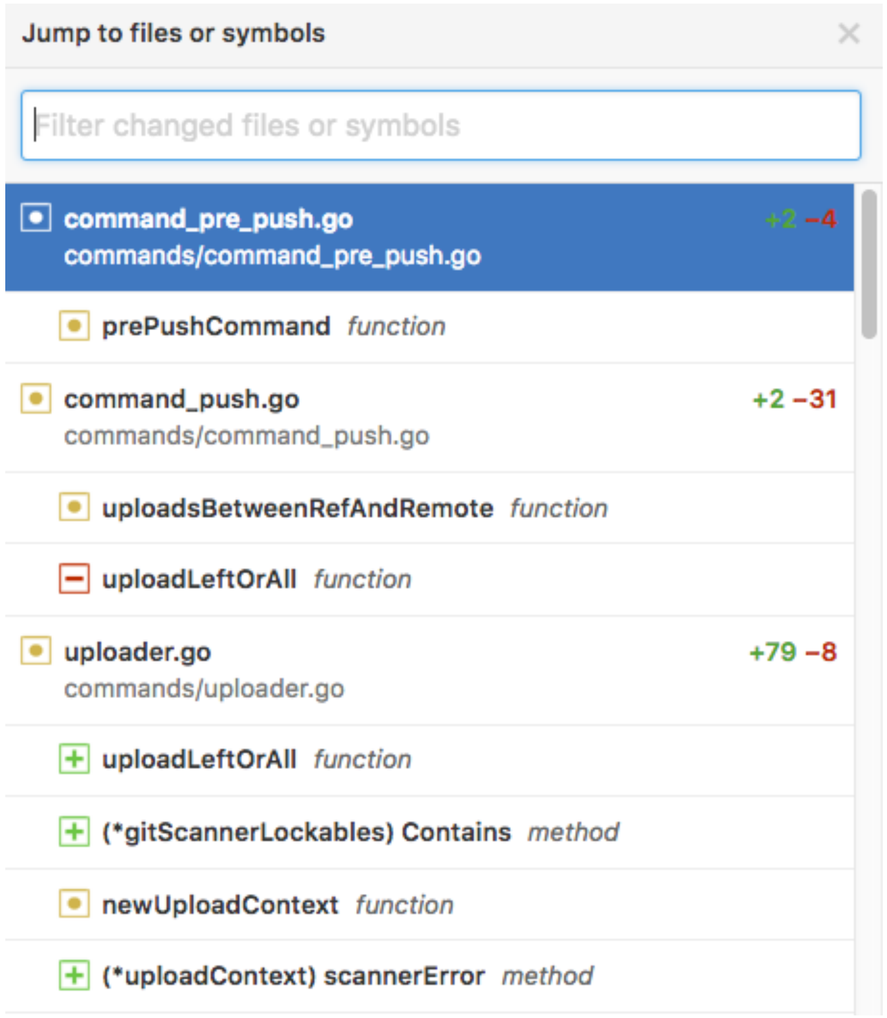
Code Folding

```c
typedef struct {
  char *name;
  Person *mom;
} Person;

Person new_person(char *name, Person *mom) {
  return (Person){.name = name, .mom = mom};
}

const char *get_name(Person *self) {
  return self->name;
}

const Person *get_mom(Person *self) {
  return self->mom;
}
```

Extend Selection

```
it('reports a tag boundary at relevant nodes in the tree', function () {
  assert.deepEqual(getTokens(buffer, iterator), [
    [
      {
        text: ' ',
        scopes: [
          {
            value: 'source.js'
          }
        ]
      },
      {
        text: 'function',
        scopes: [
          {
            value: 'source.js'
          },
          {
            value: 'meta.function.js'
          },
          {
            value: 'storage.type.function.js'
          }
        ]
      },
      {
        text: ' ',
        scopes: [
          {
            value: 'source.js'
          },
          {
            value: 'meta.function.js'
          }
        ]
      },
    ]
  ])
})
```

Pull Request Table of Contents



How Tree-sitter Works

Writing a Grammar

grammar.js

```
414      if_statement: $ => seq(
415        'if',
416        optional(seq($._simple_statement, ';')),
417        $._expression,
418        $.block,
419        optional(seq(
420          'else',
421          choice($.block, $.if_statement)
422        ))
423      ),
424
425      for_statement: $ => seq(
426        'for',
427        optional(choice($._expression, $.for_clause, $.range_clause)),
428        $.block
429      ),
430
431      for_clause: $ => seq(
432        optional($._simple_statement),
433        ';',
434        optional($._expression),
435        ';',
436        optional($._simple_statement)
437      ),
438
439      range_clause: $ => seq(
440        optional(seq(
441          $.expression_list,
442          choice('=', ':=')
443        )),
444        'range',
445        $._expression
446      ),
```

Writing a Grammar

parser.c

```
1535        case 24:
1536            if (('0' <= lookahead && lookahead <= '9') ||
1537                ('A' <= lookahead && lookahead <= 'F') ||
1538                ('a' <= lookahead && lookahead <= 'f'))
1539                ADVANCE(13);
1540            LEX_ERROR();
1541        case 25:
1542            ACCEPT_TOKEN(anon_sym_LPAREN);
1543        case 26:
1544            ACCEPT_TOKEN(anon_sym_RPAREN);
1545        case 27:
1546            if (lookahead == '=')
1547                ADVANCE(8);
1548            ACCEPT_TOKEN(anon_sym_STAR);
1549        case 28:
1550            if (lookahead == '+')
1551                ADVANCE(29);
1552            if (lookahead == '=')
1553                ADVANCE(8);
1554            ACCEPT_TOKEN(anon_sym_PLUS);
1555        case 29:
1556            ACCEPT_TOKEN(anon_sym_PLUS_PLUS);
1557        case 30:
1558            ACCEPT_TOKEN(anon_sym_COMMA);
```

Writing a Grammar

parser.c

```
13800       [2] = {
13801           [sym_identifier] = ACTIONS(109),
13802           [sym_comment] = ACTIONS(105),
13803       },
13804       [3] = {
13805           [ts_builtin_sym_end] = ACTIONS(111),
13806           [sym_comment] = ACTIONS(105),
13807       },
13808       [4] = {
13809           [sym_import_declaration] = STATE(10),
13810           [sym__top_level_declaration] = STATE(11),
13811           [sym__declaration] = STATE(12),
13812           [sym_const_declaration] = STATE(13),
13813           [sym_var_declaration] = STATE(13),
13814           [sym_function_declaration] = STATE(12),
13815           [sym_method_declaration] = STATE(12),
13816           [sym_type_declaration] = STATE(13),
13817           [aux_sym_source_file_repeat1] = STATE(14),
13818           [aux_sym_source_file_repeat2] = STATE(15),
13819           [ts_builtin_sym_end] = ACTIONS(113),
13820           [anon_sym_import] = ACTIONS(115),
13821           [anon_sym_const] = ACTIONS(117),
13822           [anon_sym_var] = ACTIONS(119),
13823           [anon_sym_func] = ACTIONS(121),
13824           [anon_sym_type] = ACTIONS(123),
13825           [sym_comment] = ACTIONS(105),
13826       },
13827       [5] = {
13828           [sym_import_spec] = STATE(1238),
13829           [sym__string_literal] = STATE(1239),
13830           [anon_sym_LPAREN] = ACTIONS(125),
13831           [anon_sym_DOT] = ACTIONS(127),
13832           [sym_identifier] = ACTIONS(129),
13833           [sym_raw_string_literal] = ACTIONS(131),
13834           [sym_interpreted_string_literal] = ACTIONS(131),
13835           [sym_comment] = ACTIONS(105),
13836       },
```

Using the parser

```c
#include "tree_sitter/runtime.h"

int main() {
  const TSDocument *document = ts_document_new();
  const TSLanguage *javascript_language = tree_sitter_javascript();

  ts_document_set_language(document, javascript_language);
  ts_document_set_input_string(document, "var x = 1; print(x);");
  ts_document_parse(document);

  TSNode root_node = ts_document_root_node(document);
  assert(ts_node_child_count(root_node) == 2);
}
```

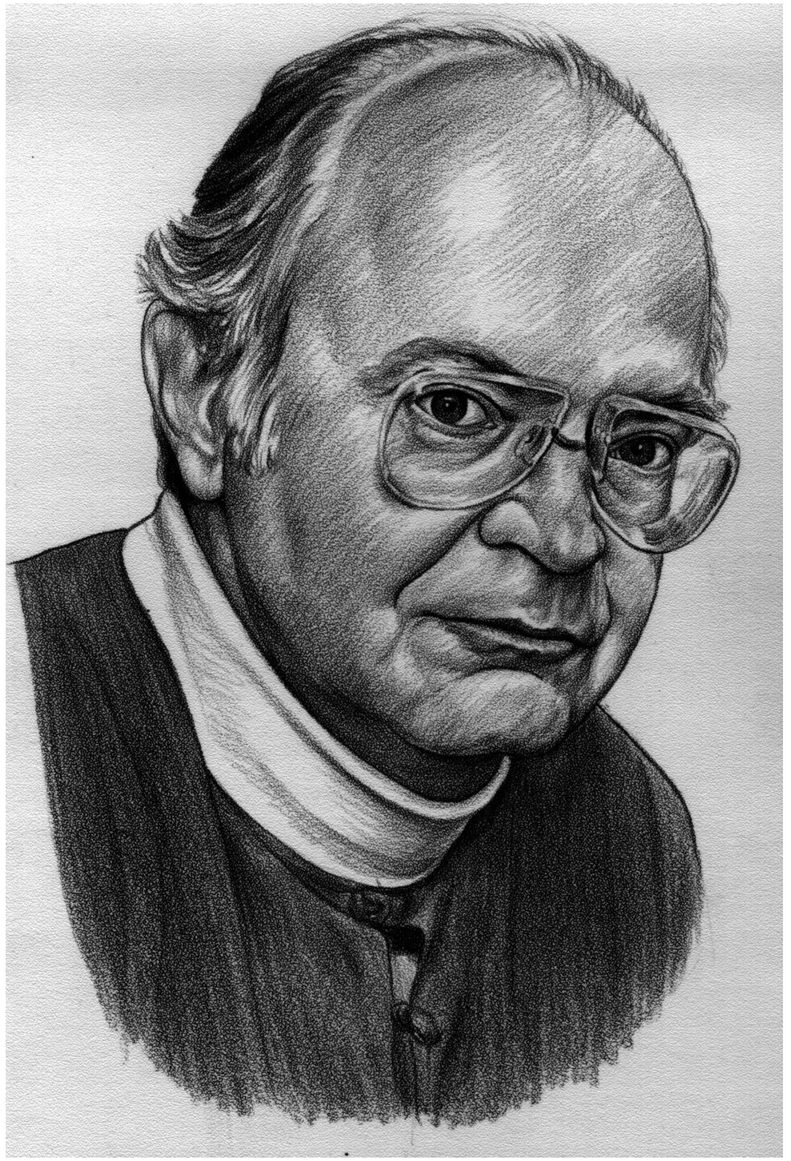
Algorithms

Existing Research

Practical Algorithms for Incremental Software Development Environments

Tim A. Wagner 1998

LR Parsing



LR Parsing

```
Text:     x * y + z
```

LR Parsing

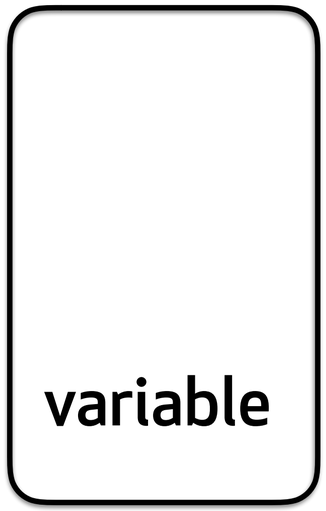
```
Text:      x * y + z
```

```
Stack:
```

LR Parsing

Text: x * y + z

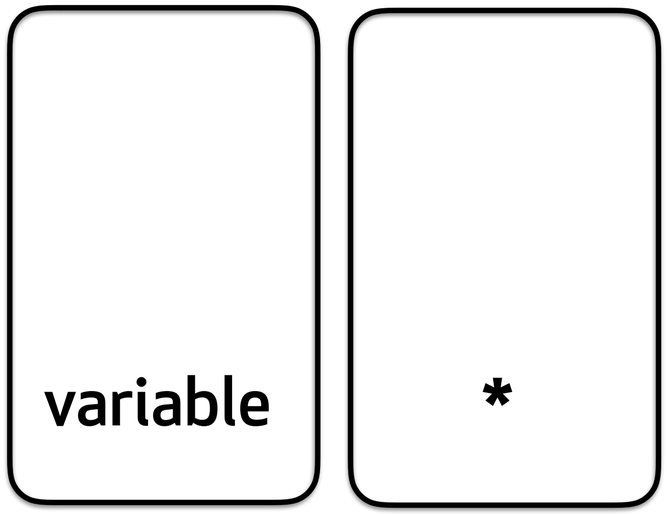
Stack:



