

Final Exam: March 22nd

- Take home exam
- Haskell coding questions
- Operational semantics questions
- Made available 10am (Pacific Time) March 22nd
- Due 10am March 23rd

CS 252:

Advanced Programming Language Principles



Parsing Combinators

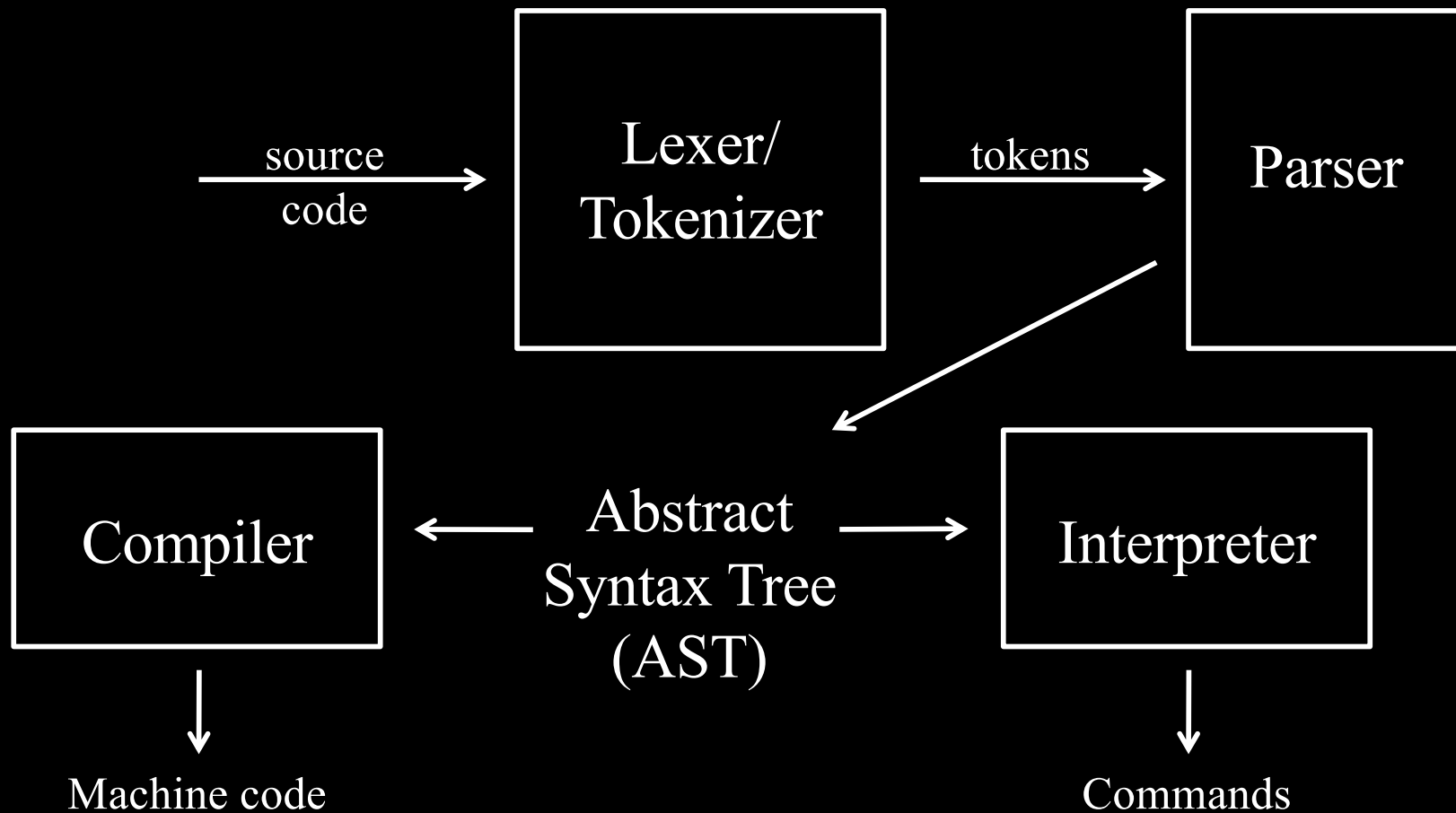
