Other Kinds of Data

Suppose we want to represent snakes:

- name
- weight
- favorite food

What kind of data is appropriate?

Other Kinds of Data

Suppose we want to represent snakes:

- name
- weight
- favorite food

What kind of data is appropriate?

Not **`num`**, **`bool`**, **`string`**, **`image`**, or **`posn`**...

Data Definitions and define-struct

Here's what we'd like:

A `snake` is

```
(make-snake string num string)
```

Data Definitions and define-struct

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(define-struct snake (name weight food))
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Creates the following:

- `make-snake`
- `snake-name`
- `snake-weight`
- `snake-food`

Data Definitions and define-struct

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A `snake` is

```
(make-snake string num string)
```

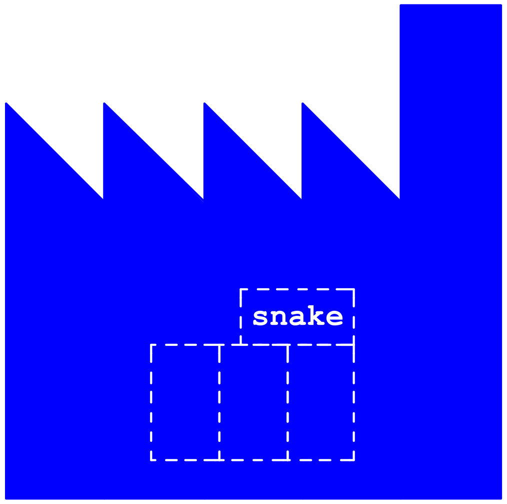
... but `make-snake` is not built into DrRacket

We can tell DrRacket about `snake`:

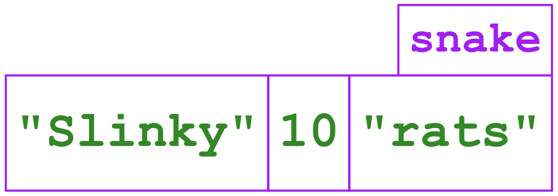
```
(define-struct snake (name weight food))
```

Creates the following:

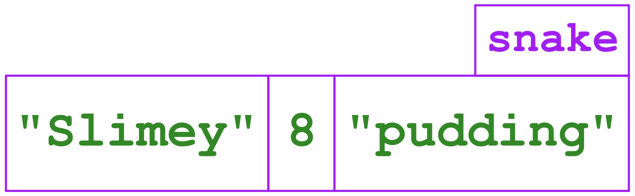
```
(snake-name (make-snake X Y Z)) → X
(snake-weight (make-snake X Y Z)) → Y
(snake-food (make-snake X Y Z)) → Z
```



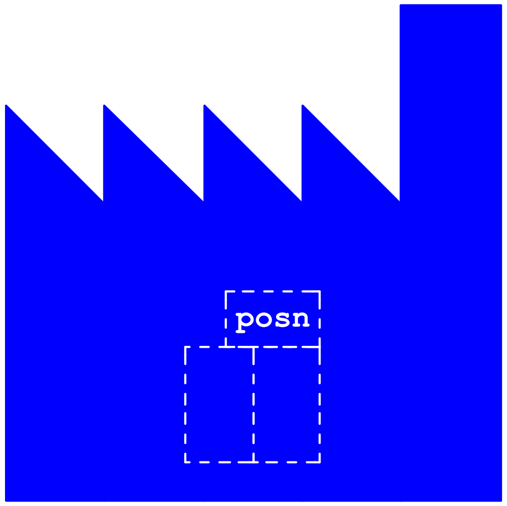
```
(define-struct snake (name weight food))
```



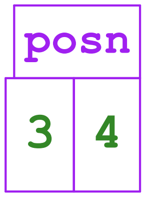
```
(make-snake "Slinky" 10 "rats")
```



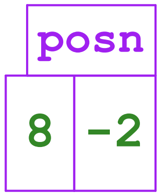
```
(make-snake "Slimey" 8 "pudding")
```



```
(define-struct posn (x y))
```



```
(make-posn 3 4)
```



```
(make-posn 8 -2)
```

Data

Deciding to define `snake` is in the first step of the design recipe

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Deciding to define **`snake`** is in the first step of the design recipe

Handin artifact: a comment and/or **`define-struct`**

```
; A snake is
;    (make-snake string num string)

(define-struct snake (name weight food))
```