LR Parsing

Text: x * y + z

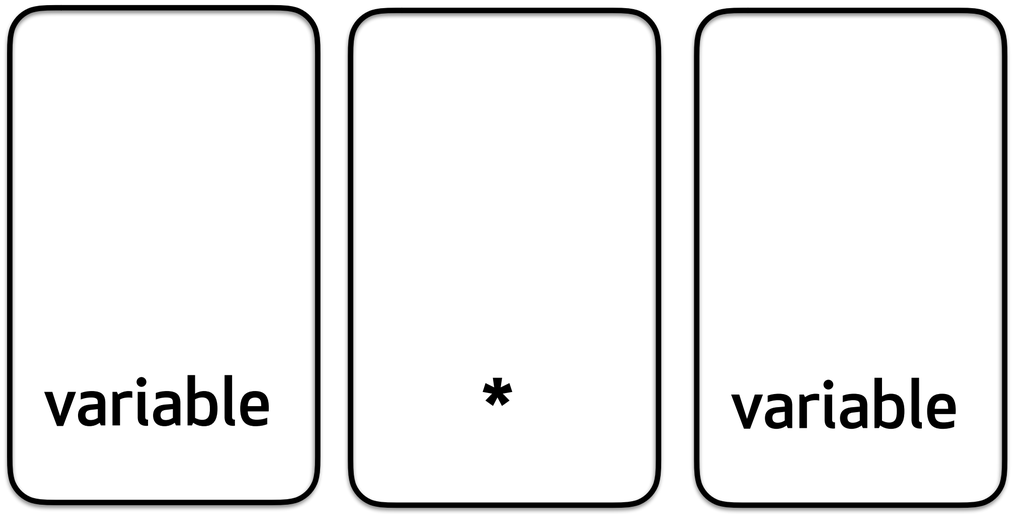
Stack:



LR Parsing

Text: x * y + z

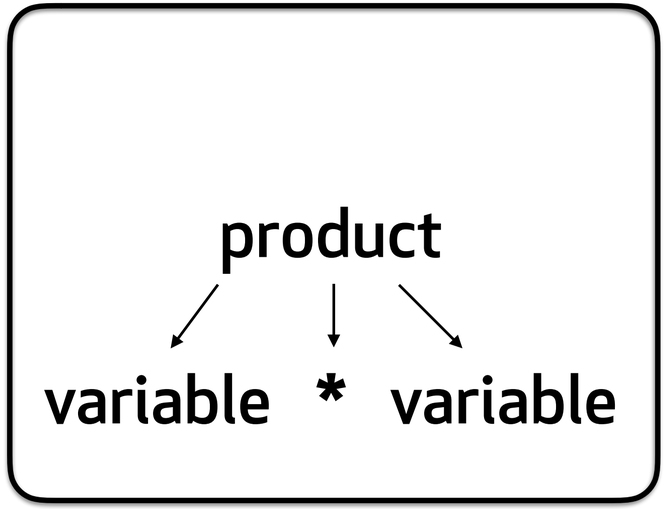
Stack:



LR Parsing

Text: `x * y + z`

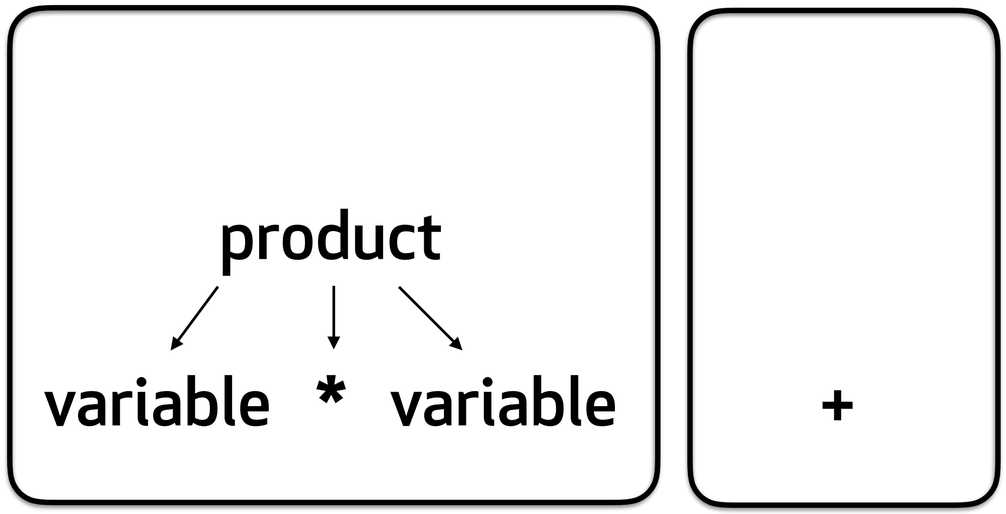
Stack:



LR Parsing

Text: `x * y + z`

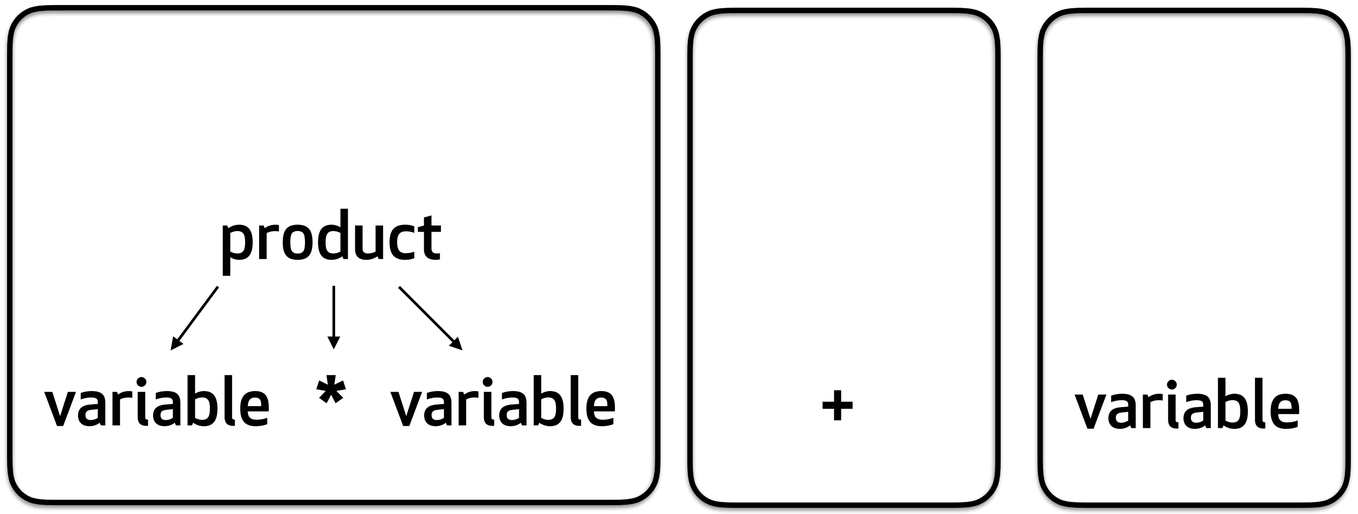
Stack:



LR Parsing

Text: `x * y + z`

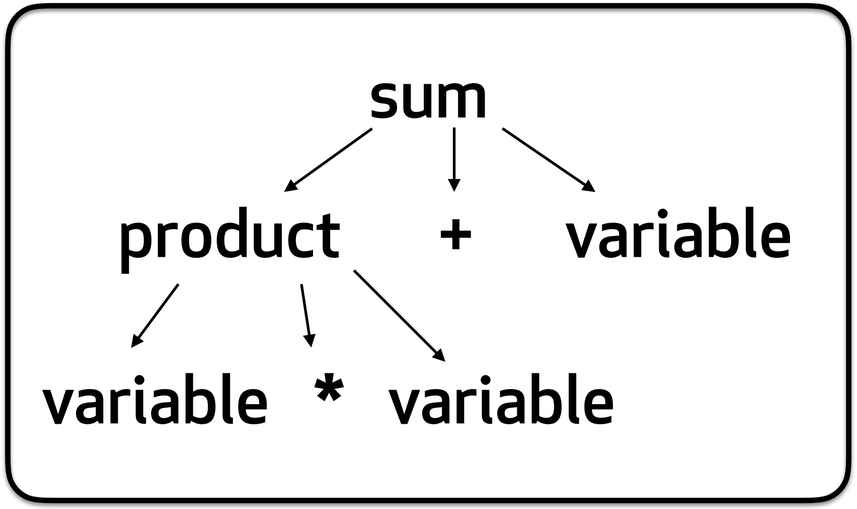
Stack:



LR Parsing

Text: `x * y + z`

Stack:



LR Parsing

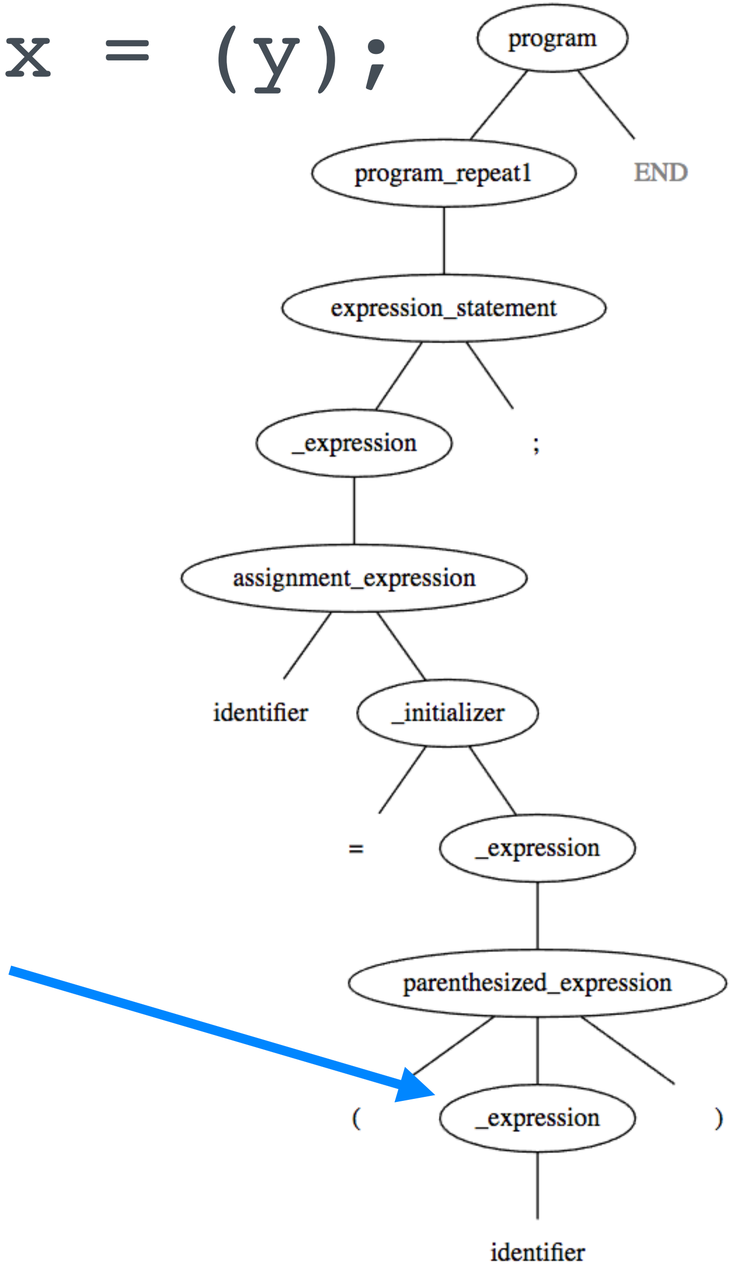
- Does this work for all languages?

