Outline

➤➤ **Data Definitions and Templates**

➤ **Syntax and Semantics**

➤ **Defensive Programming**
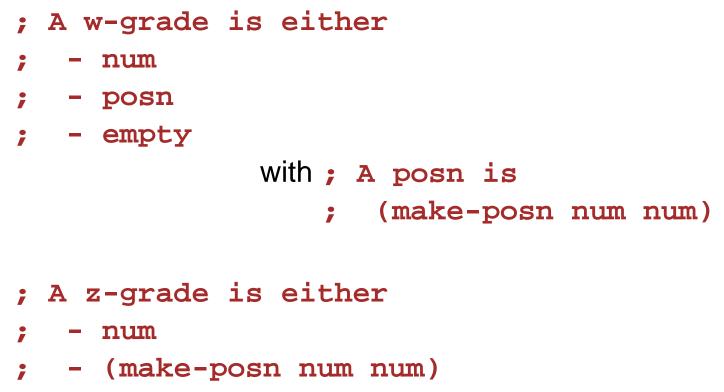
Data Definitions

Question 1:

Are both of the following data definitions ok?

```
; A w-grade is either
;   - num
;   - posn
;   - empty
```

with
```
; A posn is
;   (make-posn num num)
```

```
; A z-grade is either
;   - num
;   - (make-posn num num)
;   - empty
```

Data Definitions

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```
; A posn is
;   (make-posn num num)
```

```
; A z-grade is either
;   - num
;   - (make-posn num num)
;   - empty
```

Yes.

Data Definitions

Question 2:

Do `w-grade` and `z-grade` identify the same set of values?

```
; A w-grade is either
;   - num
;   - posn
;   - empty
```
with
```
; A posn is
;   (make-posn num num)
```

```
; A z-grade is either
;   - num
;   - (make-posn num num)
;   - empty
```

Data Definitions

Question 2:

Do `w-grade` and `z-grade` identify the same set of values?

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; A w-grade is either
;   - num
;   - posn
;   - empty
```
with
```
; A posn is
;   (make-posn num num)
```

```
; A z-grade is either
;   - num
;   - (make-posn num num)
;   - empty
```

Yes, every `w-grade` is a `w-grade`,
and every `z-grade` is a `w-grade`

Data Definitions

Are **w-grade** and **w-grade** the same data definition?

```
; A w-grade is either
;   - num
;   - posn
;   - empty
```

with
```
; A posn is
;   (make-posn num num)
```

```
; A z-grade is either
;   - num
;   - (make-posn num num)
;   - empty
```

Data Definitions

Question 3:

Are `w-grade` and `w-grade` the same data definition?

```
; A w-grade is either
;   - num
;   - posn
;   - empty
```

with `; A posn is`
`;    (make-posn num num)`

```
; A z-grade is either
;   - num
;   - (make-posn num num)
;   - empty
```

No, in the sense that they generate different templates

Data Definitions and Templates

The template depends on the *static*, *textual* content of a data definition, only

```
; A w-grade is either          (define (func-for-w-grade w)
;   - num                        (cond
;   - posn                         [(number? w) ...]
;   - empty                        [(posn? w) ... (func-for-posn w) ...]
; A posn is                       [(empty? w) ...]))
;   (make-posn num num)        (define (func-for-posn p)
                                  ... (posn-x p) ... (posn-y p) ...)


; A z-grade is either          (define (func-for-z-grade z)
;   - num                        (cond
;   - (make-posn num num)          [(number? z) ...]
;   - empty                        [(posn? z) ... (posn-x z) ... (posn-y z) ...]
                                   [(empty? z) ...]))
```

Data Definitions and Templates

Why we treat the data definition statically to generate a template:

- Provides well-defined, simple rules for generating a template

  - "Dynamic" coverage is difficult in general

  - Recall 3520 anecdote: thinking in terms of dynamic coverage $\Rightarrow$ broken programs

- Similar to the way that data choices affect modularity

  - Details of modularity are beyond the scope of this class, but we want to build the right instincts

Outline

➤ **Data Definitions and Templates**

⏩ **Syntax and Semantics**

➤ **Defensive Programming**

Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
  (/ x 2))
(f 10)
```

What's the result of clicking **Execute** ?

Execution in DrScheme

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5

Execution in DrScheme

Suppose that DrScheme's definition window contains

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(define (f x)
  (/ x 0))
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What's the result of clicking **Execute** ?

Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
  (/ x 0))
(f 10)
```

What's the result of clicking **Execute** ?

/: divide by 0

Execution in DrScheme

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Execution in DrScheme

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```

What's the result of clicking **Execute** ?

Nothing (although **f** would produce an error if it were used)

Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
   (/ x (0)))
```

What's the result of clicking **Execute** ?

Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
   (/ x (0)))
```

What's the result of clicking **Execute** ?

expected a name after an open parenthesis,
found a number — even without using **f**

Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
   (cond x))
```

What's the result of clicking **Execute** ?

Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
  (cond x))
```

What's the result of clicking **Execute** ?

cond: expected a question--answer clause — even without using **f**

Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
  (cond
    [false x]))
```

What's the result of clicking **Execute** ?

Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
  (cond
    [false x]))
```

What's the result of clicking **Execute** ?