Data

Deciding to define **`snake`** is in the first step of the design recipe

Handin artifact: a comment and/or **`define-struct`**

```
; A snake is
;    (make-snake string num string)

(define-struct snake (name weight food))
```

Now that we've defined **`snake`**, we can use it in signatures

Programming with Snakes

Implement **`snake-skinny?`**, which takes a snake and returns **`#true`** if the snake weights less than 10 pounds, **`#false`** otherwise

Programming with Snakes

Implement **`snake-skinny?`**, which takes a snake and returns **`#true`** if the snake weights less than 10 pounds, **`#false`** otherwise

Implement **`feed-snake`**, which takes a snake and returns a snake with the same name and favorite food, but five pounds heavier

Programming with Armadillos

Pick a representation for armadillos ("dillo" for short), where a dillo has a weight and may or may not be alive

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Implement **`run-over-with-car`**, which takes a dillo and returns a dead dillo of equal weight

Programming with Armadillos

Pick a representation for armadillos (“dillo” for short), where a dillo has a weight and may or may not be alive

Implement **`run-over-with-car`**, which takes a dillo and returns a dead dillo of equal weight

Implement **`feed-dillo`**, where a dillo eats 2 pounds of food at a time

Programming with Armadillos

Pick a representation for armadillos (“dillo” for short), where a dillo has a weight and may or may not be alive

Implement **`run-over-with-car`**, which takes a dillo and returns a dead dillo of equal weight

Implement **`feed-dillo`**, where a dillo eats 2 pounds of food at a time

... unless it's dead

Expanding the Zoo

We have snakes and armadillos. Let’s add ants.

An ant has

- a weight
- a location in the zoo

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We have snakes and armadillos. Let's add ants.

An ant has

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```
; An ant is
;   (make-ant num posn)
(define-struct ant (weight loc))
```

Expanding the Zoo

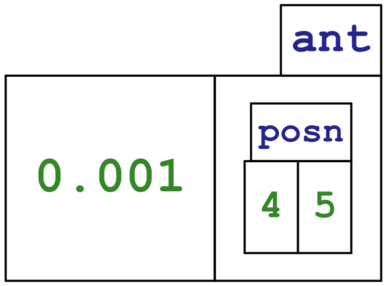
We have snakes and armadillos. Let's add ants.

An ant has

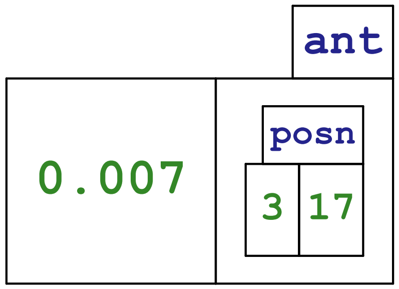
- a weight
- a location in the zoo

```
; An ant is
;   (make-ant num posn)
(define-struct ant (weight loc))

(make-ant 0.001 (make-posn 4 5))

(make-ant 0.007 (make-posn 3 17))
```

Ants



```
(make-ant 0.001 (make-posn 4 5))
```



```
(make-ant 0.007 (make-posn 3 17))
```

Programming with Ants

Define **`ant-at-home?`**, which takes an ant and reports whether it is at the origin

Signature, Purpose, and Header

```
; ant -> bool
```

Signature, Purpose, and Header

```
; ant -> bool
; Check whether ant a is home
```

Signature, Purpose, and Header

```
; ant -> bool
; Check whether ant a is home
(define (ant-at-home? a)
  ...)
```

Examples

```
; ant -> bool
; Check whether ant a is home
(define (ant-at-home? a)
  ...)
```

```
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 0 0)))
              #true)
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 1 1)))
              #false)
```

Template

```
; ant -> bool
; Check whether ant a is home
(define (ant-at-home? a)
  ... (ant-weight a)
  ... (ant-loc a) ...)
```

```
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 0 0)))
              #true)
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 1 1)))
              #false)
```

Template

```
; ant -> bool
; Check whether ant a is home
(define (ant-at-home? a)
  ... (ant-weight a)
  ... (posn-at-home? (ant-loc a)) ...)
```

New template rule: data-defn reference ⇒ template reference

Add templates for referenced data, if needed, and
implement body for referenced data

```
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 0 0)))
              #true)
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 1 1)))
              #false)
```

Template

```
; ant -> bool
; Check whether ant a is home
(define (ant-at-home? a)
  ... (ant-weight a)
  ... (posn-at-home? (ant-loc a)) ...)