Prof. Tom Austin

San José State University

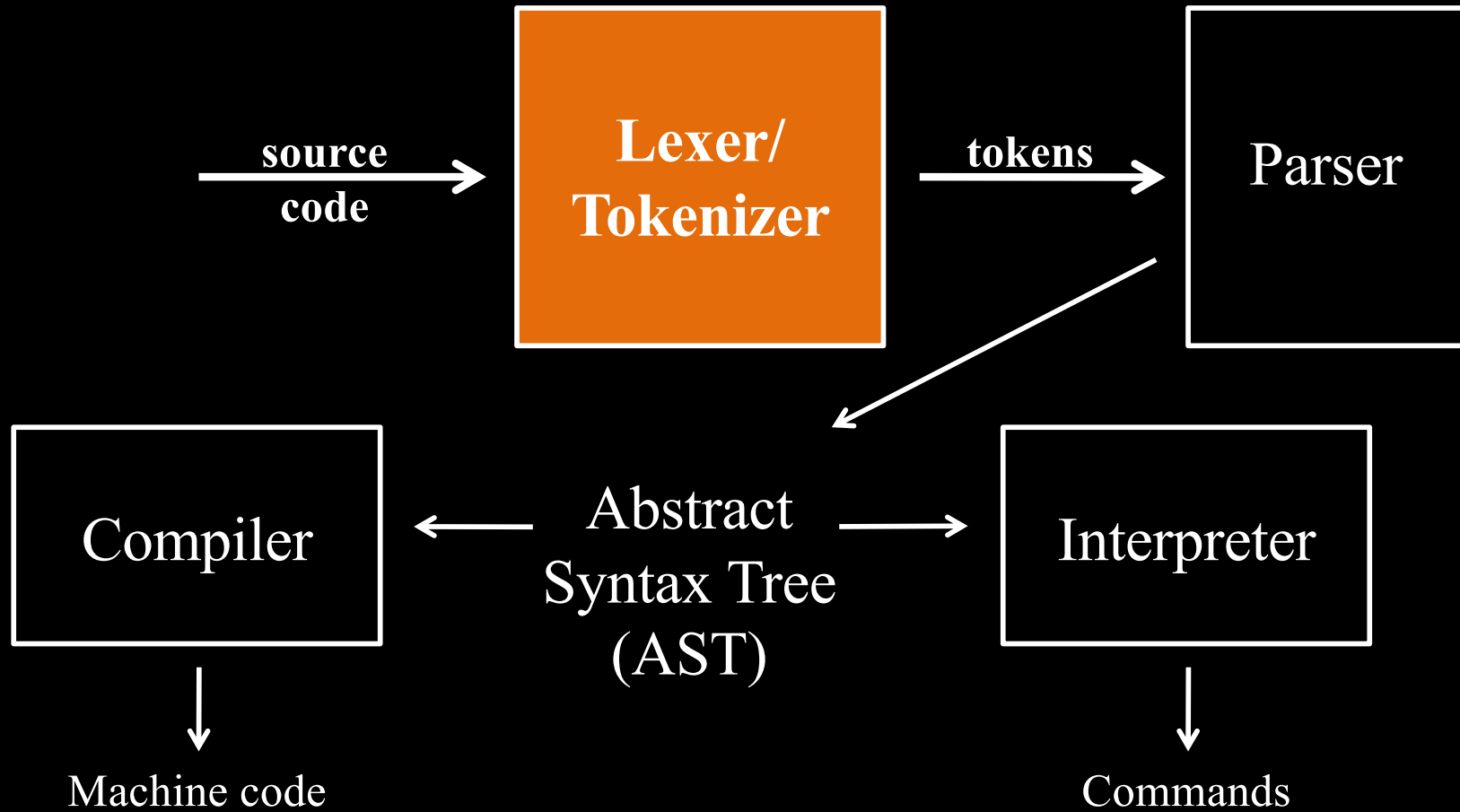
Syntax vs. Semantics

- Semantics:
 - What does a program mean?
 - Defined by an interpreter or compiler
- Syntax:
 - How is a program structured?
 - Defined by a lexer and parser