Nothing

Execution in DrScheme

Suppose that DrScheme's definition window contains

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(define (f x)
  (cond
    [false x]))
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Execution in DrScheme

Suppose that DrScheme's definition window contains

```
(define (f x)
  (cond
    [false x]))
(f 10)
```

What's the result of clicking **Execute** ?

cond: all questions were false

Errors in DrScheme

DrScheme complains about a function body

- ○ sometimes before the function is used

- ○ sometimes only when the function is called

Why?

Errors in DrScheme

DrScheme complains about a function body

- ○ sometimes before the function is used

- ○ sometimes only when the function is called

Why?

Because some errors are **syntax errors** and some errors are **run-time errors**

Syntax Errors

A *syntax error* is like a question that isn't a well-formed sentence

- `f (x) = x + 0`
  - ○ DrScheme doesn't understand this notation, just like...

- "Parlez vous Francais?"
  - ○ English-only speaker doesn't understand this notation

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- `(define (f x) (/ x (0)))`
  - Parens around a zero make no sense to DrScheme, just like...

- "Does rain dog cat?"
  - Not enough verbs for this to make sense in English

Syntax Errors

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- `(define (f x) (/ x (0)))`
  - ◦ Parens around a zero make no sense to DrScheme, just like...

- "Does rain dog cat?"
  - ◦ Not enough verbs for this to make sense in English

When DrScheme sees a syntax error, it refuses to evaluate

Run-Time Errors

A **_run-time error_** is like a well-formed question with no answer

- `(/ 12 0)`
  - A clear request to DrScheme, but no answer, just like...

- "Why are you wearing a green hat?"
  - There's no answer if I'm wearing a blue hat

Run-Time Errors

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- "Why are you wearing a green hat?"
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- `(cond [false 10])`
  - There's no reasonable choice for DrScheme, just like...

- "If you can't understand me, what's your name?"
  - No one who understands the question should answer

Run-Time Errors

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  - There's no reasonable choice for DrScheme, just like...

- "If you can't understand me, what's your name?"
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DrScheme evaluates around run-time errors until forced to answer

The Difference between DrScheme and English

In a (good) programming language, all errors are well-defined, and the rules are relatively simple

- DrScheme has a simple, well-defined grammar, and deviations from the grammar are syntax errors

- The reduction rules for each construct and primitive operation are well-defined, producing either a value or an error

Beginner Scheme Grammar

A `<var>` is a name, a `<con>` is a constant, and a `<prm>` is an operator name

A `<defn>` is one of

```
(define (<var> <var> ... <var>) <exp>)
(define <var> <exp>)
(define-struct <var> (<var> ... <var>))
```

A `<exp>` is one of

```
<var>
<con>
(<prm> <exp> ... <exp>)
(<var> <exp> ... <exp>)
(cond [<exp> <exp>] ... [<exp> <exp>])
(cond [<exp> <exp>] ... [else <exp>])
(and <exp> ... <exp>)
(or <exp> ... <exp>)
```

Evaluation Rules: and/or

```
(and true) → true
(and true question ... question)
                    → (and question ... question)
(and false question ... question) → false


(or false) → false
(or false question ... question)
                    → (or question ... question)
(or true question ... question) → true
```

Evaluation Rules: and/or

`(and true)` → `true`

`(and true` *question ... question*`)`

→ `(and` *question ... question*`)`

`(and false` *question ... question*`)` → `false`

`(or false)` → `false`

`(or false` *question ... question*`)`

→ `(or` *question ... question*`)`

`(or true` *question ... question*`)` → `true`

Note that

`(and 7 false)`

fits the grammar, but has no matching evaluation rule, so it produces a run-time error

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Suppose that DrScheme's definition window contains

```
; f : num -> num
(define (f x)
  (+ x 2))
(f 'apple)
```

What's the result of clicking **Execute** ?

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+: expects a <number>, given 'apple

Execution in DrScheme

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(define (f x)
  (+ x 2))
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```

What's the result of clicking **Execute** ?

+: expects a <number>, given 'apple

But this is really a contract violation at the call to `f`

The implementor of `f` might want to clarify that this error is someone else's fault, not a bug in `f`

Defensive Programming

```
; f : num -> num
(define (real-f x)
  (+ x 2))
(define (f x)
  (cond
    [(number? x) (real-f x)]
    [else (error 'f "not a number")]))
(f 'apple)
```

Defensive Programming

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f: not a number

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        f: not a number
```

The **error** function triggers a run-time error

Defensive Programming

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    [(number? x) (real-f x)]
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(f 'apple)
```

f: not a number

The **error** function triggers a run-time error

You don't have to program defensively in this course, but it sometimes helps to defend against your own mistakes!