LR Parsing

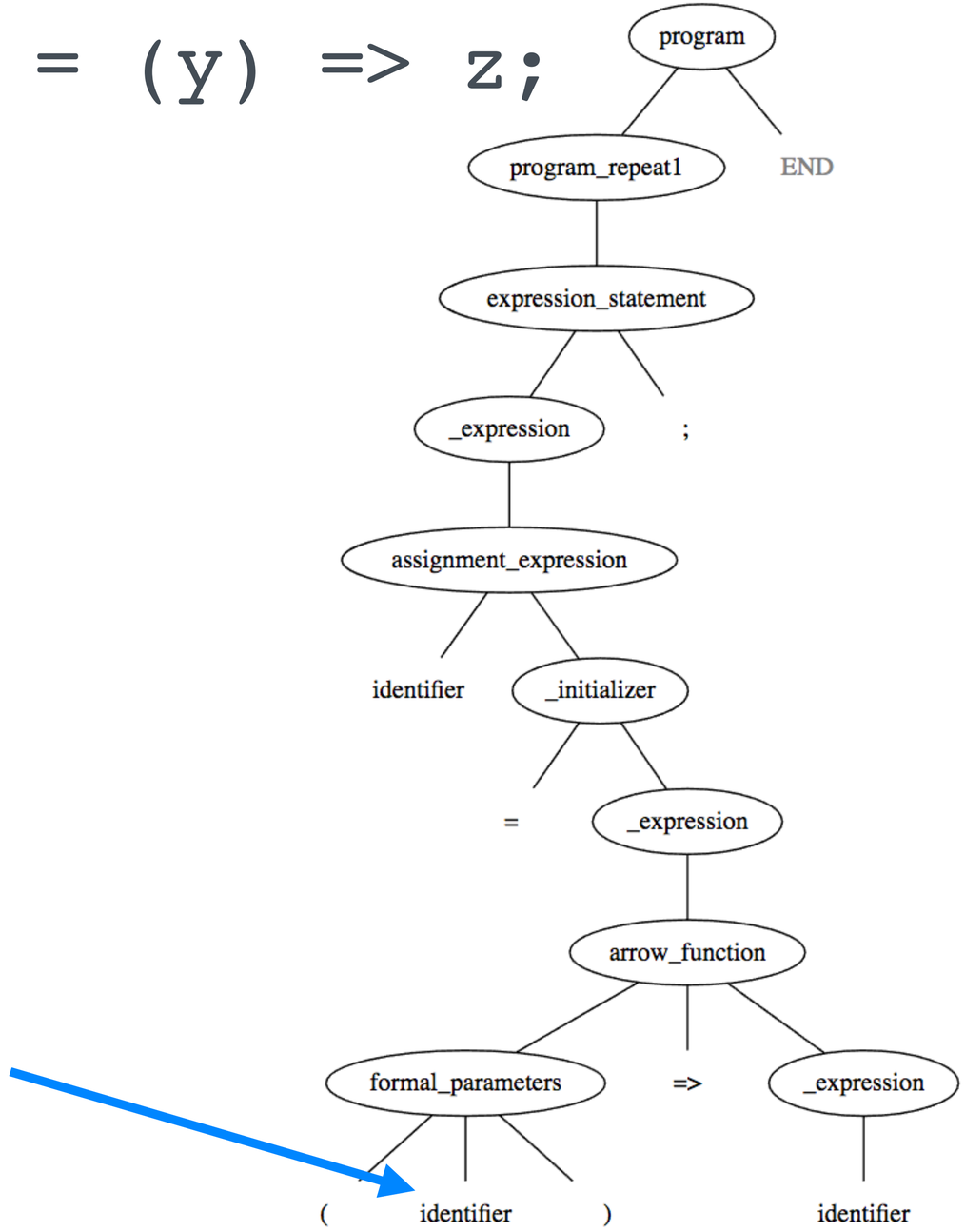
- Does this work for all languages? Nope.

```
x = (y);          // parenthesized expression
x = (y) => z; // arrow function
```

```
x = (y);
```

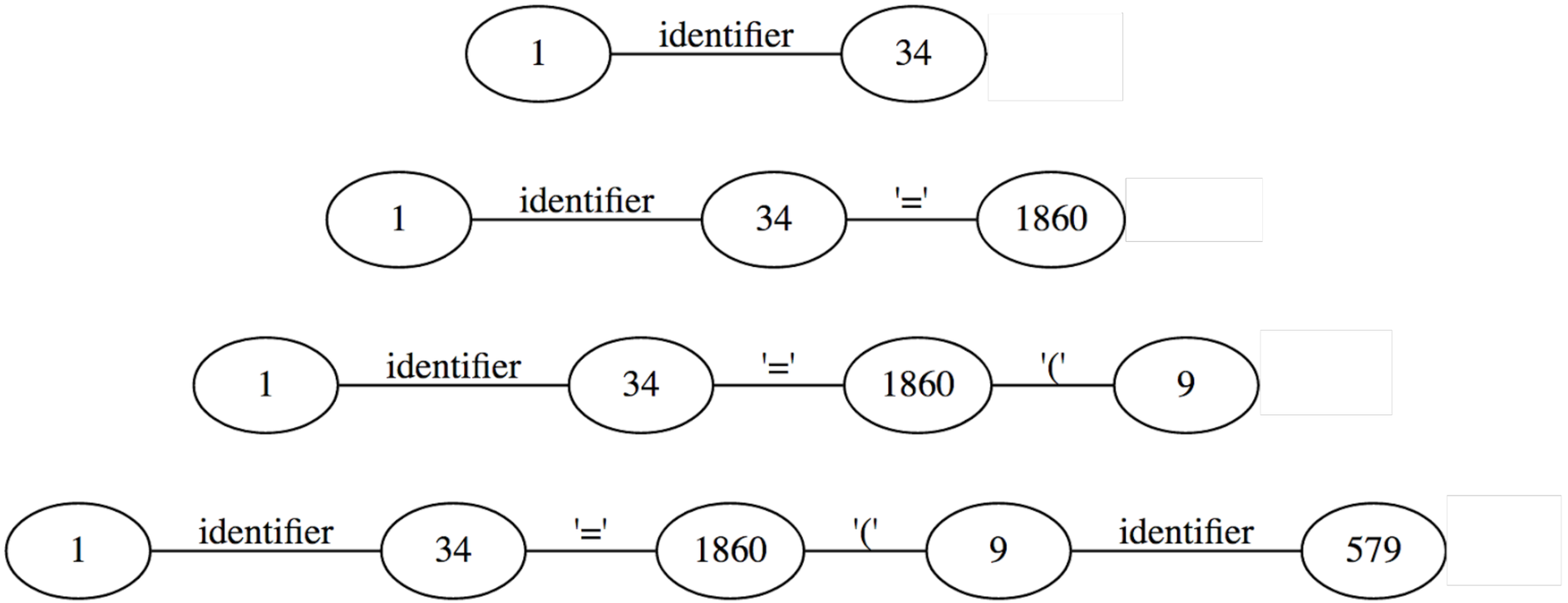

program
program_repeat1
END
expression_statement
_expression
;
assignment_expression
identifier
_initializer
=
_expression
parenthesized_expression
(
_expression
)
identifier

```
x = (y) => z;
```


program
program_repeat1
END
expression_statement
_expression
;
assignment_expression
identifier
_initializer
=
_expression
arrow_function
formal_parameters
=>
_expression
(
identifier
)
identifier

