

Technical Report CS??-??

**Mnemosyne: A Functional  
Systems Programming Language**

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2015

*I hereby recognize and pledge to fulfill my  
responsibilities as defined in the Honor Code, and  
to maintain the integrity of both myself and the  
college community as a whole.*

---

Hawk Weisman

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**HAWK WEISMAN. Mnemosyne: A Functional Systems Programming Language.**  
**(Under the direction of Dr. Robert Roos.)**

**Abstract**

While programming languages researchers have produced a number of languages with various qualities that promote effective programming, such languages often may not be used for low-level systems programming. The automation of memory management through garbage collection often limits the use of many languages for systems programming tasks.

Mnemosyne is a new functional programming language intended for systems programming, providing methods of ensuring memory safety at compile-time rather than at runtime. This report outlines the design and development of a prototype Mnemosyne implementation and provides an abbreviated specification for the language.

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# **Chapter 1**

## **Introduction**



## **Chapter 2**

### **Background and Rationale**

# Chapter 3

## Design Considerations

This chapter demonstrates how to include short code segments, how to include pseudocode, and a few other  $\text{\LaTeX}$  features.

### 3.1 Experiments

### 3.2 Threats to Validity

# **Chapter 4**

## **Implementation**

### **4.1 Parsing and Syntactic Analysis**

### **4.2 Semantic Analysis**

### **4.3 Code Generation**

# **Chapter 5**

## **Evaluation**

Another possible chapter title: Experimental Results

# **Chapter 6**

## **Discussion and Future Work**

This chapter usually contains the following items, although not necessarily in this order or sectioned this way in particular.

### **6.1 Summary of Results**

A discussion of the significance of the results and a review of claims and contributions.

### **6.2 Future Work**

### **6.3 Conclusion**

# Appendix A

## The Mnemosyne Programming Language: An Abridged Description

The following is an abbreviated description of the Mnemosyne programming language. It is for illustrative purposes only and is not intended as a complete formal specification.

### A.1 Program Structure

All Mnemosyne programs consist of one or more *modules*. A module forms the top level of a Mnemosyne program and represents a namespace within which types and functions may be defined. A module then consists of a series of one or more *definitions* and *expressions*. An expression is a value-level construct: all expressions can be evaluated to some value, either at run-time or at compile-time. Definitions, by contrast, are type-level constructs.

### A.2 Syntax

Mnemosyne expressions may be written using either the traditional S-expression syntax or the indentation-sensitive I-expressions syntax.

#### A.2.1 Notation

Syntax descriptions are written using an extended BNF notation, as follows:

$\langle symbol \rangle$  indicates a non-terminal symbol

'symbol' indicates a terminal symbol

$\langle symbol \rangle^*$  indicates zero or more repetitions of  $\langle symbol \rangle$

$\langle symbol \rangle^+$  indicates one or more repetitions of  $\langle symbol \rangle$ .

$\epsilon$  indicates the empty string

The following special symbols refer to specific Unicode characters:

$\langle \textit{lambda} \rangle$  Greek capital letter Lambda (U+03BB)

$\langle \textit{arrow} \rangle$  Rightwards arrow (U+2192)

$\langle \textit{double arrow} \rangle$  Rightwards double arrow (U+21D2)

Finally, the symbol  $\langle \textit{any} \rangle$  refers to any character.

## A.2.2 Lexical Syntax

Note: ?? contains a source code listing for the Mnemosyne parser, and should be referred to to answer specific questions regarding how the reference Mnemosyne implementation handles specific characters.

$\langle \textit{program} \rangle \rightarrow \langle \textit{token} \rangle +$

$\langle \textit{token} \rangle \rightarrow \langle \textit{lexeme} \rangle \mid \langle \textit{atmosphere} \rangle$

$\langle \textit{lexeme} \rangle \rightarrow \langle \textit{identifier} \rangle \mid \langle \textit{operator} \rangle \mid \langle \textit{keyword} \rangle \mid \langle \textit{literal} \rangle$   
 $\mid \langle \textit{sigil} \rangle \mid \langle \textit{delimiter} \rangle$

$\langle \textit{sigil} \rangle \rightarrow \text{'@'} \mid \text{'&'} \mid \text{'*'} \mid \text{'$'} \mid \text{'?'}$

$\langle \textit{delimiter} \rangle \rightarrow \text{'('} \mid \text{'('} \mid \text{'{'} \mid \text{'{'}}$

$\langle \textit{identifier} \rangle \rightarrow \langle \textit{initial} \rangle \langle \textit{subsequent} \rangle^*$

$\langle \textit{initial} \rangle \rightarrow \langle \textit{letter} \rangle \mid \langle \textit{special initial} \rangle$

$\langle \textit{subsequent} \rangle \rightarrow \langle \textit{letter} \rangle \mid \langle \textit{number} \rangle \mid \langle \textit{special subsequent} \rangle$

$\langle \textit{letter} \rangle \rightarrow \text{'a'} \mid \text{'b'} \mid \text{'c'} \mid \dots \mid \text{'z'}$   
 $\mid \text{'A'} \mid \text{'B'} \mid \text{'C'} \mid \dots \mid \text{'Z'}$

$\langle \textit{number} \rangle \rightarrow \text{'0'} \mid \text{'1'} \mid \dots \mid \text{'9'}$

$\langle \textit{special initial} \rangle \rightarrow \text{'+'} \mid \text{'-'} \mid \text{'*'} \mid \text{'<'} \mid \text{'>'} \mid \text{'='}$   
 $\mid \text{'!'}$   $\mid \text{'.'}$   $\mid \text{'%'}$   $\mid \text{'^'}$

$\langle \textit{special subsequent} \rangle \rightarrow \langle \textit{special initial} \rangle \mid \text{'\''} \mid \text{'_'}$

$\langle \textit{keyword} \rangle \rightarrow \text{'and'} \mid \text{'begin'} \mid \text{'borrow'} \mid \text{'case'} \mid \text{'cond'}$   
 $\mid \text{'class'} \mid \text{'data'} \mid \text{'define'} \mid \text{'defn'} \mid \text{'def'}$   
 $\mid \text{'delay'} \mid \text{'do'} \mid \text{'else'} \mid \text{'if'} \mid \text{'instance'}$   
 $\mid \text{'impl'} \mid \text{'lambda'} \mid \text{'let'} \mid \text{'let*'} \mid \text{'letrec'}$   
 $\mid \text{'mod'} \mid \text{'or'} \mid \text{'quasiquote'} \mid \text{'quote'} \mid \text{'ref'}$   
 $\mid \text{'set!'} \mid \text{'struct'} \mid \text{'trait'} \mid \text{'type'} \mid \text{'typeclass'}$

$\mid$  'union'  $\mid$  'unquote'  $\mid$  'unquote-splicing'  
 $\mid$   $\langle \textit{lambda} \rangle$   $\mid$   $\langle \textit{arrow} \rangle$   $\mid$   $\langle \textit{fat arrow} \rangle$   
 $\mid$   $\langle \textit{builtin type} \rangle$   
 $\mid$  '|'  $\mid$  '->'  $\mid$  '=>'  $\mid$  ','

$\langle \textit{builtin type} \rangle \rightarrow$  'i8'  $\mid$  'i16'  $\mid$  'i32'  $\mid$  'i64'  $\mid$  'int'  
 $\mid$  'u8'  $\mid$  'ui6'  $\mid$  'u32'  $\mid$  'u64'  $\mid$  'uint'  
 $\mid$  'f32'  $\mid$  'f64'  $\mid$  'float'  $\mid$  'double'  
 $\mid$  'bool'  $\mid$  'string'

$\langle \textit{atmosphere} \rangle \rightarrow \langle \textit{whitespace} \rangle \mid \langle \textit{comment} \rangle$

$\langle \textit{whitespace} \rangle \rightarrow$  ' '  
 $\mid$  tab (U+0009)  
 $\mid$  linefeed (U+000A)  
 $\mid$  carriage return (U+000D)

$\langle \textit{comment} \rangle \rightarrow$  ';'  $\langle \textit{any} \rangle^*$   $\langle \textit{line ending} \rangle$   
 $\mid$  '#'  $\langle \textit{any} \rangle^*$  '#'

### A.2.3 Program Syntax

$\langle \textit{program} \rangle \rightarrow \langle \textit{module} \rangle^+$

$\langle \textit{module} \rangle \rightarrow \langle \textit{module-def} \rangle \langle \textit{definition} \rangle^*$

$\langle \textit{module-def} \rangle \rightarrow$  '(' 'mod'  $\langle \textit{identifier} \rangle$   $\langle \textit{exports-clause} \rangle$  ')'

$\langle \textit{exports-clause} \rangle \rightarrow$  '(' 'exports'  $\langle \textit{identifier} \rangle^+$  ')'  
 $\mid \epsilon$



# Appendix B

## Manganese Source Code

All program code should be fully commented. Authorship of all parts of the code should be clearly specified.

### B.1 Mnemosyne Core Crate

#### lib.rs

```
1  //
2  // Mnemosyne: a functional systems programming language.
3  // (c) 2015 Hawk Weisman
4  //
5  // Mnemosyne is released under the MIT License. Please refer to
6  // the LICENSE file at the top-level directory of this distribution
7  // or at https://github.com/hawkw/mnemosyne/.
8  //
9  #[crate_name = "mnemosyne"]
10 #[crate_type = "lib"]
11 #[feature(rustc_private)]
12 #[feature(static_recursion)]
13 #[feature(box_syntax, box_patterns)]
14
15 /// # Mnemosyne core
16 ///
17 /// This crate contains the core Mnemosyne programming language components.
18 /// This includes the mnemosyne abstract syntax tree ('semantic::ast'),
19 /// functions for performing semantic analysis ('semantic'), functions
20 /// for compiling abstract syntax trees to LLVM bytecode ('compile'), and
21 /// assorted utility code such as a positional reference type and a
22 /// 'ForkTable' data structure for use as a symbol table.
23 ///
24 /// The Mnemosyne parser is contained in a separate crate in order to improve
25 /// compile times.
26
27 extern crate rustc;
28 extern crate libc;
29 extern crate combine;
30 extern crate iron_llvm;
```

```

31 extern crate llvm_sys;
32 #[macro_use] extern crate itertools;
33
34 use rustc::lib::llvm::{LLVMVersionMajor, LLVMVersionMinor};
35
36 use std::fmt::Debug;
37
38 include!(concat!(env!("OUT_DIR"), "/gen.rs"));
39
40 /// Returns the Mnemosyne version as a String
41 pub fn mnemosyne_version() -> String {
42     format!("Mnemosyne {}", env!("CARGO_PKG_VERSION"))
43 }
44
45 /// Macro for formatting an internal compiler error panic.
46 ///
47 /// This should be used instead of the Rust standard library's 'panic!()'
48 /// macro in the event of an unrecoverable internal compiler error.
49 #[macro_export]
50 macro_rules! ice {
51     ($msg:expr) => (
52         panic!( "[internal error] {}\n \
53                 [internal error] Something has gone horribly wrong.\n \
54                 [internal error] Please contact the Mnemosyne implementors.\n\
55                 {}, {}"
56                 , $msg
57                 , $crate::mnemosyne_version(), $crate::llvm_version()
58             )
59     );
60     ($fmt:expr, $($arg:tt)+) => (
61         panic!( "[internal error] {}\n \
62                 [internal error] Something has gone horribly wrong.\n \
63                 [internal error] Please contact the Mnemosyne implementors.\n\
64                 {}, {}"
65                 , format_args!($fmt, $($arg)+)
66                 , $crate::mnemosyne_version(), $crate::llvm_version()
67             )
68     )
69 }
70
71 pub mod position;
72 pub mod semantic;
73 pub mod compile;
74 pub mod forktable;
75 pub mod chars;
76 pub mod errors;
77
78 pub use semantic::ast;