(define (posn-at-home? p)
  ... (posn-x p) ... (posn-y p) ...)
```

```
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 0 0)))
              #true)
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 1 1)))
              #false)
```

Body

```
; ant -> bool
; Check whether ant a is home
;
; (define (ant-at-home? a)
;   ... (ant-weight a)
;   ... (posn-at-home? (ant-loc a)) ...)
;
; (define (posn-at-home? p)
;   ... (posn-x p) ... (posn-y p) ...)
(define (ant-at-home? a)
  (posn-at-home? (ant-loc a)))
(define (posn-at-home? p)
  (and (= (posn-x p) 0) (= (posn-y p) 0)))

(check-expect (ant-at-home? (make-ant 0.001 (make-posn 0 0)))
              #true)
(check-expect (ant-at-home? (make-ant 0.001 (make-posn 1 1)))
              #false)
```

Shapes of Data and Templates

The shape of the template matches the shape of the data

```
; An ant is
;   (make-ant num posn)

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

(define (ant-at-home? a)
  ... (ant-weight a)
  ... (posn-at-home? (ant-loc a)) ...)

(define (posn-at-home? p)
  ... (posn-x p) ... (posn-y p) ...)
```

Programming with Ants

Define **`feed-ant`**, which feeds an ant 0.001 lbs of food

Define **`move-ant`**, which takes an ant, an amount to move X, and an amount to move Y, and returns a moved ant

Animals

All animals need to eat...

Define `feed-animal`, which takes an animal (snake, dillo, or ant) and feeds it (5 lbs, 2 lbs, or 0.001 lbs, respectively)

Animals

All animals need to eat...

Define **`feed-animal`**, which takes an animal (snake, dillo, or ant) and feeds it (5 lbs, 2 lbs, or 0.001 lbs, respectively)

What is an **`animal`**?

Animal Data Definition

```
; An animal is either
;   - snake
;   - dillo
;   - ant
```

Animal Data Definition

```
; An animal is either
;   - snake
;   - dillo
;   - ant
```

The "either" above makes this a new kind of data definition:

data with ***varieties***

Animal Data Definition

```
; An animal is either
;   - snake
;   - dillo
;   - ant
```

The "either" above makes this a new kind of data definition:

data with ***varieties***

Examples:

```
(make-snake "slinky" 10 "rats")

(make-dillo 2 #true)

(make-ant 0.002 (make-posn 3 4))
```

Feeding Animals

```
; animal -> animal
; To feed the animal a
(define (feed-animal a)
  ...)
```

Feeding Animals

```
; animal -> animal
; To feed the animal a
(define (feed-animal a)
  ...)

(check-expect (feed-animal (make-snake "Slinky" 10 "rats"))
              (make-snake "Slinky" 15 "rats"))

(check-expect (feed-animal (make-dillo 2 #true))
              (make-dillo 4 #true))

(check-expect (feed-animal (make-ant 0.002 (make-posn 3 4)))
              (make-ant 0.003 (make-posn 3 4)))
```

Template for Animals

For the template step...

```
(define (feed-animal a)
  ...)
```

- Is `a` compound data?

Template for Animals

For the template step...

```
(define (feed-animal a)
  ...)
```

- Is `a` compound data?

- Technically yes, but the definition `animal` doesn't have `make-`*something*, so we don't use the compound-data template rule

Template for Varieties

Choice in the data definition

```
; An animal is either
;   - snake
;   - dillo
;   - ant
```

means **cond** in the template:

```
(define (feed-animal a)
  (cond
   [...  ...]
   [...  ...]
   [...  ...]))
```

Three data choices means three **cond** cases

Questions for Varieties

```
(define (feed-animal a)
  (cond
   [...  ...]
   [...  ...]
   [...  ...]))
```

How do we write a question for each case?

Questions for Varieties

```
(define (feed-animal a)
  (cond
   [...  ...]
   [...  ...]
   [...  ...]))
```

How do we write a question for each case?

It turns out that

```
    (define-struct snake (name weight food))
```

provides `snake?`

```
(snake? (make-snake "slinky" 5 "rats")) → #true
(snake? (make-dillo 2 #true)) → #false
(snake? 17) → #false
```

Template

```
(define (feed-animal a)
  (cond
   [(snake? a) ...]
   [(dillo? a) ...]
   [(ant? a) ...]))
```

New template rule: varieties ⇒ `cond`

Template

