Summary

- ASTs are abstract representation of a program
- There is way to theoretically define the abstract syntax by looking at the concrete syntax
- Now, we are defining a language with *only addition*. So, we also show how to define this AST in racket (using `define-datatype`), and then write an `unparser` to go from AST to concrete syntax and then a `parser` to go from concrete syntax to AST

Agenda: Introducing ASTs by defining what they are, and how to show them in racket.

- We will be defining our first (very trivial) language
- Will come around to (eventually) Abstract Syntax Trees
- First, a few questions about programs:

  1. What is a program? How is it represented? `<-- will tackle this today`
  2. What does it mean? How does it run?

What is a program

Say you have a python program:

```
def f(x):
    return x+2
```

- It's a sequence of characters, a sequence of tokens
- However, we are more concerned with abstract representations

A more abstract representation of a program

- **Trees** are an abstract representation. We will be using that.
- We start with a simple language: addition
  - It's representation of something like `2 + 3` is

```
    +         Abstract syntax tree : this is what it is
   / \                               represented internally
  2   3

  Equivalent concrete structures: 2 + 3
                                  + 2 3

```

```

        concrete syntax             AST
    -------------------> PARSER --------> EVALUATOR
                                               |
                                               |
                                               V
                                            ANSWER
```

From concrete to abstract

We'll work with a very simple language, *addition*.

Say we have this concrete syntax:

```
<exp> ::= <num> |                    \_ prefix
        '(+ ' <exp> ' ' <exp> ')'    /

<exp> ::= <num> |                  \_ infix
        '(' <exp> '+' <exp>')'     /
```

The abstract syntax for that language is: [1]

```
<ast> ::= <num> |          \_ grammar of trees
          + <ast> <ast>    /

We pass judgement on the astness of an ast using
this:
|--------------------|
| if n ⊠  N          | num rule
| ⇒ n AST            |
|         OR         |
| if e1 AST & e2 AST | plus rule
| ⇒ + e1 e2 AST      |
|--------------------|

-------------------------------------------------
                       | Now, the valid expressions
                       V in this language are
                         usable for rating? judgements

           _________
Judgement: | e AST |
           ---------
```

An example of the judgement:

[1] at around 14:00, sir talks about the AST structure as a language. This caught me off guard causing me to lose track. It was mentioned once before, but was unable to pick it up at that moment.

Judgement	rating	justification
3 AST	sound	num, $3 \in \mathbb{N}$
2 AST	sound	num, $2 \in \mathbb{N}$
2+3 AST	sound	plus, 2 AST & 3 AST
2+ AST	unsound	not derivable

Implementing a parser and unparser

Rest of class: we will implement regularisation of ASTs, and write two functions: `parse`, `unparse`

Implementing ASTs in Racket

Other way to define

```
<ast> ::= <num> | + <ast> <ast>
          ---------v-----------
                   |
                   V
             Variant (sum) type
      base case | Inductive case
```

Implementing it in racket:

```
> (define-datatype ast ast? ;; the second is the type predicate
    [num (n number?)]
    [plus (left ast?) (right ast?)])

> (number? 5)
#t
> symbol?
> procedure?
;; so
> (check-true (ast? (num 5)))
#t
```

`num` and `plus` get autodefined as *constructor functions* with the following signatures:

- num ::= number? –> ast?
- plus ::= [ast?, ast?] –> ast?

Eg:

```
> (num 5); --> an AST                      num 5

;; example:                                   plus
> (ast? (plus (num 5)              ;        /      \
              (num 6)))            ;    num5      num6
#t

; example of more complex????                      +
> (let ([e1 (plus (num 5) (num 6))]  ;            / \
        [e2 (plus (num 3) (num 3))]) ;          +     +
       (plus e1 e2))                 ;         / \   / \
                                     ;       n5  n6 n2  n3
```

Now something something looking at abstract to concrete syntax

Abstract syntax —unparser–> concrete syntax <—parser—-

Unparser implementation in RACKET

```
;;; unparse : ast? ----> any/c
> (define (unparse a)
    (cases ast a
      [num (n) n]
      [plus (left right)
        (list '+
              (unparse left)
              (unparse right))]))
> (unparse (num 5))
5
> (unparse (plus (num 5) (num 4)))
'(+ 5 4)
```

Parser implementation in RACKET

```
;;; parse : any/c ---> ast? || error

> (define (parse d)
    (cond [(number? d) (num d)]
          [(and (list? d)
                (= (length d) 3)
                (eq? (first d) '+))
           (plus (parse (second d))
                 (parse (third d)))]
          [else (error 'parse "invalid syntax" d)]

> (parse 5)
```

```
(num 5)
> (parse '(+ 2 3))
(plus (num 2) (num 3))
```