```

## chars.rs

```

1  /// Unicode code point for the lambda character
2  pub const LAMBDA: &'static str      = "\u{03bb}";
3  /// Unicode code point for the arrow character
4  pub const ARROW: &'static str       = "\u{8594}";
5  /// Unicode code point for the fat arrow (typeclass) character.
6  pub const FAT_ARROW: &'static str   = "\u{8685}";
7
8  pub const ALPHA_EXT: &'static str   = "+-*/<=>!:$%_~";
9  pub const OPS: &'static str         = "+-*/|=<>";

```

## errors.rs

```

1  //
2  // Mnemosyne: a functional systems programming language.
3  // (c) 2015 Hawk Weisman
4  //
5  // Mnemosyne is released under the MIT License. Please refer to
6  // the LICENSE file at the top-level directory of this distribution
7  // or at https://github.com/hawkw/mnemosyne/.
8  //
9
10 use std::fmt::{ Display, Debug };
11
12 /// Mnemosyne error handling
13
14 /// Wraps Option/Result with an 'expect_ice()' method.
15 ///
16 /// The 'expect_ice()' method functions similarly to the standard library's
17 /// 'expect()', but with the custom Mnemosyne internal compiler error message.
18 pub trait ExpectICE<T> {
19     fn expect_ice(self, msg: &str) -> T;
20 }
21
22 impl<T> ExpectICE<T> for Option<T> {
23     /// Unwraps an option, yielding the content of a 'Some'
24     ///
25     /// # Panics
26     ///
27     /// Panics using the Mnemosyne internal compiler error formatter
28     /// if the value is a 'None', with a custom panic message
29     /// provided by 'msg'.
30     ///
31     /// # Examples
32     ///
33     /// ```ignore
34     /// # use mnemosyne::errors::ExpectICE;
35     /// let x = Some("value");
36     /// assert_eq!(x.expect_ice("the world is ending"), "value");
37     /// ```
38     ///
39     /// ```ignore
40     /// # use mnemosyne::errors::ExpectICE;

```

```

41     /// let x: Option<Estr> = None;
42     /// x.expect_ice("the world is ending");
43     /// '''
44     #[inline]
45     fn expect_ice(self, msg: &str) -> T {
46         match self { Some(thing) => thing
47                     , None       => ice!(msg)
48                     }
49     }
50 }
51
52 impl<T, E> ExpectICE<T> for Result<T, E>
53 where E: Debug {
54
55     /// Unwraps a result, yielding the content of an 'Ok'.
56     ///
57     /// Panics using the Mnemosyne internal compiler error formatter
58     /// if the value is an 'Err', with a panic message including the
59     /// passed message, and the content of the 'Err'.
60     ///
61     /// # Examples
62     /// '''ignore
63     /// # use mnemosyne::errors::ExpectICE;
64     /// let x: Result<u32, Estr> = Err("emergency failure");
65     /// x.expect_ice("Testing expect");
66     /// '''
67     #[inline]
68     fn expect_ice(self, msg: &str) -> T {
69         match self { Ok(t) => t
70                     , Err(e) => ice!("{}", ":", ":", msg, e)
71                     }
72     }
73 }
74
75 /// Wraps Option/Result with an 'unwrap_ice()' method.
76 ///
77 /// The 'unwrap_ice()' method functions similarly to the standard library's
78 /// 'unwrap()', but with the custom Mnemosyne internal compiler error message.
79 pub trait UnwrapICE<T> {
80     fn unwrap_ice(self) -> T;
81 }
82
83 impl<T> UnwrapICE<T> for Option<T> {
84     /// Moves the value 'v' out of the 'Option<T>' if it is 'Some(v)'.
85     ///
86     /// Unlike the standard library's 'unwrap()', this uses the Mnemosyne
87     /// internal compiler error panic formatter.
88     ///
89     /// # Panics
90     ///
91     /// Panics if the self value equals 'None'.
92     ///

```

```

93     /// # Safety note
94     ///
95     /// In general, because this function may panic, its use is discouraged.
96     /// Instead, prefer to use pattern matching and handle the 'None'
97     /// case explicitly.
98     ///
99     /// # Examples
100    ///
101    /// '''ignore
102    /// # use mnemosyne::errors::UnwrapICE;
103    /// let x = Some("air");
104    /// assert_eq!(x.unwrap_ice(), "air");
105    /// '''
106    ///
107    /// '''ignore
108    /// # use mnemosyne::errors::UnwrapICE;
109    /// let x: Option<&str> = None;
110    /// assert_eq!(x.unwrap_ice(), "air"); // fails
111    /// '''
112    #[inline]
113    fn unwrap_ice(self) -> T {
114        match self { Some(thing) => thing
115                    , None =>
116                        ice!("called 'Option::unwrap()' on a 'None' value")
117                    }
118    }
119 }
120
121 impl<T, E> UnwrapICE<T> for Result<T, E>
122 where E: Display {
123     /// Unwraps a result, yielding the content of an 'Ok'.
124     ///
125     /// Unlike the standard library's 'unwrap()', this uses the Mnemosyne
126     /// internal compiler error panic formatter.
127     ///
128     /// # Panics
129     ///
130     /// Panics if the value is an 'Err', with a panic message provided by the
131     /// 'Err's value.
132     ///
133     /// # Examples
134     ///
135     /// '''ignore
136     /// # use mnemosyne::errors::UnwrapICE;
137     /// let x: Result<u32, &str> = Ok(2);
138     /// assert_eq!(x.unwrap_ice(), 2);
139     /// '''
140     ///
141     /// '''ignore
142     /// # use mnemosyne::errors::UnwrapICE;
143     /// let x: Result<u32, &str> = Err("emergency failure");
144     /// x.unwrap_ice(); // panics

```

```

145     /// '''
146     #[inline]
147     fn unwrap_ice(self) -> T {
148         match self { Ok(t) => t
149                     , Err(e) => ice!("{}", e)
150                     }
151     }
152 }
153 //
154 // impl<T, E> UnwrapICE<T> for Result<T, E>
155 // where E: Debug {
156 //     /// Unwraps a result, yielding the content of an 'Ok'.
157 //     ///
158 //     /// Unlike the standard library's 'unwrap()', this uses the Mnemosyne
159 //     /// internal compiler error panic formatter.
160 //     ///
161 //     /// # Panics
162 //     ///
163 //     /// Panics if the value is an 'Err', with a panic message provided by the
164 //     /// 'Err's value.
165 //     ///
166 //     /// # Examples
167 //     ///
168 //     /// '''
169 //     /// # use mnemosyne::errors::UnwrapICE;
170 //     /// let x: Result<u32, &str> = Ok(2);
171 //     /// assert_eq!(x.unwrap_ice(), 2);
172 //     /// '''
173 //     ///
174 //     /// '''{.should_panic}
175 //     /// # use mnemosyne::errors::UnwrapICE;
176 //     /// let x: Result<u32, &str> = Err("emergency failure");
177 //     /// x.unwrap_ice(); // panics with 'emergency failure'
178 //     /// '''
179 //     #[inline]
180 //     fn unwrap_ice(self) -> T {
181 //         match self {
182 //             Ok(t) => t
183 //             , Err(e) =>
184 //                 ice!("called 'Result::unwrap()' on an 'Err' value: {:?}", e)
185 //         }
186 //     }
187 // }
188
189 #[cfg(test)]
190 mod tests {
191     use super::*;
192
193     #[test]
194     fn test_option_expect_ok() {
195         let x = Some("value");
196         assert_eq!(x.expect_ice("the world is ending"), "value");

```

```

197     }
198
199     #[test]
200     #[should_panic]
201     fn test_option_expect_panic() {
202         let x: Option<&str> = None;
203         x.expect_ice("the world is ending");
204     }
205
206     #[test]
207     #[should_panic]
208     fn test_result_expect_panic() {
209         let x: Result<u32, &str> = Err("emergency failure");
210         x.expect_ice("Testing expect");
211     }
212
213     #[test]
214     fn test_option_unwrap_ok() {
215         let x = Some("air");
216         assert_eq!(x.unwrap_ice(), "air");
217     }
218
219     #[test]
220     #[should_panic]
221     fn test_option_unwrap_panic() {
222         let x: Option<&str> = None;
223         assert_eq!(x.unwrap_ice(), "air"); // fails
224     }
225
226     #[test]
227     fn test_result_unwrap_ok() {
228         let x: Result<u32, &str> = Ok(2);
229         assert_eq!(x.unwrap_ice(), 2);
230     }
231
232     #[test]
233     #[should_panic]
234     fn test_result_unwrap_panic() {
235         let x: Result<u32, &str> = Err("emergency failure");
236         x.unwrap_ice(); // panics
237     }
238 }

```

## forktable.rs

```

1  //
2  // Mnemosyne: a functional systems programming language.
3  // (c) 2015 Hawk Weisman
4  //
5  // Mnemosyne is released under the MIT License. Please refer to
6  // the LICENSE file at the top-level directory of this distribution
7  // or at https://github.com/hawkw/mnemosyne/.