```
(define (feed-animal a)
  (cond
   [(snake? a) ...]
   [(dillo? a) ...]
   [(ant? a) ...]))
```

New template rule: varieties ⇒ `cond`

Now continue template case-by-case...

Template

```
(define (feed-animal a)
  (cond
   [(snake? a) ... (feed-snake a) ...]
   [(dillo? a) ... (feed-dillo a) ...]
   [(ant? a) ... (feed-ant a) ...]))
```

Remember: references in the data definition ⇒ template references

Template

```
(define (feed-animal a)
  (cond
   [(snake? a) ... (feed-snake a) ...]
   [(dillo? a) ... (feed-dillo a) ...]
   [(ant? a) ... (feed-ant a) ...]))
```

Remember: references in the data definition ⇒ template references

```
; An animal is either
;  - snake
;  - dillo
;  - ant
```

Shapes of Data and Templates

```
; An animal is either
;   - snake
;   - dillo
;   - ant

; A snake is
; (make-snake string num string)

; A dillo is
; (make-dillo num bool)

; An ant is
; (make-ant num posn)

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

```
(define (feed-animal a)
  (cond
   [(snake? a) ... (feed-snake a) ...]
   [(dillo? a) ... (feed-dillo a) ...]
   [(ant? a) ... (feed-ant a) ...]))

(define (feed-snake s)
  ... (snake-name s) ... (snake-weight s)
  ... (snake-food s) ...)

(define (feed-dillo d)
  ... (dillo-weight d)
  ... (dillo-alive? d) ...)

(define (feed-ant a)
  ... (ant-weight d)
  ... (feed-posn (ant-loc d)) ...)

(define (feed-posn p)
  ... (posn-x p) ... (posn-y p) ...)
```

Design Recipe III

Data

- Understand the input data

Signature, Purpose, and Header

- Describe (but don't write) the function

Examples

- Show what will happen when the function is done

Template

- Set up the body based on the input data (and *only* the input)

Body

- The most creative step: implement the function body

Test

- Run the examples

Data

When the problem statement mentions **N** different varieties of a thing, write a data definition of the form

```
; A thing is
;   - variety1
;   ...
;   - varietyN
```

Design Recipe III

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Signature, Purpose, and Header

- Describe (but don't write) the function

Examples

- Show what will happen when the function is done

Template

- Set up the body based on the input data (and *only* the input)

Body

- The most creative step: implement the function body

Test

- Run the examples

Examples

When the input data has varieties, be sure to pick each variety at least once.

```
; An animal is either
;   - snake
;   - dillo
;   - ant

(check-expect (feed-animal (make-snake "Slinky" 10 "rats"))
              (make-snake "Slinky" 15 "rats"))

(check-expect (feed-animal (make-dillo 2 #true))
              (make-dillo 4 #true))

(check-expect (feed-animal (make-ant 0.002 (make-posn 3 4)))
              (make-ant 0.003 (make-posn 3 4)))
```

Design Recipe III

Data

- Understand the input data

Signature, Purpose, and Header

- Describe (but don't write) the function

Examples

- Show what will happen when the function is done

Template

- Set up the body based on the input data (and *only* the input)

Body

- The most creative step: implement the function body

Test

- Run the examples

Template

When the input data has varieties, start with **`cond`**

- **`N`** varieties ⇒ **`N`** **`cond`** lines
- Formulate a question to match each corresponding variety
- Continue template steps case-by-case

```
(define (feed-animal a)
  (cond
   [(snake? a) ...]
   [(dillo? a) ...]
   [(ant? a) ...]))
```

Template

When the input data has varieties, start with **`cond`**

- **`N`** varieties ⇒ **`N`** **`cond`** lines
- Formulate a question to match each corresponding variety
- Continue template steps case-by-case

When the data definition refers to a data definition, make the template refer to a template

```
(define (ant-at-home? a)
  ... (ant-weight a)
  ... (posn-at-home? (ant-loc a)) ...)

(define (posn-at-home? p)
  ... (posn-x p) ... (posn-y p) ...)
```

Template

When the input data has varieties, start with **cond**

- **N** varieties ⇒ **N** **cond** lines
- Formulate a question to match each corresponding variety
- Continue template steps case-by-case

When the data definition refers to a data definition, make the template refer to a template

```
(define (feed-animal a)
  (cond
   [(snake? a) ... (feed-snake a) ...]
   [(dillo? a) ... (feed-dillo a) ...]
   [(ant? a) ... (feed-ant a) ...]))
```