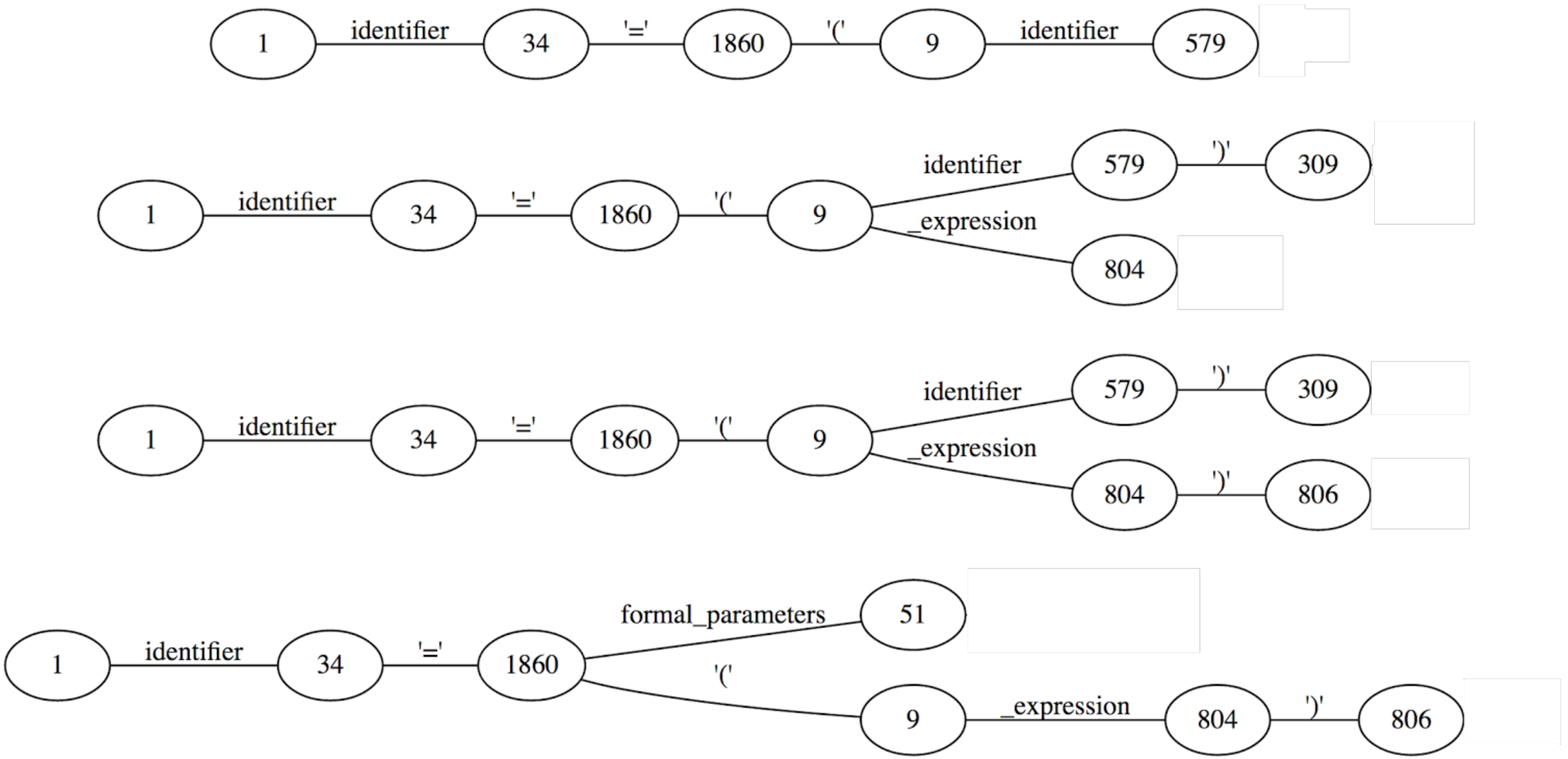
GLR Parsing

```
x = (y) => z;
```



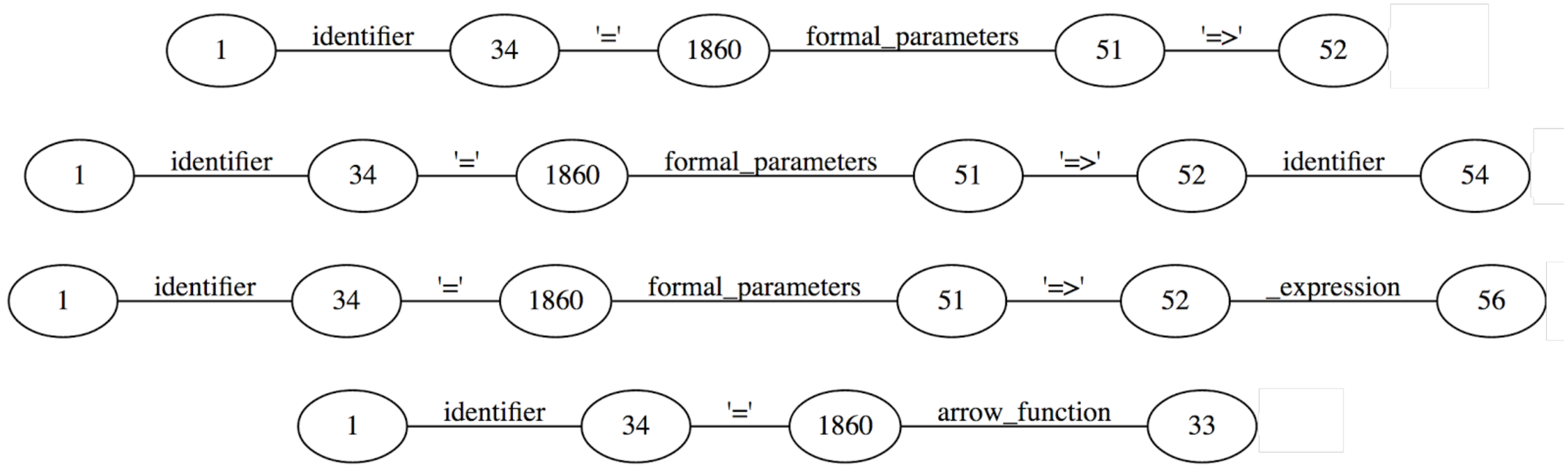
GLR Parsing

```
x = (y) => z;
```



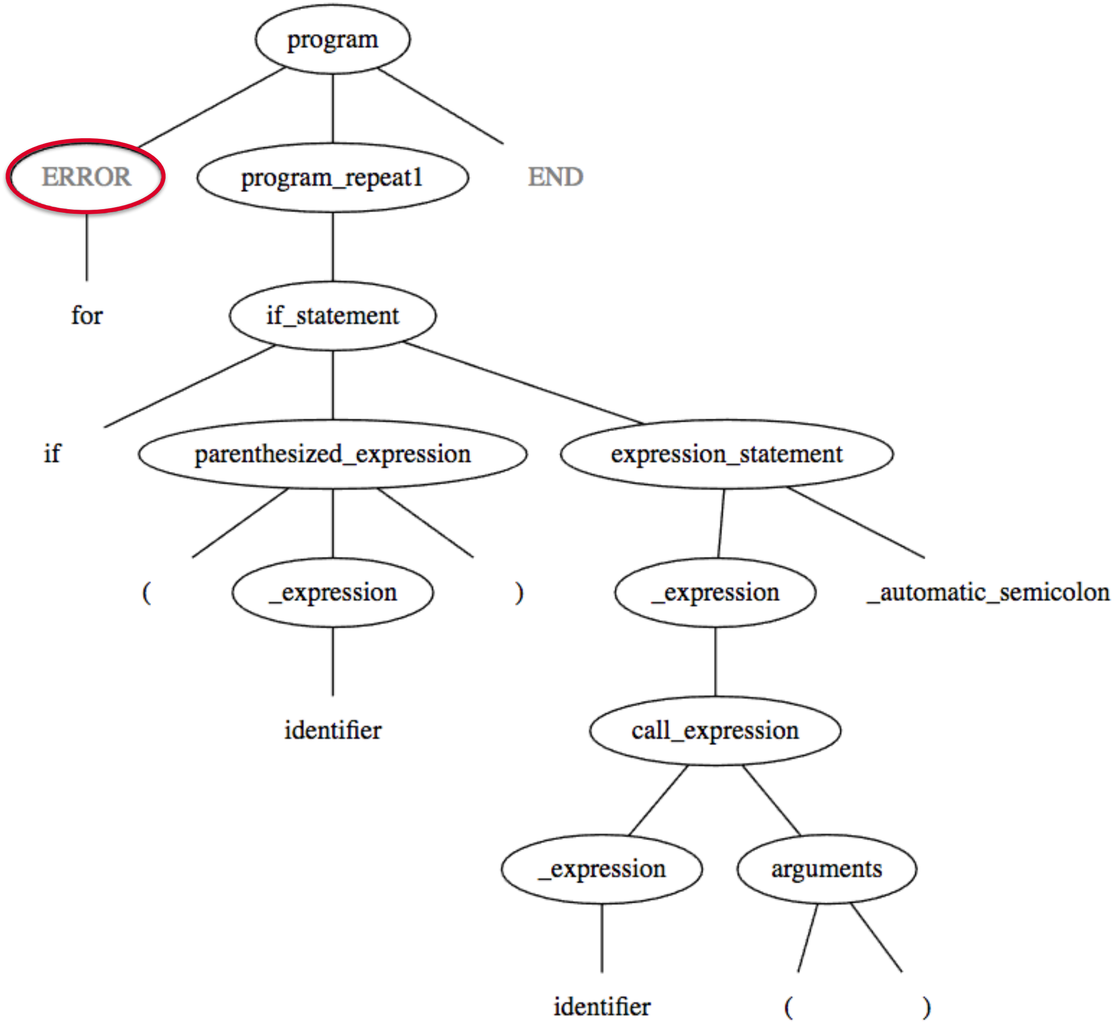
GLR Parsing

```
x = (y) => z;
```



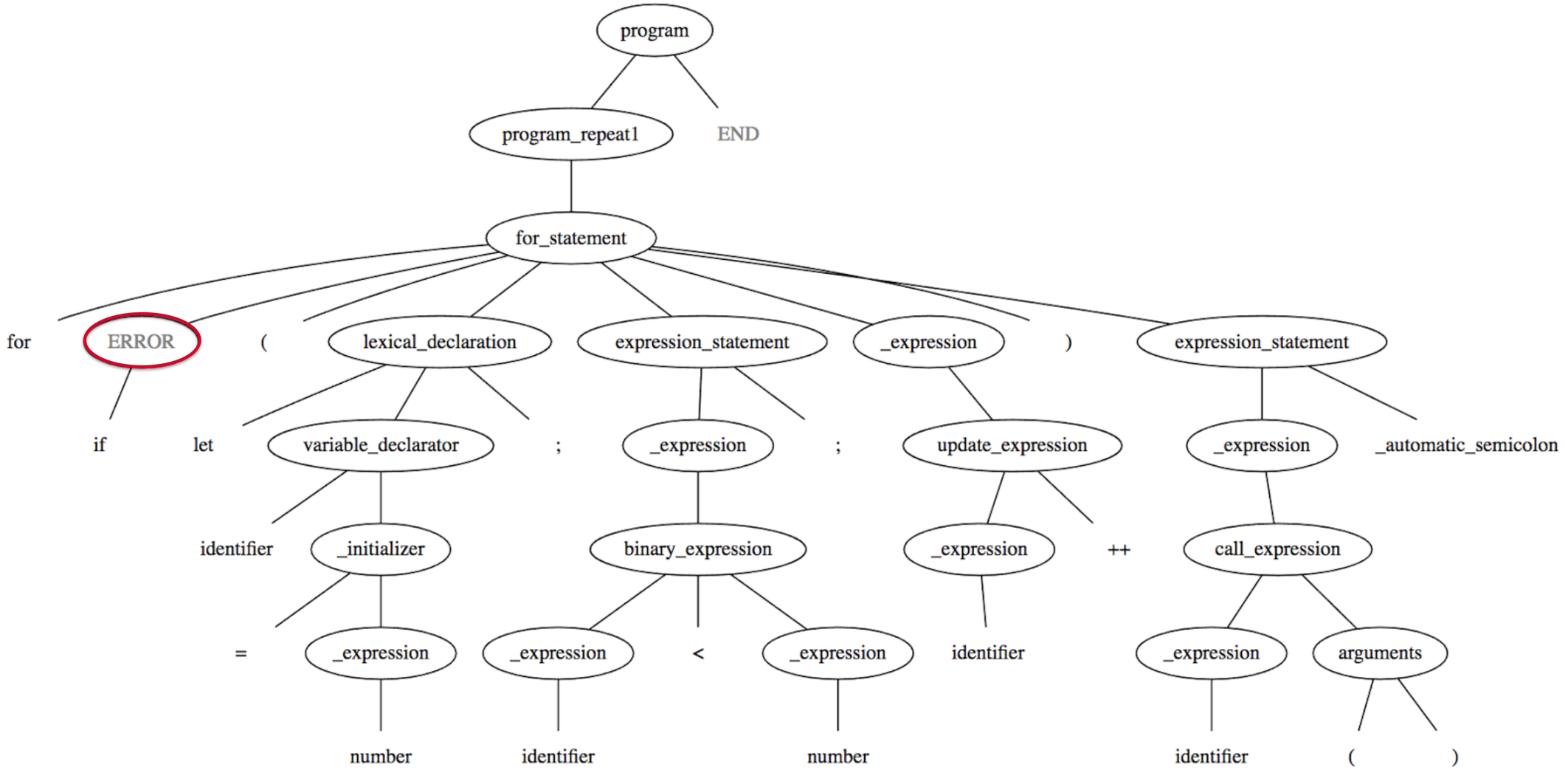
Error Recovery

```
for if (x) y()
```



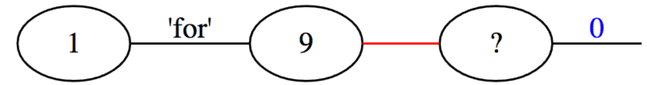
Error Recovery

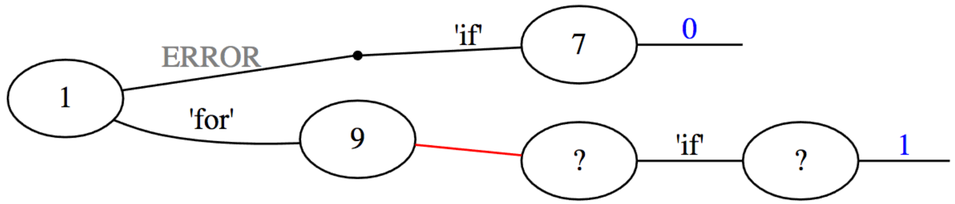
```
for if (let x = 0; x < 5; x++) y()
```