```

```

8  //
9
10 use ::errors::ExpectICE;
11
12 use std::collections::{HashMap, HashSet};
13 use std::collections::hash_map::{Keys, Values};
14 use std::hash::Hash;
15 use std::borrow::Borrow;
16 use std::ops;
17
18 /// An associative map data structure for representing scopes.
19 ///
20 /// A 'ForkTable' functions similarly to a standard associative map
21 /// data structure (such as a 'HashMap'), but with the ability to
22 /// fork children off of each level of the map. If a key exists in any
23 /// of a child's parents, the child will 'pass through' that key. If a
24 /// new value is bound to a key in a child level, that child will overwrite
25 /// the previous entry with the new one, but the previous 'key' -> 'value'
26 /// mapping will remain in the level it is defined. This means that the parent
27 /// level will still provide the previous value for that key.
28 ///
29 /// This is an implementation of the ForkTable data structure for
30 /// representing scopes. The ForkTable was initially described by
31 /// Max Clive. This implementation is based primarily by the Scala
32 /// reference implementation written by Hawk Weisman for the Decaf
33 /// compiler, which is available [here](https://github.com/hawkw/decaf/blob/master/src/main/scal
34 #[derive(Debug, Clone)]
35 pub struct ForkTable<'a, K, V>
36 where K: Eq + Hash
37       , K: 'a
38       , V: 'a
39 {
40     table: HashMap<K, V>
41     , whiteouts: HashSet<K>
42     , parent: Option<&'a ForkTable<'a, K, V>>
43     , level: usize
44 }
45
46 impl<'a, K, V> ForkTable<'a, K, V>
47 where K: Eq + Hash
48 {
49
50     /// Returns a reference to the value corresponding to the key.
51     ///
52     /// If the key is defined in this level of the table, or in any
53     /// of its' parents, a reference to the associated value will be
54     /// returned.
55     ///
56     /// The key may be any borrowed form of the map's key type, but
57     /// 'Hash' and 'Eq' on the borrowed form *must* match those for
58     /// the key type.
59     ///

```



```

60    /// # Arguments
61    ///
62    /// + 'key' - the key to search for
63    ///
64    /// # Return Value
65    ///
66    /// + 'Some(&V)' if an entry for the given key exists in the
67    ///   table, or 'None' if there is no entry for that key.
68    ///
69    /// # Examples
70    ///
71    /// ```ignore
72    /// # use mmemosyne::forktable::ForkTable;
73    /// let mut table: ForkTable<isize,&str> = ForkTable::new();
74    /// assert_eq!(table.get(&1), None);
75    /// table.insert(1, "One");
76    /// assert_eq!(table.get(&1), Some(&"One"));
77    /// assert_eq!(table.get(&2), None);
78    /// ```
79    /// ```ignore
80    /// # use mmemosyne::forktable::ForkTable;
81    /// let mut level_1: ForkTable<isize,&str> = ForkTable::new();
82    /// level_1.insert(1, "One");
83    ///
84    /// let mut level_2: ForkTable<isize,&str> = level_1.fork();
85    /// assert_eq!(level_2.get(&1), Some(&"One"));
86    /// ```
87    pub fn get<Q: ?Sized>(&self, key: &Q) -> Option<&V>
88    where K: Borrow<Q>
89          , Q: Hash + Eq
90    {
91        if self.whiteouts.contains(key) {
92            None
93        } else {
94            self.table
95                .get(key)
96                .or(self.parent
97                    .map_or(None, |ref parent| parent.get(key))
98                )
99        }
100    }
101
102    /// Returns a mutable reference to the value corresponding to the key.
103    ///
104    /// If the key is defined in this level of the table, a reference to the
105    /// associated value will be returned.
106    ///
107    /// Note that only keys defined in this level of the table can be accessed
108    /// as mutable. This is because otherwise it would be necessary for each
109    /// level of the table to hold a mutable reference to its parent.
110    ///
111    /// The key may be any borrowed form of the map's key type, but

```

```

112  /// 'Hash' and 'Eq' on the borrowed form *must* match those for
113  /// the key type.
114  ///
115  /// # Arguments
116  ///
117  /// + 'key' - the key to search for
118  ///
119  /// # Return Value
120  ///
121  /// + 'Some(&mut V)' if an entry for the given key exists in the
122  ///   table, or 'None' if there is no entry for that key.
123  ///
124  /// # Examples
125  ///
126  /// ```ignore
127  /// # use mmemosyne::forktable::ForkTable;
128  /// let mut table: ForkTable<isize,&str> = ForkTable::new();
129  /// assert_eq!(table.get_mut(&1), None);
130  /// table.insert(1, "One");
131  /// assert_eq!(table.get_mut(&1), Some(&mut "One"));
132  /// assert_eq!(table.get_mut(&2), None);
133  /// ```
134  /// ```ignore
135  /// # use mmemosyne::forktable::ForkTable;
136  /// let mut level_1: ForkTable<isize,&str> = ForkTable::new();
137  /// level_1.insert(1, "One");
138  ///
139  /// let mut level_2: ForkTable<isize,&str> = level_1.fork();
140  /// assert_eq!(level_2.get_mut(&1), None);
141  /// ```
142  pub fn get_mut<Q: ?Sized>(&mut self, key: &Q) -> Option<&mut V>
143  where K: Borrow<Q>
144        , Q: Hash + Eq
145  {
146        self.table.get_mut(key)
147  }
148
149
150  /// Removes a key from the map, returning the value at the key if
151  /// the key was previously in the map.
152  ///
153  /// If the removed value exists in a lower level of the table,
154  /// it will be whited out at this level. This means that the entry
155  /// will be 'removed' at this level and this table will not provide
156  /// access to it, but the mapping will still exist in the level where
157  /// it was defined. Note that the key will not be returned if it is
158  /// defined in a lower level of the table.
159  ///
160  /// The key may be any borrowed form of the map's key type, but
161  /// 'Hash' and 'Eq' on the borrowed form *must* match those for
162  /// the key type.
163  ///

```

```

164    /// # Arguments
165    ///
166    /// + 'key' - the key to remove
167    ///
168    /// # Return Value
169    ///
170    /// + 'Some(V)' if an entry for the given key exists in the
171    ///   table, or 'None' if there is no entry for that key.
172    ///
173    /// # Examples
174    /// ```ignore
175    /// # use mmemosyne::forktable::ForkTable;
176    /// let mut table: ForkTable<isize,&str> = ForkTable::new();
177    /// table.insert(1, "One");
178    ///
179    /// assert_eq!(table.remove(&1), Some("One"));
180    /// assert_eq!(table.contains_key(&1), false);
181    /// ```
182    /// ```ignore
183    /// # use mmemosyne::forktable::ForkTable;
184    /// let mut level_1: ForkTable<isize,&str> = ForkTable::new();
185    /// level_1.insert(1, "One");
186    /// assert_eq!(level_1.contains_key(&1), true);
187    ///
188    /// let mut level_2: ForkTable<isize,&str> = level_1.fork();
189    /// assert_eq!(level_2.chain_contains_key(&1), true);
190    /// assert_eq!(level_2.remove(&1), None);
191    /// assert_eq!(level_2.chain_contains_key(&1), false);
192    /// ```
193    pub fn remove(&mut self, key: &K) -> Option<V>
194    where K: Clone
195    {
196        self.whiteouts.insert(key.clone());
197        self.table.remove(&key)
198    }
199
200    /// Removes a key from this layer's map and whiteouts, so that
201    /// definitions of that key from lower levels are exposed.
202    ///
203    /// Unlike 'ForkTable::remove()', if the removed value exists in a
204    /// lower level of the table, it will NOT be whited out. This means
205    /// that the definition of that entry from lower levels of the table
206    /// will be exposed at this level.
207    ///
208    /// The key may be any borrowed form of the map's key type, but
209    /// 'Hash' and 'Eq' on the borrowed form must match those for
210    /// the key type.
211    ///
212    /// # Arguments
213    ///
214    /// + 'key' - the key to expose
215    ///

```

```

216     /// # Return Value
217     ///
218     /// + 'Some(V)' if an entry for the given key exists in the
219     ///     table, or 'None' if there is no entry for that key.
220     ///
221     pub fn expose<Q: ?Sized>(&mut self, key: &Q) -> Option<V>
222     where K: Borrow<Q>
223           , Q: Hash + Eq
224     {
225         self.whiteouts.remove(key);
226         self.table.remove(key)
227     }
228
229     /// Inserts a key-value pair from the map.
230     ///
231     /// If the key already had a value present in the map, that
232     /// value is returned. Otherwise, 'None' is returned.
233     ///
234     /// If the key is currently whited out (i.e. it was defined
235     /// in a lower level of the map and was removed) then it will
236     /// be un-whited out and added at this level.
237     ///
238     /// # Arguments
239     ///
240     /// + 'k' - the key to add
241     /// + 'v' - the value to associate with that key
242     ///
243     /// # Return Value
244     ///
245     /// + 'Some(V)' if a previous entry for the given key exists in the
246     ///     table, or 'None' if there is no entry for that key.
247     ///
248     /// # Examples
249     ///
250     /// Simply inserting an entry:
251     ///
252     /// ```ignore
253     /// # use mnemosyne::forktable::ForkTable;
254     /// let mut table: ForkTable<isize,&str> = ForkTable::new();
255     /// assert_eq!(table.get(&1), None);
256     /// table.insert(1, "One");
257     /// assert_eq!(table.get(&1), Some(&"One"));
258     /// ```
259     ///
260     /// Overwriting the value associated with a key:
261     ///
262     /// ```ignore
263     /// # use mnemosyne::forktable::ForkTable;
264     /// let mut table: ForkTable<isize,&str> = ForkTable::new();
265     /// assert_eq!(table.get(&1), None);
266     /// assert_eq!(table.insert(1, "one"), None);
267     /// assert_eq!(table.get(&1), Some(&"one"));

```

```

268  ///
269  /// assert_eq!(table.insert(1, "One"), Some("one"));
270  /// assert_eq!(table.get(&1), Some(&"One"));
271  /// ```
272  pub fn insert(&mut self, k: K, v: V) -> Option<V> {
273      if self.whiteouts.contains(&k) {
274          self.whiteouts.remove(&k);
275      };
276      self.table.insert(k, v)
277  }
278
279  /// Returns true if this level contains a value for the specified key.
280  ///
281  /// The key may be any borrowed form of the map's key type, but
282  /// 'Hash' and 'Eq' on the borrowed form must match those for
283  /// the key type.
284  ///
285  /// # Arguments
286  ///
287  /// + 'k' - the key to search for
288  ///
289  /// # Return Value
290  ///
291  /// + 'true' if the given key is defined in this level of the
292  ///   table, 'false' if it does not.
293  ///
294  /// # Examples
295  /// ```ignore
296  /// # use mmemosyne::forktable::ForkTable;
297  /// let mut table: ForkTable<isize,&str> = ForkTable::new();
298  /// assert_eq!(table.contains_key(&1), false);
299  /// table.insert(1, "One");
300  /// assert_eq!(table.contains_key(&1), true);
301  /// ```
302  /// ```ignore
303  /// # use mmemosyne::forktable::ForkTable;
304  /// let mut level_1: ForkTable<isize,&str> = ForkTable::new();
305  /// assert_eq!(level_1.contains_key(&1), false);
306  /// level_1.insert(1, "One");
307  /// assert_eq!(level_1.contains_key(&1), true);
308  ///
309  /// let mut level_2: ForkTable<isize,&str> = level_1.fork();
310  /// assert_eq!(level_2.contains_key(&1), false);
311  /// ```
312  pub fn contains_key<Q: ?Sized>(&self, key: &Q) -> bool
313  where K: Borrow<Q>
314      , Q: Hash + Eq
315  {
316      !self.whiteouts.contains(key) &&
317      self.table.contains_key(key)
318  }
319