Review: Overview of Compilation



Tokenization



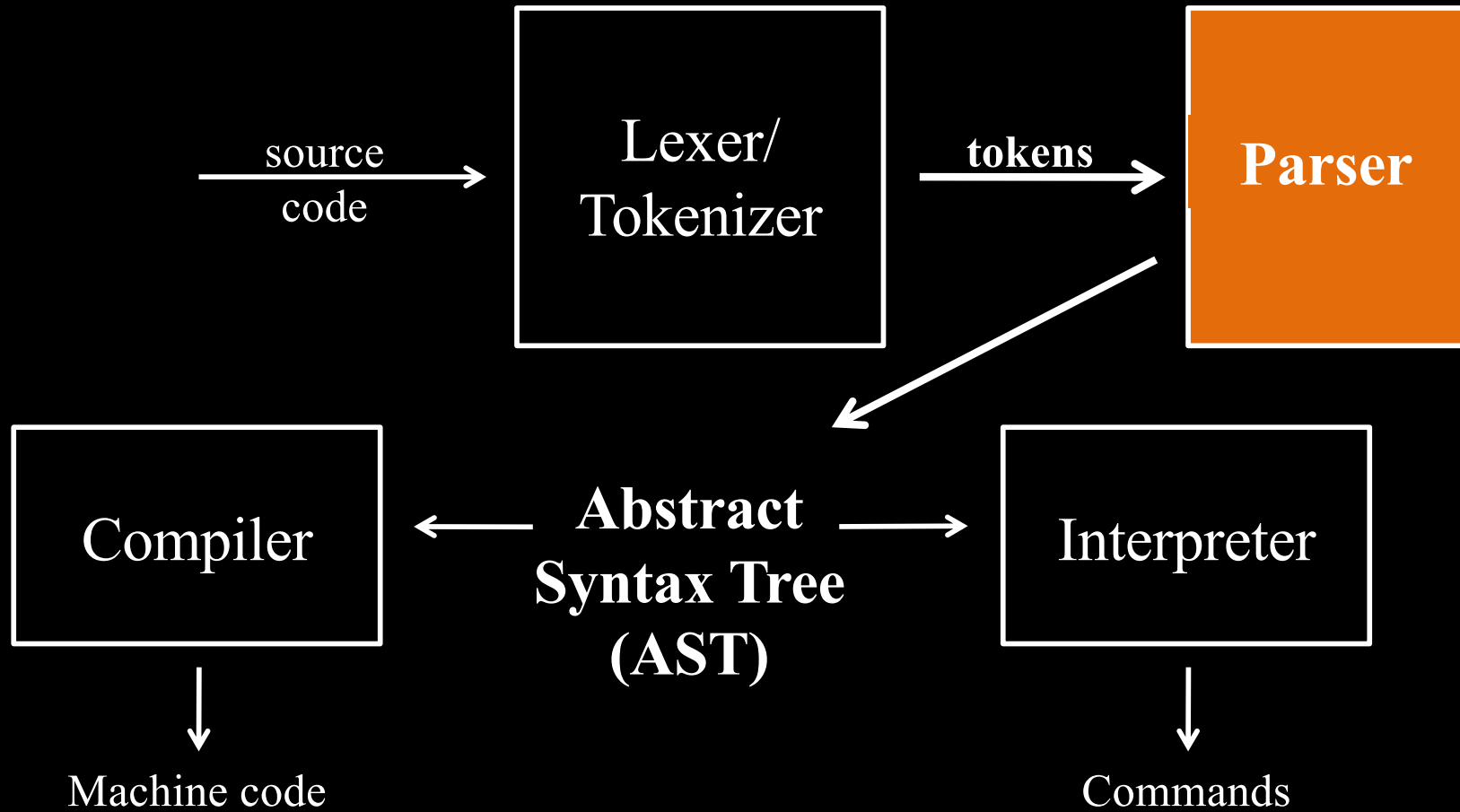
Tokenization

- Converts characters to the *words* of the language.
- Popular lexers:
 - Lex/Flex (C/C++)
 - ANTLR & JavaCC (Java)
 - *Parsec* (Haskell)