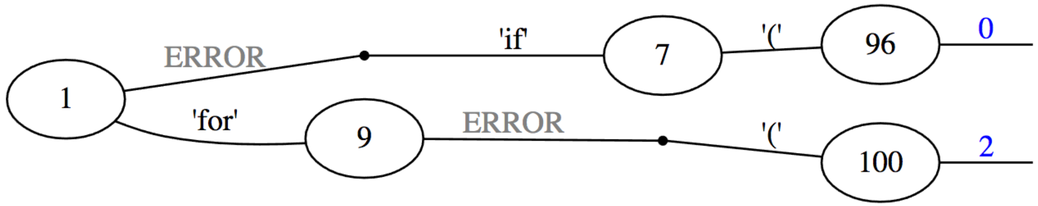


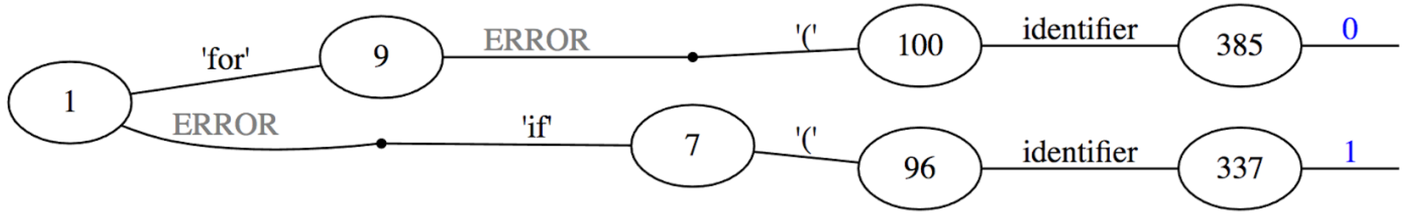
Error Recovery

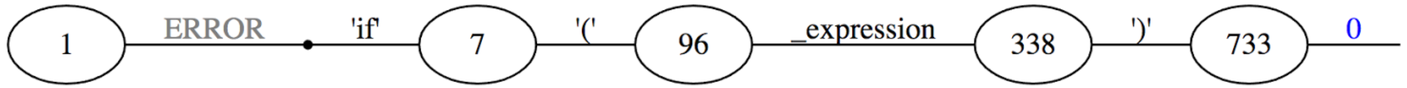
```
for if (x) y()
```





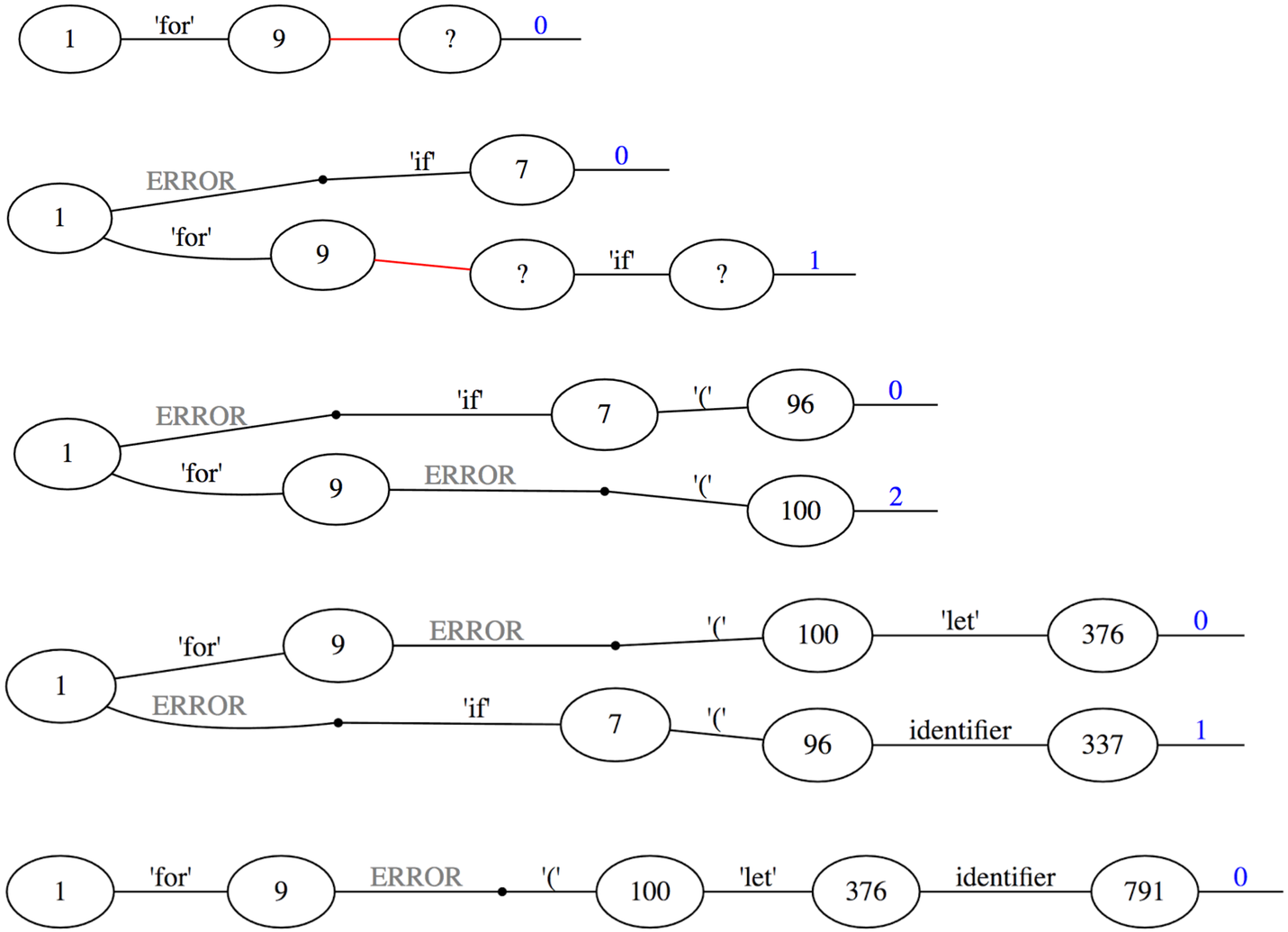






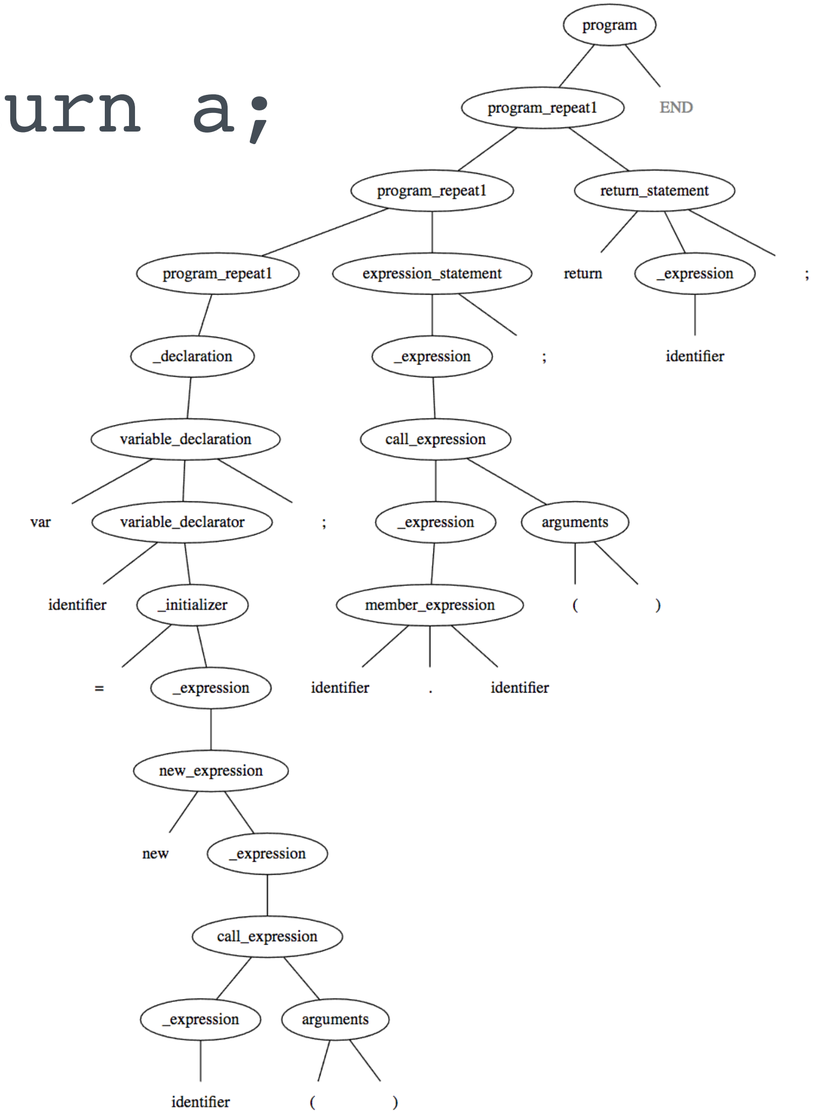
Error Recovery

```
for if (let x = 0; x < 5; x++) y()
```



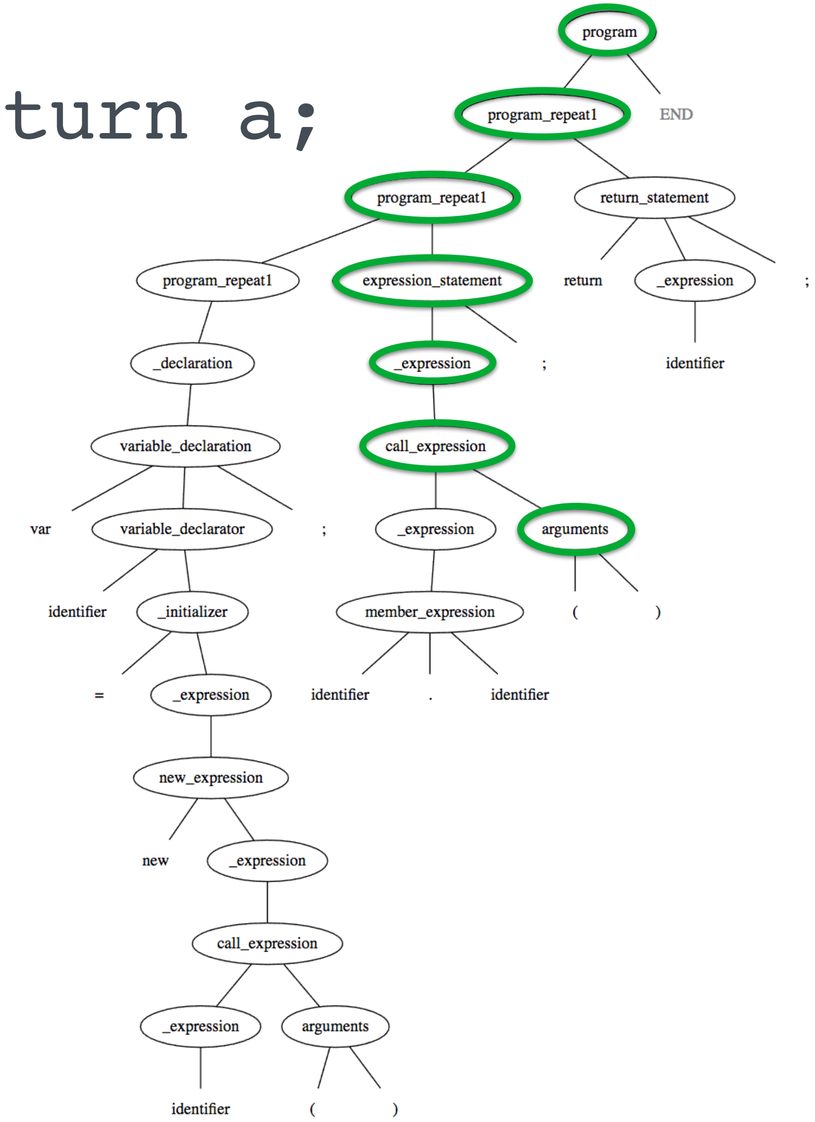
Incremental Parsing

```
Text:  var a = new B(); a.c(); return a;
```



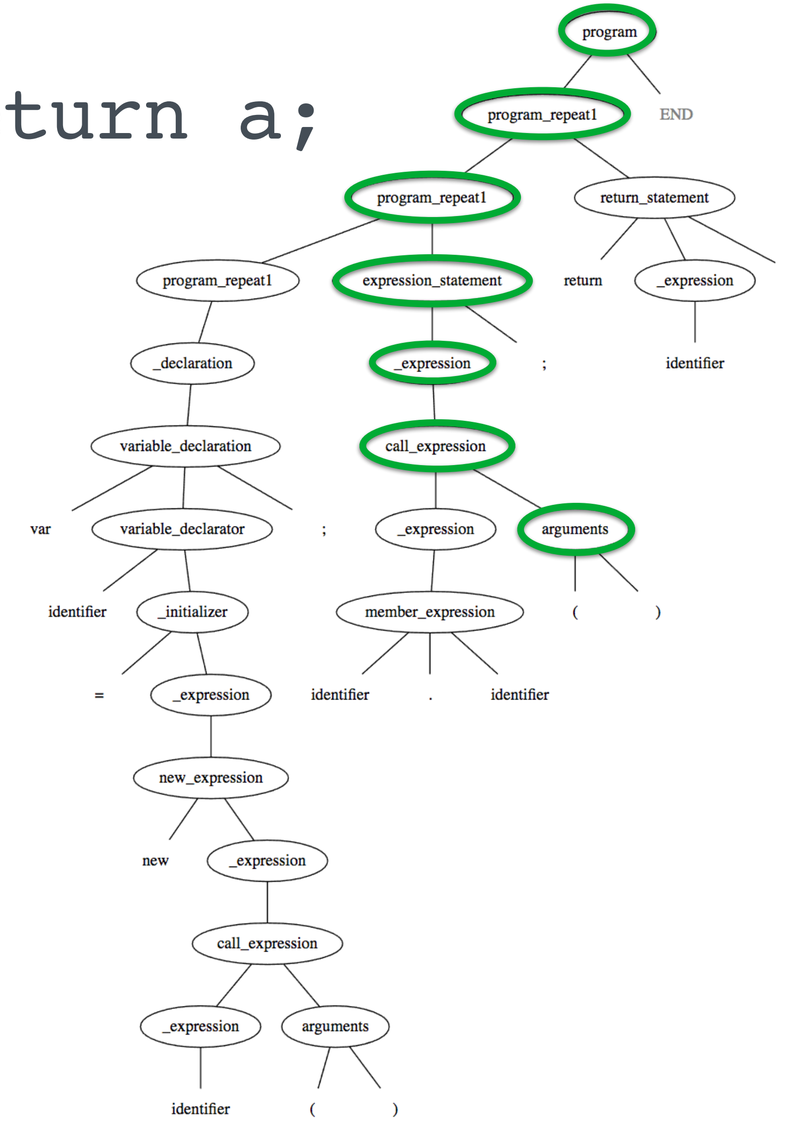
Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```



Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```



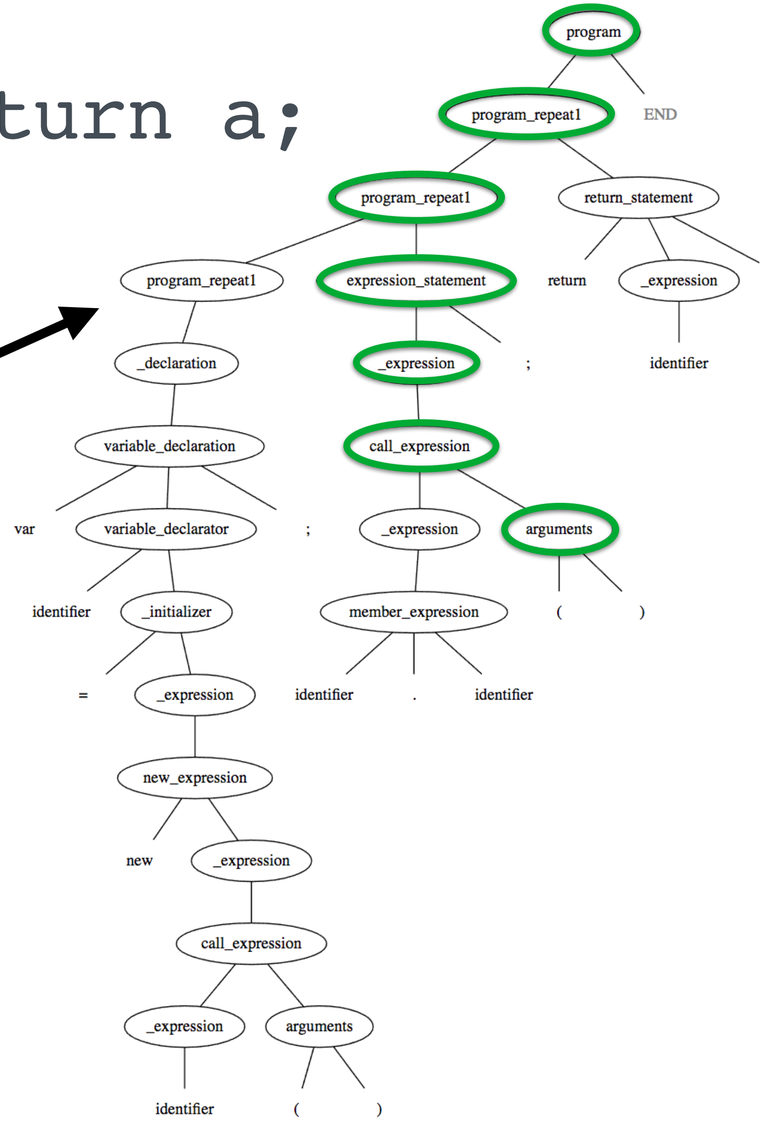

```
Stack:
```

Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

Stack:

variable declaration



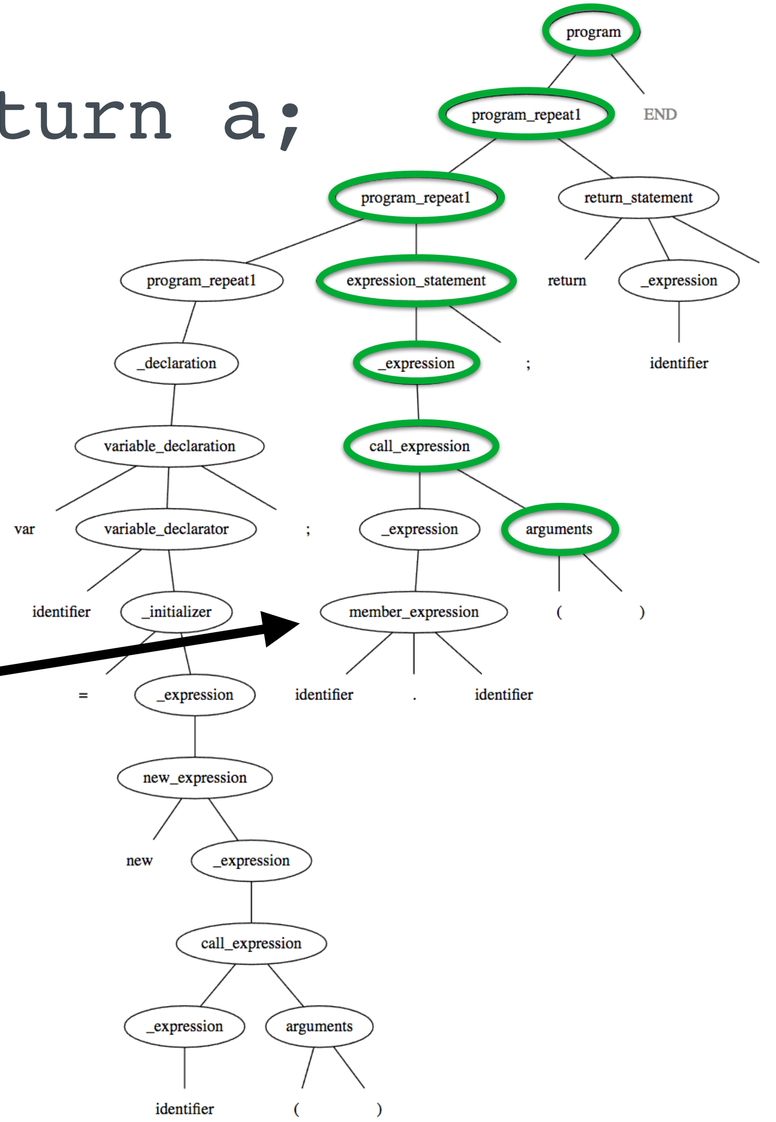
Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

Stack:

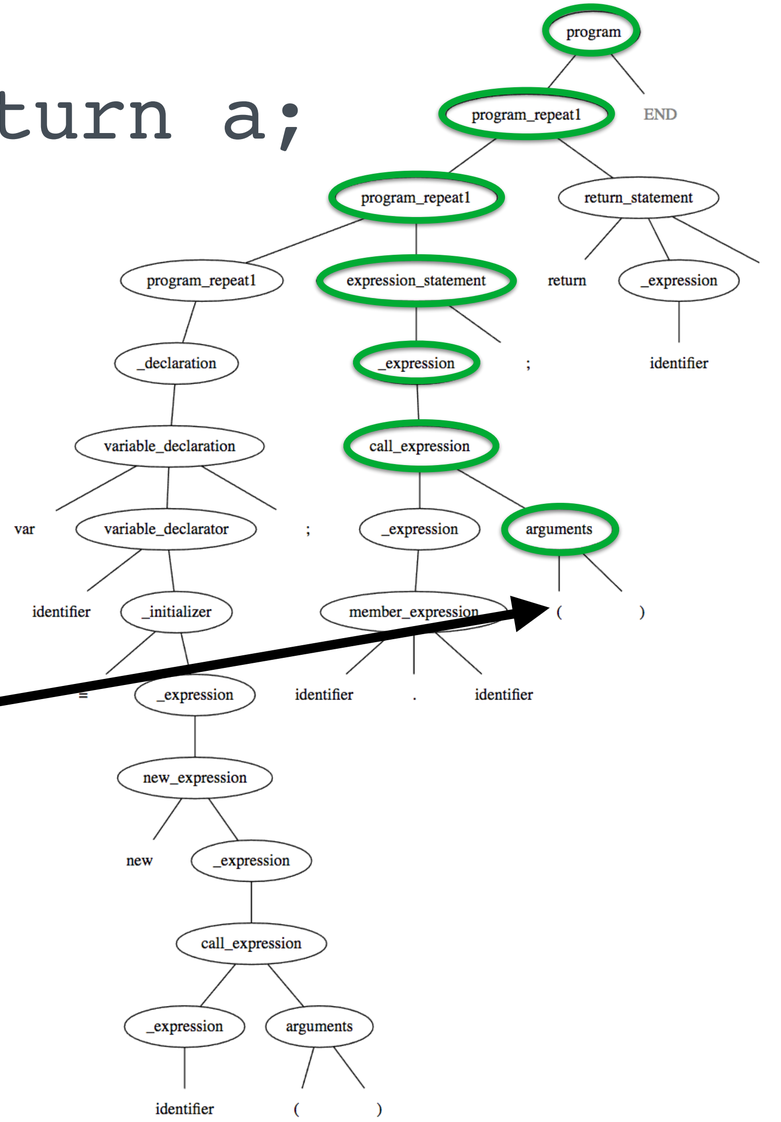
variable declaration

member expression

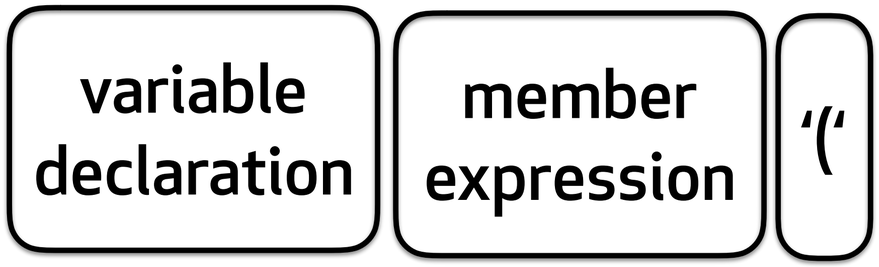


Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

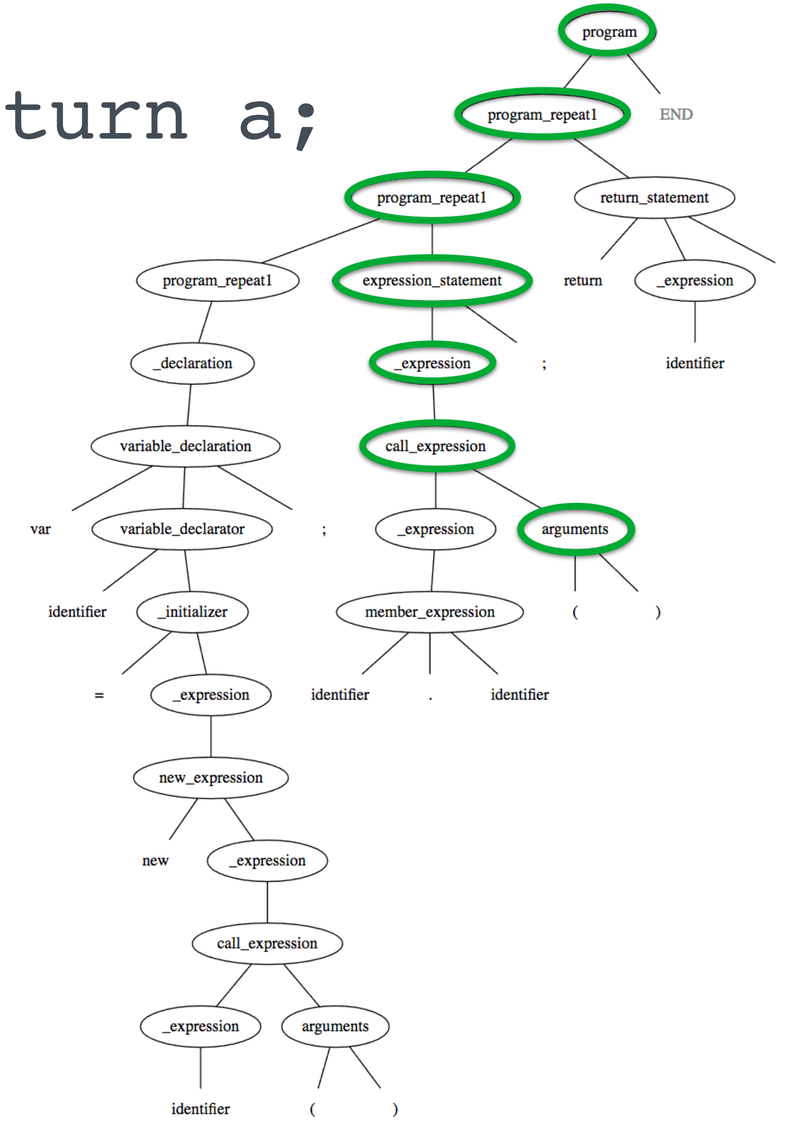


Stack:

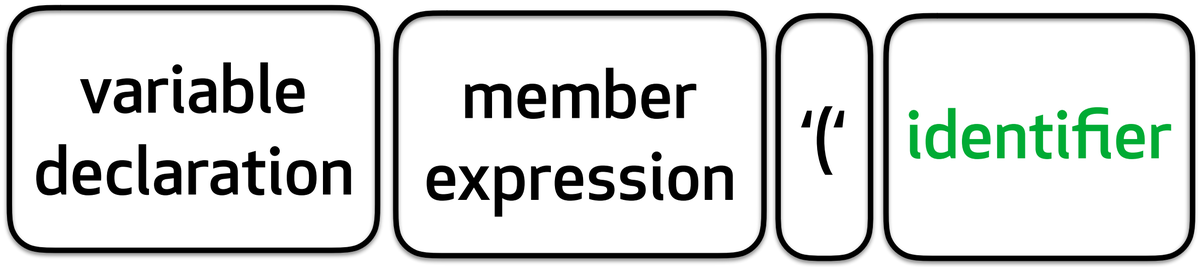


Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

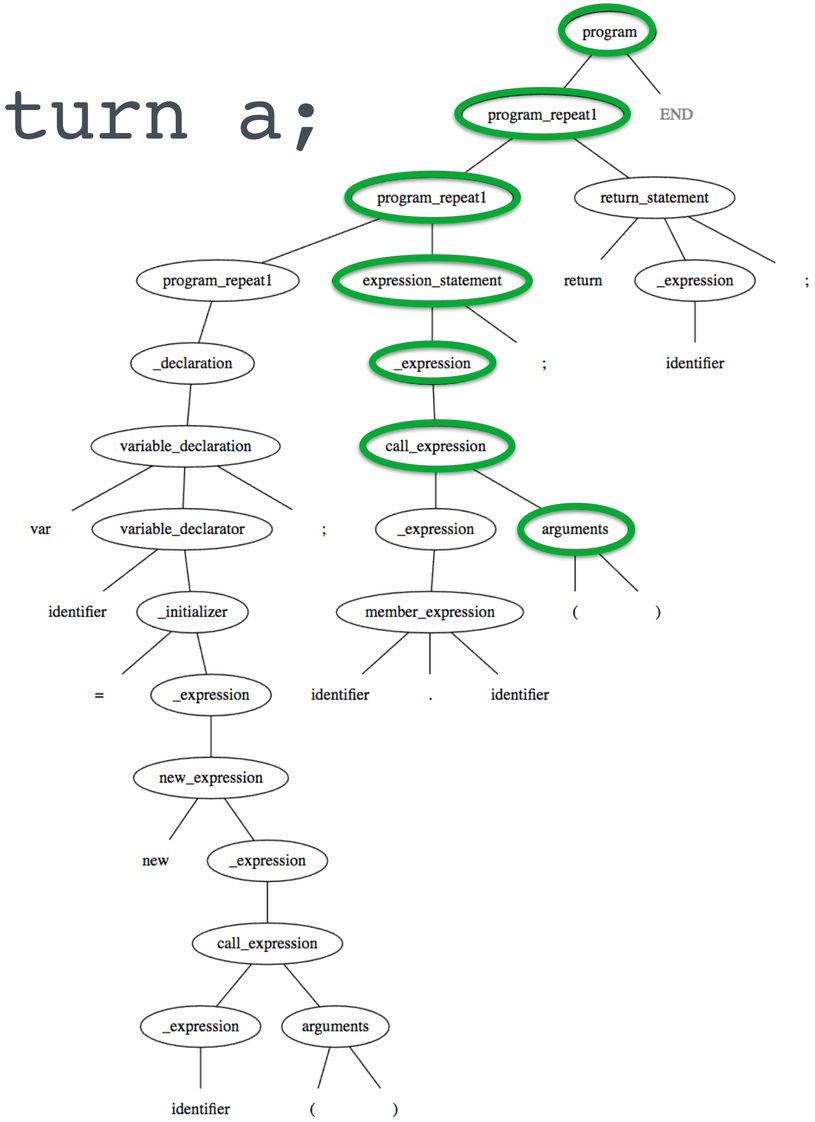


Stack:

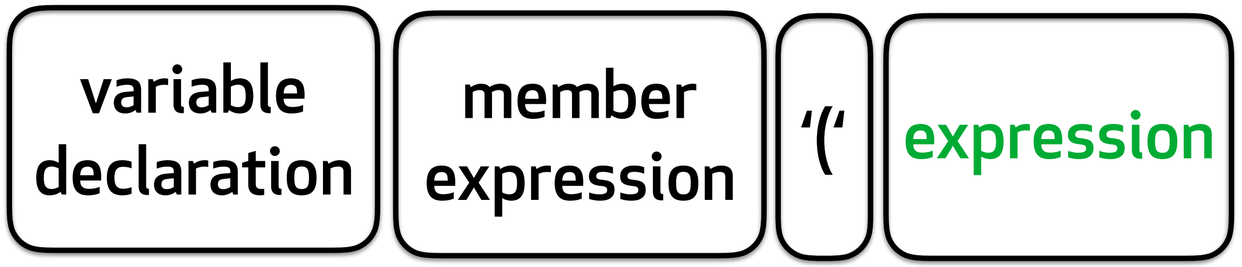


Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

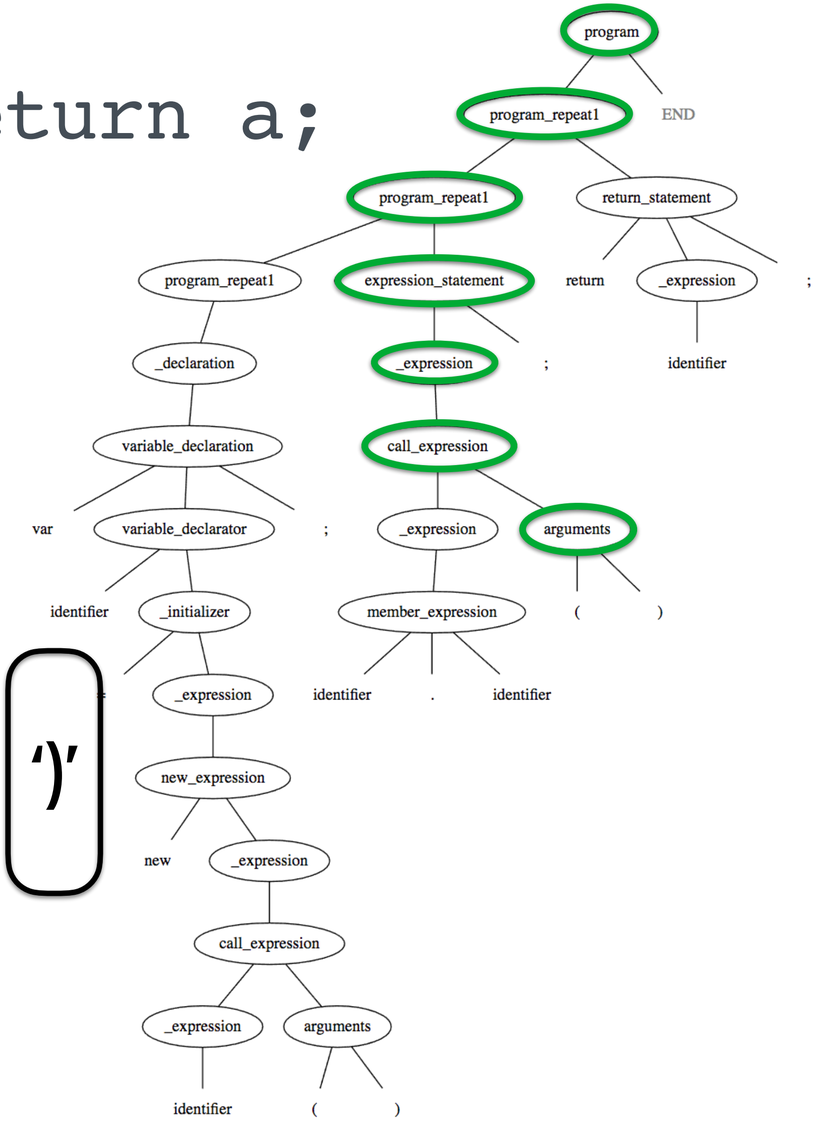


Stack:



Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

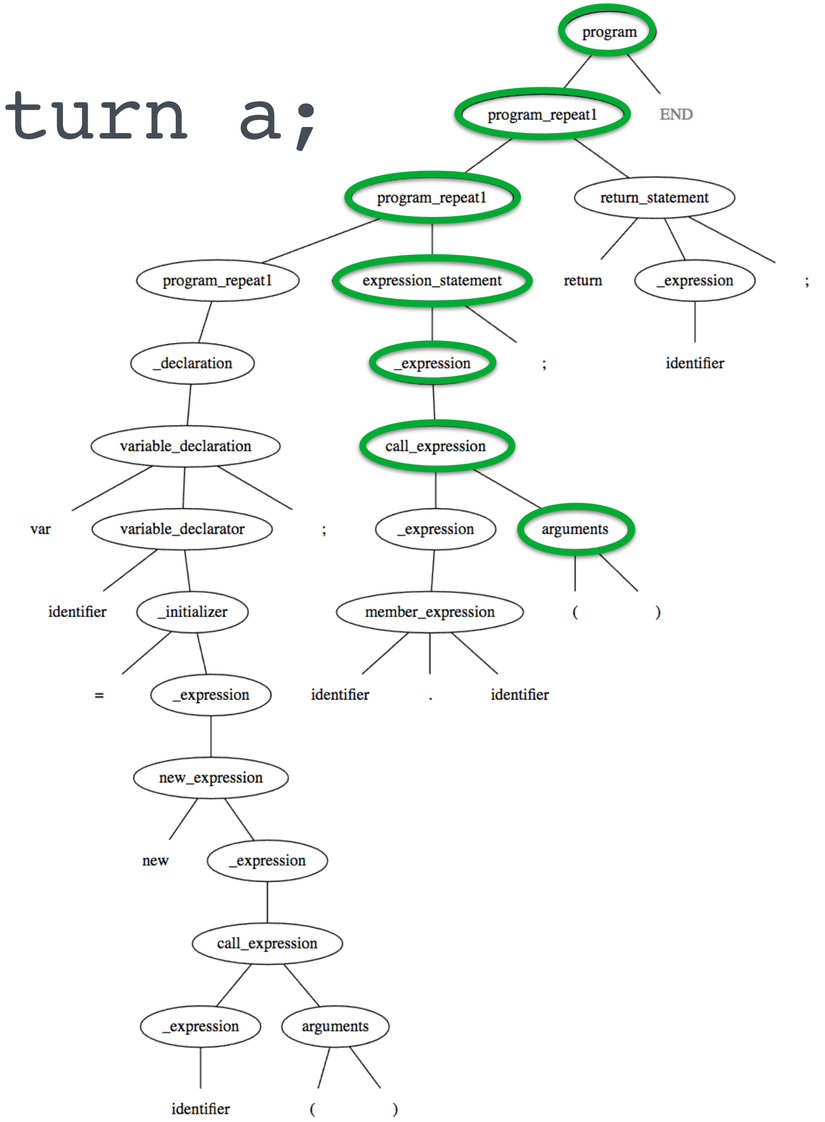



```
Stack:
```

variable declaration | member expression | “(“ | expression | “)”

Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

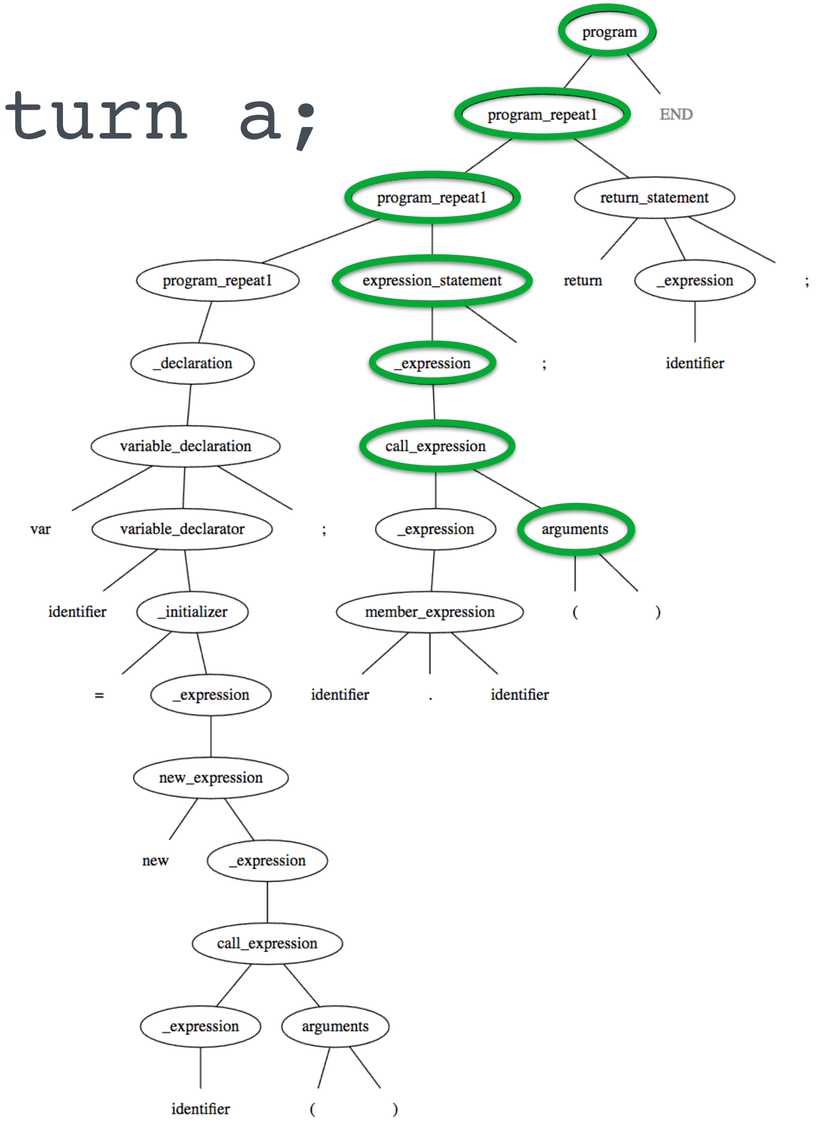


Stack:

- variable declaration
- member expression
- arguments

Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```



Stack:

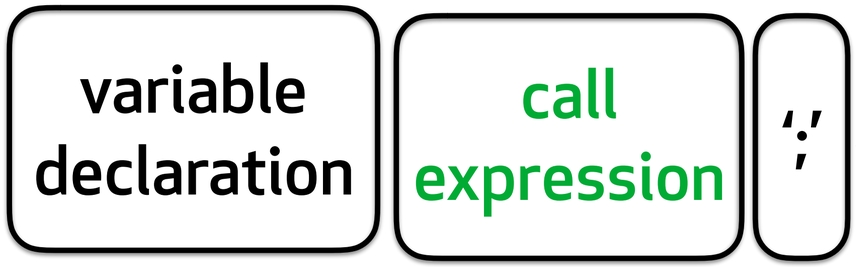
variable declaration

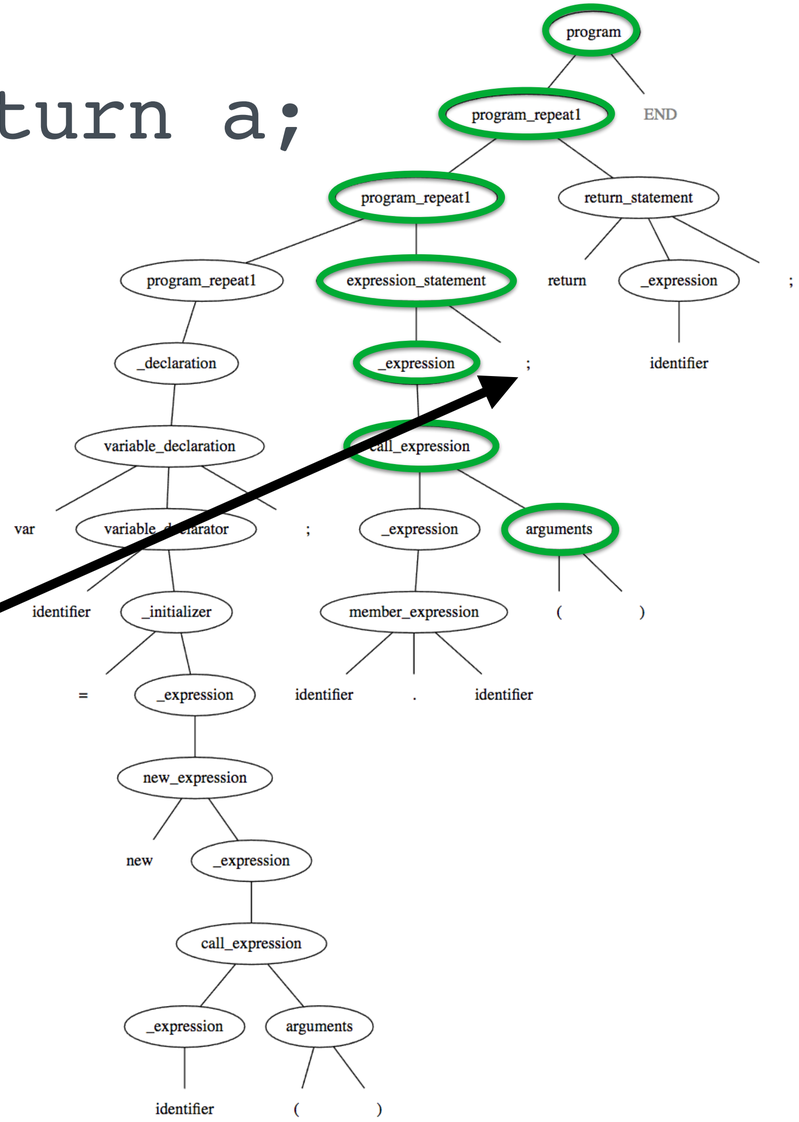
call expression

Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

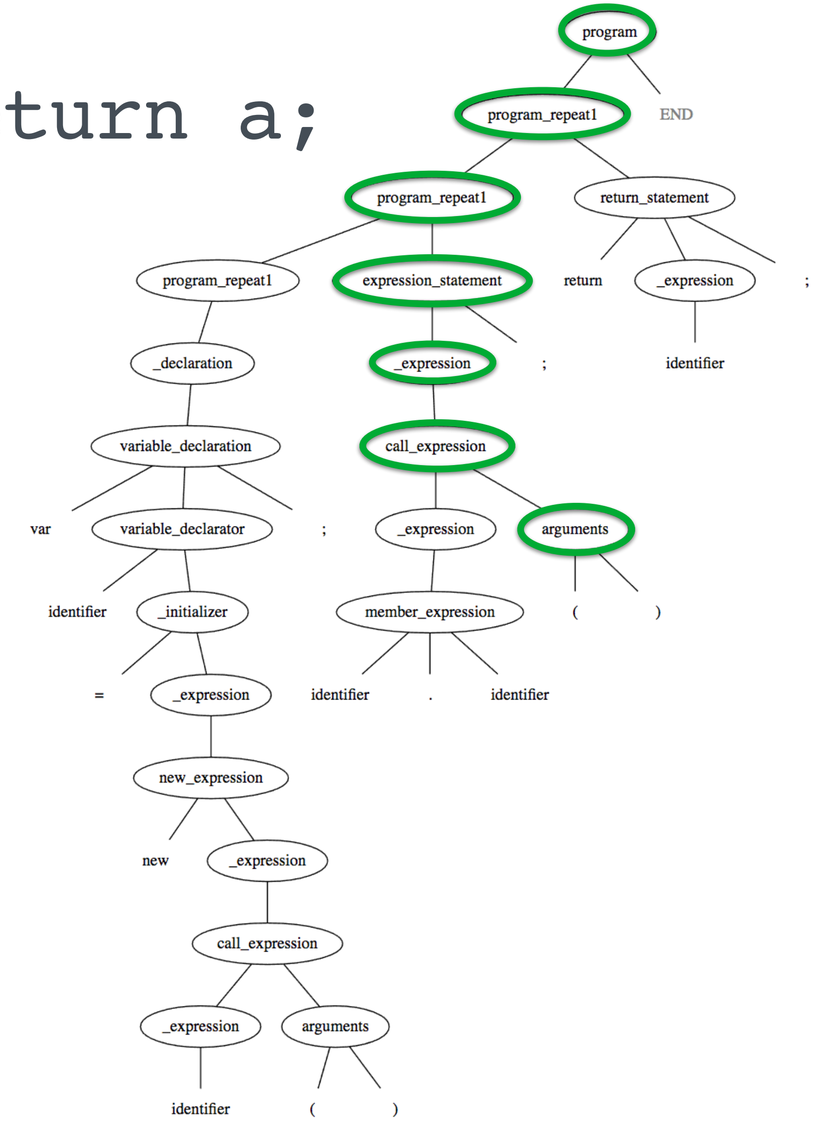
Stack:





Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```



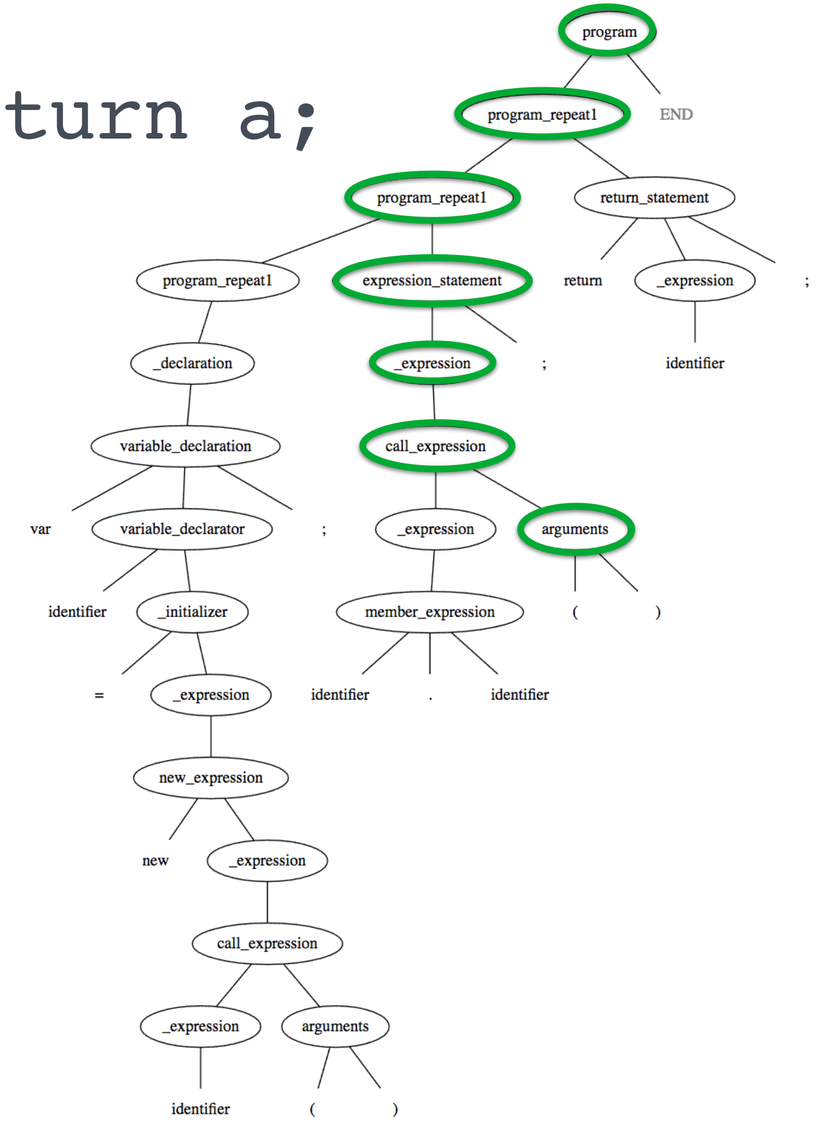
Stack:

variable declaration

expression statement

Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```




```
Stack:
```

program
repetition

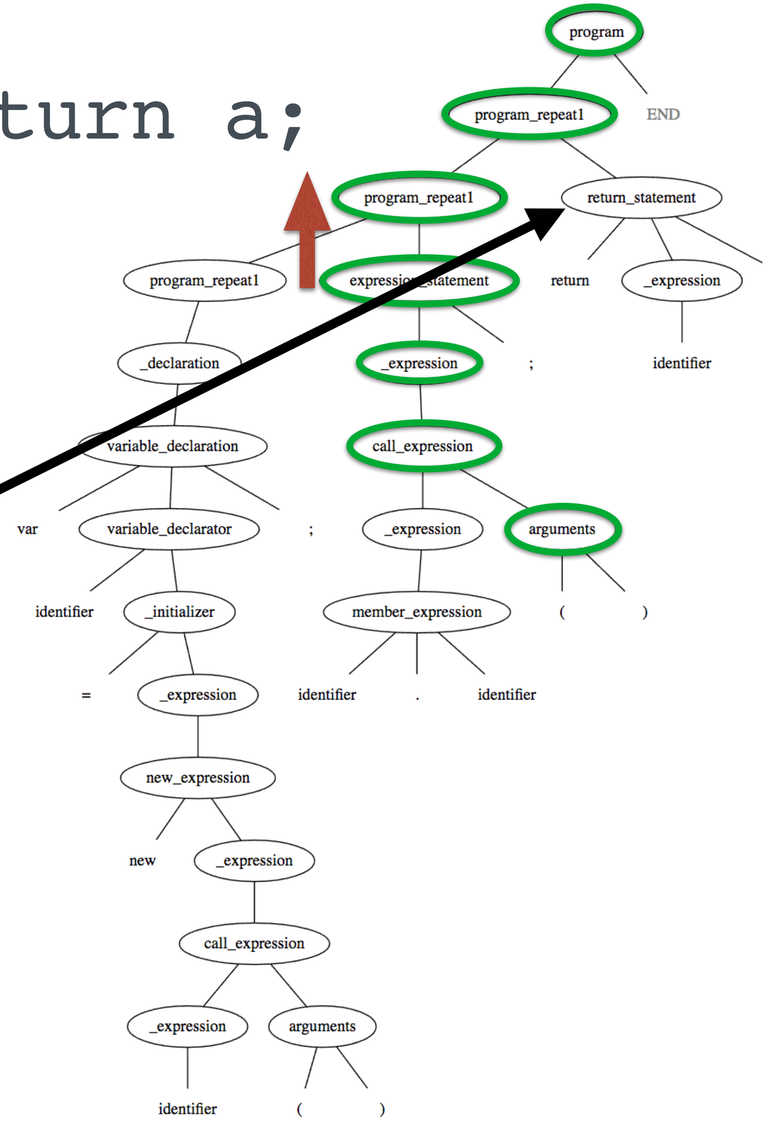
Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

Stack:

program repetition

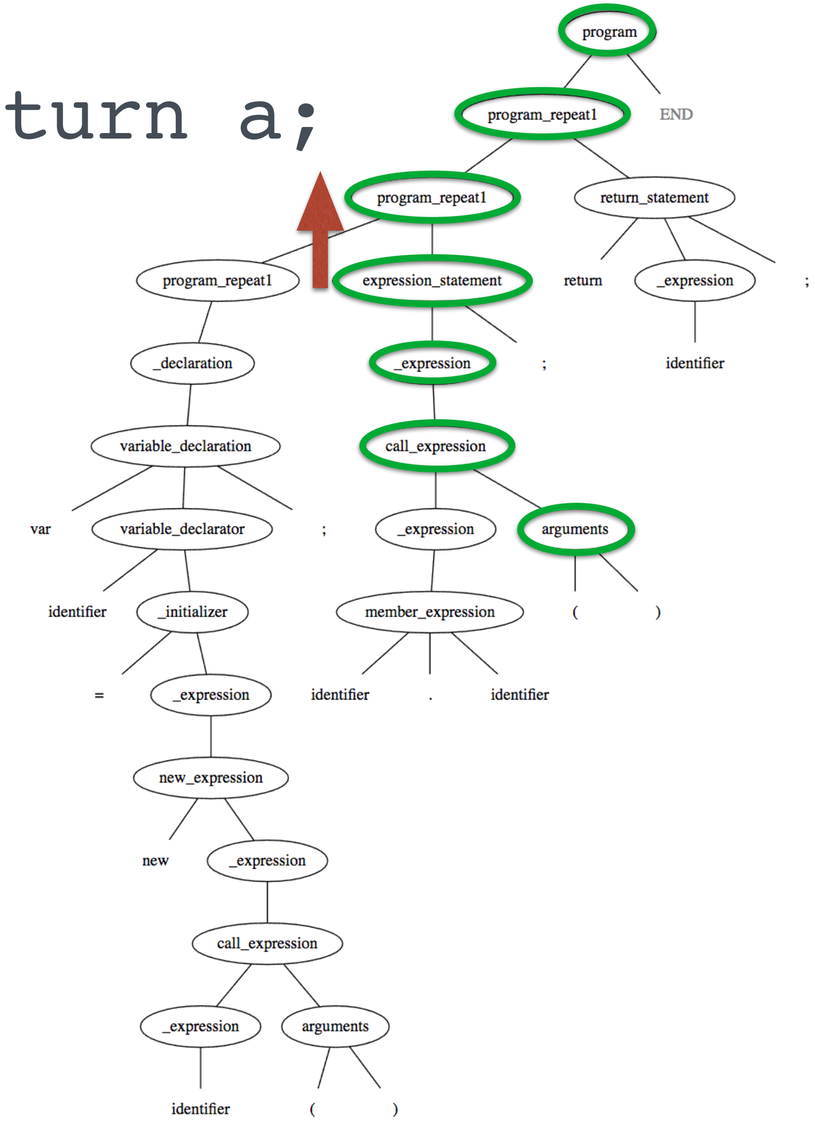
return statement



Incremental Parsing

```
Text:  var a = new B(); a.c(d); return a;
```

Stack: program



Next Steps

- Add support for more languages
- New Atom features using the syntax trees
- New GitHub.com features using syntax trees

Thank You!

@maxbrunsfeld