```

```

320  /// Returns true if the key is defined in this level of the table, or
321  /// in any of its' parents and is not whited out.
322  ///
323  /// The key may be any borrowed form of the map's key type, but
324  /// 'Hash' and 'Eq' on the borrowed form must match those for
325  /// the key type.
326  ///
327  /// # Arguments
328  ///
329  /// + 'k' - the key to search for
330  ///
331  /// # Return Value
332  ///
333  /// + 'true' if the given key is defined in the table,
334  ///   'false' if it does not.
335  ///
336  /// # Examples
337  /// ```ignore
338  /// # use mmemosyne::forktable::ForkTable;
339  /// let mut table: ForkTable<isize,&str> = ForkTable::new();
340  /// assert_eq!(table.chain_contains_key(&1), false);
341  /// table.insert(1, "One");
342  /// assert_eq!(table.chain_contains_key(&1), true);
343  /// ```
344  /// ```ignore
345  /// # use mmemosyne::forktable::ForkTable;
346  /// let mut level_1: ForkTable<isize,&str> = ForkTable::new();
347  /// assert_eq!(level_1.chain_contains_key(&1), false);
348  /// level_1.insert(1, "One");
349  /// assert_eq!(level_1.chain_contains_key(&1), true);
350  ///
351  /// let mut level_2: ForkTable<isize,&str> = level_1.fork();
352  /// assert_eq!(level_2.chain_contains_key(&1), true);
353  /// ```
354  pub fn chain_contains_key<Q:? Sized>(&self, key: &Q) -> bool
355  where K: Borrow<Q>
356  , Q: Hash + Eq
357  {
358      self.table.contains_key(key) ||
359      (!self.whiteouts.contains(key) &&
360       self.parent
361        .map_or(false, |ref p| p.chain_contains_key(key))
362      )
363  }
364
365  /// Forks this table, returning a new 'ForkTable<K,V>'.
366  ///
367  /// This level of the table will be set as the child's
368  /// parent. The child will be created with an empty backing
369  /// 'HashMap' and no keys whited out.
370  ///
371  /// Note that the new 'ForkTable<K,V>' has a lifetime

```

```

372     /// bound ensuring that it will live at least as long as the
373     /// parent 'ForkTable'.
374     pub fn fork(&'a self) -> ForkTable<'a, K, V> {
375         ForkTable { table: HashMap::new()
376                     , whiteouts: HashSet::new()
377                     , parent: Some(self)
378                     , level: self.level + 1
379                     }
380     }
381
382     /// Constructs a new 'ForkTable<K,V>'
383     pub fn new() -> ForkTable<'a, K,V> {
384         ForkTable { table: HashMap::new()
385                     , whiteouts: HashSet::new()
386                     , parent: None
387                     , level: 0
388                     }
389     }
390
391     /// Wrapper for the backing map's 'values()' function.
392     ///
393     /// Provides an iterator visiting all values in arbitrary
394     /// order. Iterator element type is &'b V.
395     pub fn values(&self) -> Values<K, V> { self.table.values() }
396
397     /// Wrapper for the backing map's 'keys()' function.
398     ///
399     /// Provides an iterator visiting all keys in arbitrary
400     /// order. Iterator element type is &'b K.
401     pub fn keys(&self) -> Keys<K, V> { self.table.keys() }
402 }
403
404     /// Allows 'table[&key]' indexing syntax.
405     ///
406     /// This is just a wrapper for 'get(&key)'
407     ///
408     /// '''ignore
409     /// # use mnemosyne::forktable::ForkTable;
410     /// let mut table: ForkTable<isize,&str> = ForkTable::new();
411     /// table.insert(1, "One");
412     /// assert_eq!(table[&1], "One");
413     /// '''
414     impl<'a, 'b, K, Q: ?Sized, V> ops::Index<&'b Q> for ForkTable<'a, K, V>
415     where K: Borrow<Q>
416         , K: Eq + Hash
417         , Q: Eq + Hash
418     {
419         type Output = V;
420
421         #[inline]
422         fn index(&self, index: &Q) -> &Self::Output {
423             self.get(index)

```

```

424         .expect_ice("undefined index")
425     }
426
427 }
428
429 /// Allows mutable 'table[key]' indexing syntax.
430 ///
431 /// This is just a wrapper for 'get_mut(key)'
432 ///
433 /// '''ignore
434 /// # use mnemosyne::forktable::ForkTable;
435 /// let mut table: ForkTable<isize,&str> = ForkTable::new();
436 /// table.insert(1, "One");
437 /// table[1] = "one";
438 /// assert_eq!(table[1], "one")
439 /// '''
440 impl<'a, 'b, K, Q: ?Sized, V> ops::IndexMut<&'b Q> for ForkTable<'a, K, V>
441 where K: Borrow<Q>
442     , K: Eq + Hash
443     , Q: Eq + Hash
444 {
445     #[inline]
446     fn index_mut(&mut self, index: &Q) -> &mut V {
447         self.get_mut(index)
448             .expect_ice("undefined index")
449     }
450 }
451
452 #[cfg(test)]
453 mod tests {
454     use super::ForkTable;
455
456     #[test]
457     fn test_get_defined() {
458         let mut table: ForkTable<isize,&str> = ForkTable::new();
459         assert_eq!(table.get(&1), None);
460         table.insert(1, "One");
461         assert_eq!(table.get(&1), Some(&"One"));
462     }
463
464     #[test]
465     fn test_get_undefined() {
466         let mut table: ForkTable<isize,&str> = ForkTable::new();
467         table.insert(1, "One");
468         assert_eq!(table.get(&2), None);
469     }
470
471     #[test]
472     fn test_get_multilevel() {
473         let mut level_1: ForkTable<isize,&str> = ForkTable::new();
474         level_1.insert(1, "One");
475

```



```

476         let mut level_2: ForkTable<isize,&str> = level_1.fork();
477         assert_eq!(level_2.get(&1), Some(&"One"));
478     }
479
480     #[test]
481     fn test_get_mut_defined() {
482         let mut table: ForkTable<isize,&str> = ForkTable::new();
483         assert_eq!(table.get_mut(&1), None);
484         table.insert(1, "One");
485         assert_eq!(table.get_mut(&1), Some(&mut "One"));
486     }
487
488     #[test]
489     fn test_get_mut_undefined() {
490         let mut table: ForkTable<isize,&str> = ForkTable::new();
491         table.insert(1, "One");
492         assert_eq!(table.get_mut(&2), None);
493     }
494     #[test]
495     fn test_get_mut_multilevel() {
496         let mut level_1: ForkTable<isize,&str> = ForkTable::new();
497         level_1.insert(1, "One");
498
499         let mut level_2: ForkTable<isize,&str> = level_1.fork();
500         assert_eq!(level_2.get_mut(&1), None);
501     }
502     #[test]
503     fn test_remove_returned() {
504         let mut table: ForkTable<isize,&str> = ForkTable::new();
505         table.insert(1, "One");
506         assert_eq!(table.remove(&1), Some("One"));
507     }
508     #[test]
509     fn test_remove_not_defined_after() {
510         let mut table: ForkTable<isize,&str> = ForkTable::new();
511         table.insert(1, "One");
512         table.remove(&1);
513         assert_eq!(table.get(&1), None);
514     }
515
516     #[test]
517     fn test_remove_multilevel() {
518         let mut level_1: ForkTable<isize,&str> = ForkTable::new();
519         level_1.insert(1, "One");
520         assert_eq!(level_1.contains_key(&1), true);
521
522         let mut level_2: ForkTable<isize,&str> = level_1.fork();
523         assert_eq!(level_2.chain_contains_key(&1), true);
524         assert_eq!(level_2.remove(&1), None);
525         assert_eq!(level_2.chain_contains_key(&1), false);
526     }
527

```

```

528     #[test]
529     fn test_insert_defined_after() {
530         let mut table: ForkTable<isize,&str> = ForkTable::new();
531         assert_eq!(table.get(&1), None);
532         table.insert(1, "One");
533         assert_eq!(table.get(&1), Some(&"One"));
534     }
535
536     #[test]
537     fn test_insert_overwrite() {
538         let mut table: ForkTable<isize,&str> = ForkTable::new();
539         assert_eq!(table.get(&1), None);
540         assert_eq!(table.insert(1, "one"), None);
541         assert_eq!(table.get(&1), Some(&"one"));
542
543         assert_eq!(table.insert(1, "One"), Some(&"one"));
544         assert_eq!(table.get(&1), Some(&"One"));
545     }
546
547     #[test]
548     fn test_contains_key() {
549         let mut table: ForkTable<isize,&str> = ForkTable::new();
550         assert_eq!(table.contains_key(&1), false);
551         table.insert(1, "One");
552         assert_eq!(table.contains_key(&1), true);
553     }
554
555     #[test]
556     fn test_contains_key_this_level_only () {
557         let mut level_1: ForkTable<isize,&str> = ForkTable::new();
558         assert_eq!(level_1.contains_key(&1), false);
559         level_1.insert(1, "One");
560         assert_eq!(level_1.contains_key(&1), true);
561
562         let mut level_2: ForkTable<isize,&str> = level_1.fork();
563         assert_eq!(level_2.contains_key(&1), false);
564     }
565
566     #[test]
567     fn test_chain_contains_key_this_level() {
568         let mut table: ForkTable<isize,&str> = ForkTable::new();
569         assert_eq!(table.chain_contains_key(&1), false);
570         table.insert(1, "One");
571         assert_eq!(table.chain_contains_key(&1), true);
572     }
573
574     #[test]
575     fn test_contains_key_multilevel() {
576         let mut level_1: ForkTable<isize,&str> = ForkTable::new();
577         assert_eq!(level_1.chain_contains_key(&1), false);
578         level_1.insert(1, "One");
579         assert_eq!(level_1.chain_contains_key(&1), true);

```

```

580
581     let mut level_2: ForkTable<isize,&str> = level_1.fork();
582     assert_eq!(level_2.chain_contains_key(&1), true);
583 }
584
585 #[test]
586 fn test_indexing() {
587     let mut table: ForkTable<isize,&str> = ForkTable::new();
588     table.insert(1, "One");
589     assert_eq!(table[&1], "One");
590 }
591
592 #[test]
593 fn test_index_mut() {
594     let mut table: ForkTable<isize,&str> = ForkTable::new();
595     table.insert(1, "One");
596     table[&1] = "one";
597     assert_eq!(table[&1], "one")
598 }
599 }