Categories of Tokens

- Reserved words or keywords
 - e.g. `if`, `while`
- Literals or constants
 - e.g. `123`, `"hello"`
- Special symbols
 - e.g. `;`, `<=`, `+`
- Identifiers
 - e.g. `balance`, `tyrionLannister`

Parsing



Parsing

- Parsers take tokens and combine them into *abstract syntax trees* (ASTs).
- Defined by *context free grammars* (CFGs).
- Parsers can be divided into
 - bottom-up/shift-reduce parsers
 - top-down parsers

Context Free Grammars

- Grammars specify a language
- Backus-Naur form format

$$\begin{aligned} \text{Expr} &\rightarrow \text{Number} \\ &| \text{Number} + \text{Expr} \end{aligned}$$

- **Terminals** cannot be broken down further.
- **Non-terminals** can be broken down into further phrases.

Sample grammar

$\text{expr} \rightarrow \text{expr} + \text{expr}$
 $\quad \quad | \text{expr} - \text{expr}$
 $\quad \quad | (\text{expr})$
 $\quad \quad | \text{number}$

$\text{number} \rightarrow \text{number digit}$
 $\quad \quad | \text{digit}$

$\text{digit} \rightarrow 0 \mid 1 \mid 2 \mid \dots \mid 9$

Bottom-up Parsers

- a.k.a. **shift-reduce parsers**
 1. shift tokens onto a stack
 2. reduce to a non-terminal.
- **LR**: left-to-right, rightmost derivation
- Look-Ahead LR parsers (**LALR**)
 - most popular style of LR parsers
 - YACC/Bison
- Fading from popularity.

Top-down parsers

- Non-terminals expanded to match tokens.
- **LL**: left-to-right, leftmost derivation
- **LL(k)** parsers look ahead k elements
 - example LL(k) parser: JavaCC
 - LL(1) parsers are of special interest

Parser combinators

- Combine simpler parsers to make a more complex parser
- Example in Parsec:

```
num :: GenParser Char st String  
num = many1 digit
```

Type of result

```
import Text.ParserCombinators.Parsec

num :: GenParser Char st String
num = many1 digit

main = do
    print $ parse num "example 1" "42"
```

```
import Text.ParserCombinators.Parsec

num :: GenParser Char st Integer
num = do
    str <- many1 digit
    return $ read str

main = do
    print $ parse num "example 2" "42"
```

Some useful functions

- `many/many1`: 0/1 or more of ...
- `noneOf`: Anything but ...
- `spaces`: whitespace characters
- `char`: the character ...
- `string`: the string ...

CSV parser (1st attempt)

(in-class)

Year, Make, Model, Length

1997, Ford, E350, 2.34

2000, Mercury, Cougar, 2.38

Example Using <|>, <?>, and try

```
eol = try (string "\n\r")
```

```
<|> string "\n"
```

```
<?> "end of line"
```

If you
can't match,
rewind.

CSV parser (2nd attempt)

(in-class)

Year, Make, Model, Length

1997, Ford, E350, 2.34

2000, Mercury, Cougar, 2.38

JSON example

```
{ name: "Complex number example",  
  nums: [  
    { real: 42, imaginary: 1 },  
    { real: 30, imaginary: 0 },  
    { real: 15, imaginary: 7 } ],  
  knownIssues: null,  
  verified: false }
```

Lab: Parsec

This lab is available in Canvas.

Starter code is available on the course website.