```

## position.rs

```

1  //
2  // Mnemosyne: a functional systems programming language.
3  // (c) 2015 Hawk Weisman
4  //
5  // Mnemosyne is released under the MIT License. Please refer to
6  // the LICENSE file at the top-level directory of this distribution
7  // or at https://github.com/hawkw/mnemosyne/.
8  //
9
10 use std::ops::{Deref, DerefMut};
11 use std::hash;
12 use std::fmt;
13 use std::convert::From;
14
15 use combine::primitives::SourcePosition;
16
17 /// Struct representing a position within a source code file.
18 ///
19 /// This represents positions using 'i32's because that's how
20 /// positions are represented in 'combine' (the parsing library
21 /// that we will use for the Mnemosyne parser). I personally would
22 /// have used 'usize's...
23 #[derive(Copy, Clone, PartialEq, Eq, Debug, PartialOrd, Ord)]
24 pub struct Position { pub col: i32
25                     , pub row: i32
26                     , pub raw: i32
27                     }
28
29 impl Position {

```

```

30
31     /// Create a new 'Position' at the given column and row.
32     #[inline]
33     pub fn new(col: i32, row: i32) -> Self {
34         Position { col: col
35                   , row: row
36                   , raw: col + row
37                 }
38     }
39
40 }
41
42 impl From<SourcePosition> for Position {
43     /// Create a new 'Position' from a 'combine' 'SourcePosition'.
44     ///
45     /// # Example
46     /// '''ignore
47     /// # extern crate combine;
48     /// # extern crate memosyne;
49     /// # use combine::primitives::SourcePosition;
50     /// # use memosyne::position::Position;
51     /// # fn main() {
52     ///     let sp = SourcePosition { column: 1, line: 1 };
53     ///     assert_eq!(Position::from(sp), Position::new(1,1));
54     /// # }
55     /// '''
56     fn from(p: SourcePosition) -> Self { Position::new(p.column, p.line) }
57 }
58
59 impl From<(i32,i32)> for Position {
60     /// Create a new 'Position' from a tuple of i32s.
61     ///
62     /// # Example
63     /// '''ignore
64     /// # use memosyne::position::Position;
65     /// let tuple: (i32,i32) = (1,1);
66     /// assert_eq!(Position::from(tuple), Position::new(1,1));
67     /// '''
68     fn from((col, row): (i32,i32)) -> Self { Position::new(col,row) }
69 }
70
71
72 impl fmt::Display for Position {
73     fn fmt(&self, f: &mut fmt::Formatter) -> fmt::Result {
74         write!(f, "line {}, column {}", self.row, self.col)
75     }
76 }
77
78 /// A pointer to a value with an associated 'Position'
79 #[derive(Clone, Debug)]
80 pub struct Positional<T> { pub pos: Position
81                          , pub value: T

```

```

82         }
83
84     impl<T> Positional<T> {
85         /// Create a new Positional marker at the given position.
86         pub fn at(col: i32, row: i32, value: T) -> Positional<T> {
87             Positional { pos: Position::new(col, row)
88                 , value: value }
89         }
90
91         pub fn value(&self) -> &T { &self.value }
92     }
93
94
95     impl<T> fmt::Display for Positional<T>
96     where T: fmt::Display {
97         fn fmt(&self, f: &mut fmt::Formatter) -> fmt::Result {
98             write!(f, "{} at {}", self.value, self.pos)
99         }
100     }
101
102     /// A positional pointer is still equal to the underlying
103     /// value even if they have different positions. This is
104     /// important so that we can test that two identifiers are
105     /// the same.
106     impl<T> PartialEq for Positional<T>
107     where T: PartialEq {
108         fn eq(&self, other: &Positional<T>) -> bool {
109             self.value == other.value
110         }
111     }
112
113     /// If two things are equal, then they better have the same
114     /// hash as well. Otherwise there will be sadness.
115     ///
116     /// Homefully this is Ideologically Correct.
117     impl<T> hash::Hash for Positional<T>
118     where T: hash::Hash {
119         fn hash<H: hash::Hasher>(&self, state: &mut H) {
120             self.value.hash(state)
121         }
122     }
123
124
125     /// This is literally just waving my hands for the compiler.
126     ///
127     /// Hopefully it understands what I mean.
128     impl<T> Eq for Positional<T>
129     where T: Eq
130         , T: PartialEq
131         {}
132
133     impl<T> Deref for Positional<T> {

```

```

134     type Target = T;
135     fn deref(&self) -> &T {
136         &self.value
137     }
138 }
139
140 impl<T> DerefMut for Positional<T> {
141     fn deref_mut(&mut self) -> &mut T {
142         &mut self.value
143     }
144 }
145
146 #[cfg(test)]
147 mod tests {
148     use super::*;
149     use combine::primitives::SourcePosition;
150
151     #[test]
152     fn test_from_sourceposition() {
153         let sp = SourcePosition { column: 1, line: 1 };
154         assert_eq!(Position::from(sp), Position::new(1,1));
155     }
156
157     #[test]
158     fn test_from_tuple() {
159         let tuple: (i32,i32) = (1,1);
160         assert_eq!(Position::from(tuple), Position::new(1,1));
161     }
162 }

```

## compile/mod.rs

```

1  //
2  // Mnemosyne: a functional systems programming language.
3  // (c) 2015 Hawk Weisman
4  //
5  // Mnemosyne is released under the MIT License. Please refer to
6  // the LICENSE file at the top-level directory of this distribution
7  // or at https://github.com/hawkw/mnemosyne/.
8  //
9
10 use std::ffi::CString;
11 use std::cmp::Ordering;
12 use std::mem;
13
14 use libc::c_uint;
15 use llvm_sys::prelude::LLVMValueRef;
16
17 use iron_llvm::core;
18 use iron_llvm::core::types::{ Type

```

```

19         , TypeCtor
20         , RealTypeCtor
21         , RealTypeRef
22         , IntTypeCtor
23         , IntTypeRef
24     };
25 use iron_llvm::{LLVMRef, LLVMRefCtor};
26
27 use errors::ExpectICE;
28 use forktable::ForkTable;
29 use position::Positional;
30 use ast::{ Node
31         , Form
32         , DefForm
33         , Ident
34         , Function };
35
36 use semantic::annotations::{ ScopedState
37                             , Scoped
38                             };
39 use semantic::types;
40 use semantic::types::{ Primitive
41                     , Reference
42                     };
43
44 /// Result type for compiling an AST node to LLVM IR
45 ///
46 /// An 'IRResult' contains either a 'ValueRef', if compilation was successful,
47 /// or a 'Positional<String>' containing an error message and the position of
48 /// the line of code which could not be compiled.
49 pub type IRResult = Result<LLVMValueRef, Vec<Positional<String>>>;
50
51 /// Result type for compiling a type to an LLVM 'TypeRef'.
52 pub type TypeResult<T: Type + Sized> = Result<T, Positional<String>>;
53
54 pub type NamedValues<'a> = ForkTable<'a, &'a str, LLVMValueRef>;
55
56 #[inline] fn word_size() -> usize { mem::size_of::<usize>() }
57
58 /// Trait for that which may join in The Great Work
59 pub trait Compile {
60     /// Compile 'self' to an LLVM 'ValueRef'
61     ///
62     /// # Returns:
63     /// - 'Ok' containing a 'ValueRef' if this was compiled correctly.
64     /// - An 'Err' with a vector of error messages containing any
65     ///   errors that occurred during compilation.
66     ///
67     /// # Panics:
68     /// - If something has gone horribly wrong. This does NOT panic if the
69     ///   code could not be compiled because it was incorrect, but it will
70     ///   panic in the event of an internal compiler error.

```

```

71     fn to_ir(&self, context: LLVMContext) -> IRResult;
72 }
73
74 /// Trait for type tags that can be translated to LLVM
75 // pub trait TranslateType {
76 //     /// Translate 'self' to an LLVM 'TypeRef'
77 //     ///
78 //     /// # Returns:
79 //     ///     - 'Ok' containing a 'TypeRef' if this was compiled correctly.
80 //     ///     - An 'Err' with a positional error message in the event of
81 //     ///         a type error.
82 //     ///
83 //     /// # Panics:
84 //     ///     - In the event of an internal compiler error (i.e. if a well-formed
85 //     ///         type could not be gotten from LLVM correctly).
86 //     fn translate_type(&self, context: LLVMContext) -> TypeResult;
87 // }
88
89 /// LLVM compilation context.
90 ///
91 /// This is based rather loosely on MIT License code from
92 /// the [iron-kaleidoscope](https://github.com/jauhnien/iron-kaleidoscope)
93 /// tutorial, and from ['librustc_trans'](https://github.com/rust-lang/rust/blob/master/src/librustc_trans.rs)
94 /// from the Rust compiler.
95 pub struct LLVMContext<'a> { llctx: core::Context
96                             , llmod: core::Module
97                             , llbuilder: core::Builder
98                             , named_vals: NamedValues<'a>
99                             }
100
101 /// because we are in the Raw Pointer Sadness Zone (read: unsafe),
102 /// it is necessary that we assert that everything exists.
103 macro_rules! not_null {
104     ($target:expr) => ({
105         let e = $target;
106         if e.is_null() {
107             ice!( "assertion failed: {} returned null!"
108                 , stringify!($target)
109             );
110         } else { e }
111     })
112 }
113
114 /// converts a raw pointer that may be null to an Option
115 /// the compiler will yell about this, claiming that it involves
116 /// an unused unsafe block, but the unsafe block is usually necessary.
117 macro_rules! optionalise {
118     ($target:expr) => ({
119         let e = unsafe { $target };
120         if e.is_null() {
121             None
122         } else { Some(e) }
123     })
124 }

```



```

123     })
124 }
125
126 macro_rules! try_vec {
127     ($expr:expr) => ({
128         if !$expr.is_empty() {
129             return Err($expr)
130         }
131     })
132 }
133
134 // ----- SEGFAULT EXISTS SOMEWHERE BELOW THIS LINE -----
135
136 //
137 // impl<'a> LLVMContext<'a> {
138 //
139 //     /// Constructs a new LLVM context.
140 //     ///
141 //     /// # Returns:
142 //     ///     - An 'LLVMContext'
143 //     ///
144 //     /// # Panics:
145 //     ///     - If the LLVM C ABI returned a null value for the 'Context',
146 //     ///       'Builder', or 'Module'
147 //     pub fn new(module_name: &str) -> Self {
148 //         LLVMContext { llctx: core::Context::get_global()
149 //             , llmod: core::Module::new(module_name)
150 //             , llbuilder: core::Builder::new()
151 //             , named_vals: NamedValues::new()
152 //         }
153 //     }
154 //
155 //     /// Dump the module's contents to stderr for debugging
156 //     ///
157 //     /// Apparently this is the only reasonable way to get a textual
158 //     /// representation of a 'Module' in LLVM
159 //     pub fn dump(&self) { self.llmod.dump() }
160 //
161 //     pub fn int_type(&self, size: usize) -> IntTypeRef {
162 //         IntTypeRef::get_int_in_context(&self.llctx, size as c_uint)
163 //     }
164 //
165 //     pub fn float_type(&self) -> RealTypeRef {
166 //         RealTypeRef::get_float_in_context(&self.llctx)
167 //     }
168 //     pub fn double_type(&self) -> RealTypeRef {
169 //         RealTypeRef::get_double_in_context(&self.llctx)
170 //     }
171 //     pub fn byte_type(&self) -> IntTypeRef {
172 //         IntTypeRef::get_int8_in_context(&self.llctx)
173 //     }
174 //

```

```

175 //      /// Get any existing declarations for a given function name.
176 //      ///
177 //      /// # Returns:
178 //      ///   - 'Some' if there is an existing previous declaration
179 //      ///     for this function.
180 //      ///   - 'None' if the function has not been declared previously.
181 //      ///
182 //      /// # Panics:
183 //      ///   - If the C string representation for the function name could
184 //      ///     not be created.
185 //      pub fn get_fn(&self, name: &Ident) -> Option<core::FunctionRef> {
186 //          self.llmod.get_function_by_name(name.value.as_ref())
187 //      }
188 // }
189
190 // impl<'a> Compile for Scoped<'a, Form<'a, ScopedState>> {
191 //     fn to_ir(&self, context: LLVMContext) -> IRResult {
192 //         match **self {
193 //             Form::Define(ref form) => unimplemented!()
194 //             , Form::Let(ref form) => unimplemented!()
195 //             , Form::If { .. } => unimplemented!()
196 //             , Form::Call { .. } => unimplemented!()
197 //             , Form::Lambda(ref fun) => unimplemented!()
198 //             , Form::Logical(ref exp) => unimplemented!()
199 //             , Form::Lit(ref c) => unimplemented!()
200 //             , Form::NameRef(ref form) => unimplemented!()
201 //         }
202 //     }
203 // }
204 //
205 // impl<'a> Compile for Scoped<'a, DefForm<'a, ScopedState>> {
206 //     fn to_ir(&self, context: LLVMContext) -> IRResult {
207 //         match **self {
208 //             DefForm::TopLevel { ref name, ref value, .. } =>
209 //                 unimplemented!()
210 //             , DefForm::Function { ref name, ref fun } => {
211 //                 match context.get_fn(name) {
212 //                     Some(previous) => unimplemented!()
213 //                     , None => unimplemented!()
214 //                 }
215 //             }
216 //         }
217 //     }
218 // }
219 //
220 //
221 // impl<'a> Compile for Scoped<'a, Function<'a, ScopedState>> {
222 //     fn to_ir(&self, context: LLVMContext) -> IRResult {
223 //         let mut errs: Vec<Positional<String>> = vec![];
224 //         // Check to see if the pattern binds an equivalent number of arguments
225 //         // as the function signature (minus one, which is the return type).

```

```

227 //      for e in &self.equations {
228 //          match e.pattern_length()
229 //              .cmp(&self.arity()) {
230 //                  // the equation's pattern is shorter than the function's arity
231 //                  // eventually, we'll autocurry this, but for now, we error.
232 //                  // TODO: maybe there should be a warning as well?
233 //                  Ordering::Less => errs.push(Positional {
234 //                      pos: e.position.clone()
235 //                      , value: format!( "[error] equation had fewer bindings \
236 //                                      than function arity\n \
237 //                                      [error] auto-currying is not currently \
238 //                                      implemented.\n \
239 //                                      signature: {} \n function: {} \n"
240 //                                      , self.sig
241 //                                      , (*e).to_sexpr(0)
242 //                                      )
243 //                      })
244 //                  // the equation's pattern is longer than the function's arity
245 //                  // this is super wrong and always an error.
246 //                  , Ordering::Greater => errs.push(Positional {
247 //                      pos: e.position.clone()
248 //                      , value: format!( "[error] equation bound too many arguments\n \
249 //                                      signature: {} \n function: {} \n"
250 //                                      , self.sig
251 //                                      , (*e).to_sexpr(0)
252 //                                      )
253 //                      })
254 //                  , _ => {}
255 //              }
256 //      }
257 //      // TODO: this could be made way more idiomatic...
258 //      try_vec!(errs);
259 //      unimplemented!()
260 //  }
261 //
262 // }
263 //
264 //
265 //
266 // // impl TranslateType for types::Type {
267 // //     fn translate_type(&self, context: LLVMContext) -> TypeResult {
268 // //         match *self {
269 // //             types::Type::Ref(ref r) => r.translate_type(context)
270 // //             , types::Type::Prim(ref p) => p.translate_type(context)
271 // //             , _ => unimplemented!() // TODO: figure this out
272 // //         }
273 // //     }
274 // // }
275 //
276 // // impl TranslateType for Reference {
277 // //     fn translate_type(&self, context: LLVMContext) -> TypeResult {
278 // //         unimplemented!() // TODO: figure this out

```

```

279 // //      }
280 // // }
281 //
282 // // impl TranslateType for Primitive {
283 // //      fn translate_type(&self, context: LLVMContext) -> TypeResult {
284 // //          Ok(match *self {
285 // //              Primitive::IntSize => context.int_type(word_size())
286 // //              , Primitive::UIntSize => context.int_type(word_size())
287 // //              , Primitive::Int(bits) => context.int_type(bits as usize)
288 // //              , Primitive::UInt(bits) => context.int_type(bits as usize)
289 // //              , Primitive::Float => context.float_type()
290 // //              , Primitive::Double => context.double_type()
291 // //              , Primitive::Byte => context.byte_type()
292 // //              , _ => unimplemented!() // TODO: figure this out
293 // //          })
294 // //      unimplemented!()
295 // // }
296 // // }

```

## B.2 Mnemosyne Parser Crate

### lib.rs

```

1 //
2 // Mnemosyne: a functional systems programming language.
3 // (c) 2015 Hawk Weisman
4 //
5 // Mnemosyne is released under the MIT License. Please refer to
6 // the LICENSE file at the top-level directory of this distribution
7 // or at https://github.com/hawkw/mnemosyne/.
8 //
9
10 extern crate combine;
11 extern crate combine_language;
12 extern crate mnemosyne as core;
13
14 use combine::*;
15 use combine_language::{ LanguageEnv
16                       , LanguageDef
17                       , Identifier
18                       };
19 use combine::primitives::{ Stream
20                          , Positioner
21                          , SourcePosition
22                          };
23 use core::chars;
24 use core::semantic::*;
25 use core::semantic::annotations::{ Annotated
26                                  , UnscopedState
27                                  , Unscoped
28                                  };

```

```

29 use core::semantic::types::*;
30 use core::semantic::ast::*;
31 use core::position::*;
32
33 use std::rc::Rc;
34
35 type ParseFn<'a, I, T> = fn (&MnEnv<'a, I>, State<I>) -> ParseResult<T, I>;
36
37 type U = UnscopedState;
38
39 mod tests;
40
41 /// Wraps a parsing function with a language definition environment.
42 ///
43 /// TODO: this could probably push identifiers to the symbol table here?
44 #[derive(Copy)]
45 struct MnParser<'a: 'b, 'b, I, T>
46 where I: Stream<Item=char>
47     , I::Range: 'b
48     , I: 'b
49     , I: 'a
50     , T: 'a {
51     env: &'b MnEnv<'a, I>
52     , parser: ParseFn<'a, I, T>
53 }
54
55 impl<'a, 'b, I, T> Clone for MnParser<'a, 'b, I, T>
56 where I: Stream<Item=char>
57     , I::Range: 'b
58     , I: 'b
59     , T: 'a
60     , 'a: 'b {
61
62     fn clone(&self) -> Self {
63         MnParser { env: self.env , parser: self.parser }
64     }
65 }
66
67 impl<'a, 'b, I, T> Parser for MnParser<'a, 'b, I, T>
68 where I: Stream<Item=char>
69     , I::Range: 'b
70     , I: 'b
71     , T: 'a
72     , 'a: 'b {
73
74     type Input = I;
75     type Output = T;
76
77     fn parse_state(&mut self, input: State<I>) -> ParseResult<T, I> {
78         (self.parser)(self.env, input)
79     }
80

```

```

81 }
82
83 struct MnEnv<'a, I>
84 where I: Stream<Item = char>
85     , I::Item: Positioner<Position = SourcePosition>
86     , I: 'a {
87     env: LanguageEnv<'a, I>
88 }
89
90 impl<'a, I> std::ops::Deref for MnEnv<'a, I>
91 where I: Stream<Item=char>
92     , I: 'a {
93     type Target = LanguageEnv<'a, I>;
94     fn deref(&self) -> &LanguageEnv<'a, I> { &self.env }
95 }
96
97 impl<'a, 'b, I> MnEnv<'a, I>
98 where I: Stream<Item=char>
99     , I::Item: Positioner<Position = SourcePosition>
100     , I::Range: 'b {
101
102     /// Wrap a function into a MnParser with this environment
103     fn parser<T>(&'b self, parser: ParseFn<'a, I, T>)
104         -> MnParser<'a, 'b, I, T> {
105         MnParser { env: self, parser: parser }
106     }
107
108     #[allow(dead_code)]
109     fn parse_def(&self, input: State<I>) -> ParseResult<Form<'a, U>, I> {
110         let function_form
111             = self.name()
112               .and(self.function())
113               .map(|(name, fun)| DefForm::Function { name: name
114                                                         , fun: fun });
115         let top_level
116             = self.name()
117               .and(self.type_name())
118               .and(self.expr())
119               .map(|((name, ty), body)|
120                 DefForm::TopLevel { name: name
121                                     , annot: ty
122                                     , value: Rc::new(body) });
123
124         self.reserved("def").or(self.reserved("define"))
125             .with(function_form.or(top_level))
126             .map(Form::Define)
127             .parse_state(input)
128     }
129
130     #[allow(dead_code)]
131     fn parse_if(&self, input: State<I>) -> ParseResult<Form<'a, U>, I> {
132         self.reserved("if")

```

```

133         .with(self.expr())
134         .and(self.expr())
135         .and(optional(self.expr()))
136         .map(|((cond, if_clause), else_clause)|
137             Form::If { condition: Rc::new(cond)
138                       , if_clause: Rc::new(if_clause)
139                       , else_clause: else_clause.map(Rc::new)
140                     })
141         .parse_state(input)
142     }
143
144     #[allow(dead_code)]
145     fn parse_lambda(&self, input: State<I>) -> ParseResult<Form<'a, U>, I> {
146         self.reserved("lambda")
147         .or(self.reserved(chars::LAMBDA))
148         .with(self.function())
149         .map(Form::Lambda)
150         .parse_state(input)
151     }
152
153     #[allow(dead_code)]
154     fn parse_function(&self, input: State<I>) -> ParseResult<Function<'a, U>, I> {
155         let fn_kwd = choice([ self.reserved("fn")
156                             , self.reserved("lambda")
157                             , self.reserved(chars::LAMBDA)
158                             ]);
159
160         self.parens(fn_kwd.with(
161             self.signature()
162             .and(many1(self.equation()))
163             .map(|(sig, eqs)| Function { sig: sig
164                                         , equations: eqs
165                                         })
166             ))
167         .parse_state(input)
168     }
169
170     #[allow(dead_code)]
171     fn parse_primitive_ty(&self, input: State<I>) -> ParseResult<Type, I> {
172         choice([ self.reserved("int")
173                 .with(value(Primitive::IntSize))
174                 , self.reserved("uint")
175                 .with(value(Primitive::IntSize))
176                 , self.reserved("float")
177                 .with(value(Primitive::Float))
178                 , self.reserved("double")
179                 .with(value(Primitive::Double))
180                 , self.reserved("bool")
181                 .with(value(Primitive::Bool))
182                 , self.reserved("i8")
183                 .with(value(Primitive::Int(Int::Int8)))
184                 , self.reserved("i16")

```

```

185         .with(value(Primitive::Int(Int::Int16)))
186     , self.reserved("i32")
187         .with(value(Primitive::Int(Int::Int32)))
188     , self.reserved("i64")
189         .with(value(Primitive::Int(Int::Int64)))
190     , self.reserved("u8")
191         .with(value(Primitive::Uint(Int::Int8)))
192     , self.reserved("u16")
193         .with(value(Primitive::Uint(Int::Int16)))
194     , self.reserved("u32")
195         .with(value(Primitive::Uint(Int::Int32)))
196     , self.reserved("u64")
197         .with(value(Primitive::Uint(Int::Int64)))
198     ])
199     .map(|primitive| Type::Prim(primitive))
200     .parse_state(input)
201 }
202
203 pub fn raw_ptr_ty(&self, input: State<I>) -> ParseResult<Type, I> {
204     char('&').with(self.type_name())
205         .map(|t| Type::Ref(Reference::Raw(Rc::new(t))))
206         .parse_state(input)
207 }
208
209 pub fn unique_ptr_ty(&self, input: State<I>) -> ParseResult<Type, I> {
210     char('@').with(self.type_name())
211         .map(|t| Type::Ref(Reference::Unique(Rc::new(t))))
212         .parse_state(input)
213 }
214
215 pub fn borrow_ptr_ty(&self, input: State<I>) -> ParseResult<Type, I> {
216     char('&').with(self.type_name())
217         .map(|t| Type::Ref(Reference::Borrowed(Rc::new(t))))
218         .parse_state(input)
219 }
220
221 fn parse_type(&self, input: State<I>) -> ParseResult<Type, I> {
222     choice([ self.parser(MnEnv::parse_primitive_ty)
223         , self.parser(MnEnv::raw_ptr_ty)
224         , self.parser(MnEnv::unique_ptr_ty)
225         , self.parser(MnEnv::borrow_ptr_ty)
226     ])
227     .parse_state(input)
228 }
229
230 fn parse_name_deref(&self, input: State<I>) -> ParseResult<NameRef, I> {
231     char('&').with(self.name())
232         .map(NameRef::Deref)
233         .parse_state(input)
234 }
235
236 fn parse_name_unique(&self, input: State<I>) -> ParseResult<NameRef, I> {
237     char('@').with(self.name())

```



```

237         .map(NameRef::Unique)
238         .parse_state(input)
239     }
240
241     fn parse_name_borrow(&self, input: State<I>)-> ParseResult<NameRef, I> {
242         char('&').with(self.name())
243         .map(NameRef::Borrowed)
244         .parse_state(input)
245     }
246
247     fn parse_owned_name(&self, input: State<I>) -> ParseResult<NameRef, I> {
248         self.name()
249         .map(NameRef::Owned)
250         .parse_state(input)
251     }
252
253     fn parse_name_ref(&self, input: State<I>)
254         -> ParseResult<Form<'a, U>, I> {
255         choice([ self.parser(MnEnv::parse_name_deref)
256             , self.parser(MnEnv::parse_name_unique)
257             , self.parser(MnEnv::parse_name_borrow)
258             , self.parser(MnEnv::parse_owned_name)
259             ])
260         .map(Form::NameRef)
261         .parse_state(input)
262     }
263
264     // fn parse_typeclass_arrow(&self, input: State<I>) -> ParseResult<Ustr, I> {
265     //     self.reserved_op("=>")
266     //     .or(self.reserved_op(FAT_ARROW))
267     //     .parse_state(input)
268     // }
269
270     // fn parse_arrow(&self, input: State<I>) -> ParseResult<Ustr, I> {
271     //     self.reserved_op(">")
272     //     .or(self.reserved_op(ARROW))
273     //     .parse_state(input)
274     // }
275
276     fn parse_prefix_constraint(&self, input: State<I>)
277         -> ParseResult<Constraint, I> {
278         self.parens(self.reserved_op("=>")
279             .or(self.reserved_op(chars::FAT_ARROW))
280             .with(self.name())
281             .and(many1(self.name()))) )
282         .map(|(c, gs)| Constraint { typeclass: c
283             , generics: gs })
284         .parse_state(input)
285     }
286
287     fn parse_infix_constraint(&self, input: State<I>)
288         -> ParseResult<Constraint, I> {

```

```

289     self.braces(self.name()
290                 .skip(self.reserved_op("=>")
291                     .or(self.reserved_op(chars::FAT_ARROW)))
292                 .and(many1(self.name())) )
293     .map(|(c, gs)| Constraint { typeclass: c
294                             , generics: gs })
295     .parse_state(input)
296 }
297
298 fn parse_constraint(&self, input: State<I>)
299     -> ParseResult<Constraint, I> {
300     self.parser(MnEnv::parse_prefix_constraint)
301     .or(self.parser(MnEnv::parse_infix_constraint))
302     .parse_state(input)
303 }
304
305 pub fn constraint(&'b self) -> MnParser<'a, 'b, I, Constraint> {
306     self.parser(MnEnv::parse_constraint)
307 }
308
309 fn parse_prefix_sig(&self, input: State<I>) -> ParseResult<Signature, I> {
310     self.parens(self.reserved_op(">")
311                 .or(self.reserved_op(chars::ARROW))
312                 .with(optional(many1(self.constraint()))))
313                 .and(many1(self.type_name())) )
314     .map(|(cs, glob)| Signature { constraints: cs
315                             , typechain: glob })
316     .parse_state(input)
317 }
318
319 fn parse_infix_sig(&self, input: State<I>) -> ParseResult<Signature, I> {
320     self.braces(optional(many1(self.constraint()))
321                 .and(sep_by1::< Vec<Type>
322                     , _, _>( self.lex(self.type_name())
323                             , self.reserved_op(">")
324                             .or(self.reserved_op(
325                                 chars::ARROW)
326                             )
327                     )))
328     .map(|(cs, glob)| Signature { constraints: cs
329                             , typechain: glob })
330     .parse_state(input)
331 }
332
333 fn parse_signature(&self, input: State<I>) -> ParseResult<Signature, I> {
334
335     // let prefix =
336     //     self.parens(self.reserved_op(">")
337     //                 .or(self.reserved_op(ARROW))
338     //                 .with(optional(many1(self.constraint()))))
339     //                 .and(many1(self.type_name())) )
340     //     .map(|(cs, glob)| Signature { constraints: cs

```

```

341         //                                     , typechain: glob });
342         //
343         // let infix =
344         //     self.braces(optional(many1(self.constraint())))
345         //         .and(sep_by1::< Vec<Type>
346         //             , _, _>( self.lex(self.type_name())
347         //                 , self.reserved_op(">")
348         //                 .or(self.reserved_op(ARROW)))
349         //         )))
350         //     .map(|(cs, glob)| Signature { constraints: cs
351         //         , typechain: glob });
352         // prefix.or(infix)
353         // .parse_state(input)
354         self.parser(MnEnv::parse_prefix_sig)
355         .or(self.parser(MnEnv::parse_infix_sig))
356         .parse_state(input)
357     }
358
359     pub fn signature(&'b self) -> MnParser<'a, 'b, I, Signature> {
360         self.parser(MnEnv::parse_signature)
361     }
362
363     fn parse_binding(&self, input: State<I>)
364         -> ParseResult<Unscoped<'a, Binding<'a, U>>, I> {
365         let pos = input.position.clone();
366         self.parser(MnEnv::parse_name)
367             .and(self.type_name())
368             .and(self.expr())
369             .map(|((name, typ), value)|
370                 Annotated::new( Binding { name: name
371                                     , typ: typ
372                                     , value: Rc::new(value)
373                                     }
374                                     , Position::from(pos)
375                                 ))
376             .parse_state(input)
377     }
378
379     #[allow(dead_code)]
380     fn parse_logical(&self, input: State<I>)
381         -> ParseResult<Logical<'a, U>, I> {
382         let and = self.reserved("and")
383             .with(self.expr())
384             .and(self.expr())
385             .map(|(a, b)| Logical::And { a: Rc::new(a)
386                                     , b: Rc::new(b)
387                                     });
388
389         let or = self.reserved("or")
390             .with(self.expr())
391             .and(self.expr())
392             .map(|(a, b)| Logical::And { a: Rc::new(a)

```

```

393                                     , b: Rc::new(b)
394                                     });
395
396         and.or(or)
397         .parse_state(input)
398     }
399
400     pub fn int_const(&'b self) -> MnParser<'a, 'b, I, Literal> {
401         self.parser(MnEnv::parse_int_const)
402     }
403
404     #[allow(dead_code)]
405     fn parse_int_const(&self, input: State<I>) -> ParseResult<Literal, I> {
406         self.integer()
407         .map(Literal::IntConst)
408         .parse_state(input)
409     }
410
411     fn parse_let(&self, input: State<I>) -> ParseResult<Form<'a, U>, I> {
412
413         let binding_form =
414             self.reserved("let")
415             .with(self.parens(many(self.parens(self.binding()))))
416             .and(many(self.expr()))
417             .map(|(bindings, body)| LetForm::Let { bindings: bindings
418                                                         , body: body });
419
420         choice([ binding_form ])
421         .map(Form::Let)
422         .parse_state(input)
423     }
424
425     fn parse_name (&self, input: State<I>) -> ParseResult<Ident, I> {
426         let position = input.position.clone();
427         self.env.identifier::<'b>()
428         .map(|name| Positional { pos: Position::from(position)
429                                 , value: name })
430         .parse_state(input)
431     }
432
433     fn parse_call(&self, input: State<I>) -> ParseResult<Form<'a, U>, I> {
434         self.name()
435         .and(many(self.expr()))
436         .map(|(name, args)| Form::Call { fun: name, body: args })
437         .parse_state(input)
438     }
439
440     fn parse_expr(&self, input: State<I>) -> ParseResult<Expr<'a, U>, I> {
441         let pos = Position::from(input.position.clone());
442         self.env.parens(choice([ try(self.call())
443                                 , try(self.def())
444                                 , try(self.if_form())

```

```

445         , try(self.lambda())
446         , try(self.let_form())
447     ]))
448     .or(try(self.int_const()
449         .map(Form::Lit)))
450     .or(try(self.name_ref()))
451     .map(|f| Annotated::new(f, pos) )
452     .parse_state(input)
453 }
454
455 fn parse_pattern(&self, input: State<I>) -> ParseResult<Pattern, I> {
456     let pat_elem =
457         self.name().map(PatElement::Name)
458         .or(self.int_const().map(PatElement::Lit));
459
460     self.parens(many(pat_elem))
461     .parse_state(input)
462 }
463
464 pub fn pattern(&'b self) -> MnParser<'a, 'b, I, Pattern> {
465     self.parser(MnEnv::parse_pattern)
466 }
467
468 fn parse_equation(&self, input: State<I>)
469     -> ParseResult< Annotated< 'a
470                     , Equation< 'a, U>
471                     , U>
472                     , I> {
473     let pos = Position::from(input.position.clone());
474     self.parens(self.pattern()
475         .and(many(self.expr()))
476         .map(|(pat, body)| Annotated::new( Equation { pattern: pat
477                                     , body: body }
478                                     , pos ))
479     .parse_state(input)
480 }
481
482 pub fn equation(&'b self) -> MnParser< 'a, 'b, I
483     , Annotated< 'a
484     , Equation<'a, U>
485     , U>
486     > {
487     self.parser(MnEnv::parse_equation)
488 }
489
490 pub fn expr(&'b self) -> MnParser<'a, 'b, I, Expr<'a, U>> {
491     self.parser(MnEnv::parse_expr)
492 }
493
494 pub fn def(&'b self) -> MnParser<'a, 'b, I, Form<'a, U>> {
495     self.parser(MnEnv::parse_def)
496 }

```

```

497
498 pub fn if_form(&'b self) -> MnParser<'a, 'b, I, Form<'a, U>> {
499     self.parser(MnEnv::parse_if)
500 }
501
502 pub fn let_form(&'b self) -> MnParser<'a, 'b, I, Form<'a, U>> {
503     self.parser(MnEnv::parse_let)
504 }
505
506 pub fn lambda(&'b self) -> MnParser<'a, 'b, I, Form<'a, U>> {
507     self.parser(MnEnv::parse_lambda)
508 }
509
510 pub fn call(&'b self) -> MnParser<'a, 'b, I, Form<'a, U>> {
511     self.parser(MnEnv::parse_call)
512 }
513
514 pub fn name(&'b self) -> MnParser<'a, 'b, I, Ident> {
515     self.parser(MnEnv::parse_name)
516 }
517
518 pub fn name_ref(&'b self) -> MnParser<'a, 'b, I, Form<'a, U>> {
519     self.parser(MnEnv::parse_name_ref)
520 }
521
522
523 pub fn binding(&'b self)
524     -> MnParser<'a, 'b, I, Unscoped<'a, Binding<'a, U>>> {
525     self.parser(MnEnv::parse_binding)
526 }
527
528 pub fn type_name(&'b self) -> MnParser<'a, 'b, I, types::Type> {
529     self.parser(MnEnv::parse_type)
530 }
531
532 pub fn function(&'b self) -> MnParser<'a, 'b, I, Function<'a, U>> {
533     self.parser(MnEnv::parse_function)
534 }
535
536 }
537 pub fn parse_module<'a>(code: &'a str)
538     -> Result< Vec<Expr<'a, UnscopedState>>
539         , ParseError<&'a str>>
540 {
541     let env = LanguageEnv::new(LanguageDef {
542         ident: Identifier {
543             start: letter().or(satisfy(move |c| chars::ALPHA_EXT.contains(c)))
544             , rest: alpha_num().or(satisfy(move |c| chars::ALPHA_EXT.contains(c)))
545             , reserved: [ // a number of these reserved words have no meaning yet
546                 "and"                , "begin"
547                 , "case"              , "cond"          , "class"
548                 , "data"

```

```

549         , "define"           , "defn"           , "def"
550         , "delay"            , "fn"
551         , "do"                , "else"
552         , "if"                , "lambda"        , chars::LAMBDA
553         , "let"               , "let*"          , "letrec"
554         , "or"
555         , "quasiquote"        , "quote"         , "unquote"
556         , "set!"              , "unquote-splicing"
557         , "struct"            , "union"
558         , "i8"                , "u8"
559         , "i16"               , "u16"
560         , "i32"               , "u32"           , "f32"
561         , "i64"               , "u64"           , "f64"
562         , "int"               , "uint"          , "float"
563         , "bool"              ,                  , "double"
564         , "ref"               , "move"          , "borrow"
565         , "trait"             , "typeclass"
566         , "instance"          , "impl"
567         ].iter().map(|x| (*x).into())
568         .collect()
569     }
570     , op: Identifier {
571         start: satisfy(move |c| chars::OPS.contains(c))
572         , rest: satisfy(move |c| chars::OPS.contains(c))
573         , reserved: [ ">=", ">", "\\\"", "|", chars::ARROW, chars::FAT_ARROW]
574         .iter().map(|x| (*x).into()).collect()
575     }
576     , comment_line: string(";").map(|_| ())
577     , comment_start: string("#|").map(|_| ())
578     , comment_end: string("#").map(|_| ())
579 });
580 let env = MnEnv { env: env };
581
582 env.white_space()
583     .with(many1::<Vec<Expr<'a, U>>, _>(env.expr()))
584     .parse(code)
585     .map(|(e, _)| e)
586 }

```

## tests.rs

```

1 use super::parse_module;
2
3 use core::semantic::ast::Node;
4
5 macro_rules! expr_test {
6     ($name:ident, $code:expr) => {
7         #[test]
8         fn $name() {
9             assert_eq!( parse_module($code)
10                 .unwrap()[0]
11                 .to_sexpr(0)

```

```

12         , $code)
13     }
14 }
15 }
16
17 expr_test!(test_basic_add, "(+ 1 2)");
18 expr_test!(test_basic_sub, "(- 3 4)");
19 expr_test!(test_basic_div, "(/ 5 6)");
20 expr_test!(test_basic_mul, "(* 1 2)");
21 expr_test!(test_nested_arith_1, "(+ 1 (- 2 3))");
22 expr_test!(test_nested_arith_2, "(* (+ 1 2) 3 4)");
23 expr_test!(test_nested_arith_3, "(+ (/ 1 2) (* 3 4))");
24
25 expr_test!(test_call_1, "(my_fn 1 2)");
26 expr_test!(test_call_2, "(my_fn (my_other_fn a_var a_different_var))");
27 expr_test!(test_call_3
28     , "(my_fn (my_other_fn a_var a_different_var) VarWithUppercase Othervar)");
29 expr_test!(test_call_4
30     , "(my_fn (my_other_fn a_var a_different_var) (another_fn a_var))");
31
32 expr_test!(test_call_ptr_1, "(my_fn a *b)");
33 expr_test!(test_call_ptr_2, "(my_fn *a *b)");
34 expr_test!(test_call_ptr_3, "(my_fn &a)");
35 expr_test!(test_call_ptr_4, "(my_fn a &b)");
36 expr_test!(test_call_ptr_5, "(my_fn &a &b)");
37 expr_test!(test_call_ptr_6, "(my_fn @a)");
38 expr_test!(test_call_ptr_7, "(my_fn a @b)");
39 expr_test!(test_call_ptr_8, "(my_fn @a @b)");
40
41 expr_test!(test_defsyntax_1,
42     "(define fac (\u{3bb} (\u{8594} int int)
43     \t((0) 1)
44     \t((n) (fac (- n 1))))\n)");
45
46 #[test]
47 fn test_defsyntax_sugar() {
48     let string =
49 r#"
50 (def fac (fn {int -> int}
51     ((0) 1)
52     ((n) (fac (- n 1)))))"#;
53     assert_eq!( parse_module(string).unwrap()[0]
54                 .to_sexpr(0)
55                 , "(define fac (\u{3bb} (\u{8594} int int)
56     \t((0) 1)
57     \t((n) (fac (- n 1))))\n) " )
58 }

```

## B.3 Manganese Application Crate

main.rs



```

1  //
2  // The Manganese Mnemosyne Compilation System
3  // (c) 2015 Hawk Weisman
4  //
5  // Mnemosyne is released under the MIT License. Please refer to
6  // the LICENSE file at the top-level directory of this distribution
7  // or at https://github.com/hawkw/mnemosyne/.
8  //
9  extern crate clap;
10 extern crate mnemosyne;
11 extern crate mnemosyne_parser as parser;
12
13 use clap::{Arg, App, SubCommand};
14
15 use std::error::Error;
16 use std::io::Read;
17 use std::fs::File;
18 use std::path::PathBuf;
19
20 use mnemosyne::ast;
21 use mnemosyne::ast::Node;
22 use mnemosyne::errors::UnwrapICE;
23
24 const VERSION_MAJOR: u32 = 0;
25 const VERSION_MINOR: u32 = 1;
26
27 fn main() {
28     let matches = App::new("Manganese")
29         .version(&format!("v{}.{} for {} ({})"
30             , VERSION_MAJOR
31             , VERSION_MINOR
32             , mnemosyne::mnemosyne_version()
33             , mnemosyne::llvm_version()
34         ))
35         .author("Hawk Weisman <hi@hawkweisman.me>")
36         .about("[Mn] Manganese: The Mnemosyne Compilation System")
37         .args_from_usage(
38             "<INPUT> 'Source code file to compile'
39             -d, --debug 'Display debugging information'")
40         .get_matches();
41
42     let path = matches.value_of("INPUT")
43         .map(PathBuf::from)
44         .unwrap();
45
46     let code = File::open(&path)
47         .map_err(|error| String::from(error.description()))
48         .and_then(|mut file| {
49             let mut s = String::new();
50             file.read_to_string(&mut s)
51                 .map_err(|error| String::from(error.description()))
52                 .map(|_| s)

```

```
53         })
54         .unwrap();
55
56     let ast = parser::parse_module(code.as_ref())
57         .unwrap();
58
59     for node in ast { println!("{}", (*node).to_sexpr(0)) }
60 }
```

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