Announcements
Pairs Review
Pairs and Lists
Pairs and Lists

In the late 1950s, computer scientists used confusing names
Pairs and Lists

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• **cons**: Two-argument procedure that creates a pair
Pairs and Lists

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- **cons**: Two-argument procedure that creates a pair

\[
(\text{cons} \ 1 \ 2)
\]
Pairs and Lists

In the late 1950s, computer scientists used confusing names

- `cons`: Two-argument procedure that creates a pair
- `car`: Procedure that returns the first element of a pair

(cons 1 2)
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(cons 1 2)  

1 2
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```
(cons 1 2)  
1     2

(cons 2 nil)  
2   → nil
```
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- A (non-empty) list in Scheme is a pair in which the second element is **nil** or a Scheme list

(cons 1 2)  
(cons 2 nil)
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(cons 1 2)  
1 2

(cons 2 nil)  
2 → nil
2

(cons 2 nil)

2
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```scheme
> (cons 1 (cons 2 nil))
```
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**Important!** Scheme lists are written in parentheses separated by spaces.

\[
> \text{(cons 1 (cons 2 nil))}
\]
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\[
> (\text{cons } 1 \text{ (cons } 2 \text{ nil})) \\
(1 \ 2)
\]
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**Important!** Scheme lists are written in parentheses separated by spaces

A dotted list has some value for the second element of the last pair that is not a list

```
> (cons 1 (cons 2 nil))
(1 2)
```
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```
> (cons 1 (cons 2 nil))  
(1 2)
> (define x (cons 1 2))
```
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```scheme
> (cons 1 (cons 2 nil))
(1 2)
> (define x (cons 1 2))
> x
```

\[ \text{CONS} \quad \text{Car} \quad \text{Cdr} \quad \text{Nil} \]
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```
> (cons 1 (cons 2 nil))
(1 2)
> (define x (cons 1 2))
> x
(1 . 2)
```
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```
> (cons 1 (cons 2 nil))
(1 2)
> (define x (cons 1 2))
> x
(1 . 2)
```

Not a well-formed list!
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```
> (cons 1 (cons 2 nil))
(1 2)
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> x
(1 . 2)
> (car x)
Not a well-formed list!
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```
> (cons 1 (cons 2 nil))
(1 2)
> (define x (cons 1 2))
x
(1 . 2)
> (car x)
1
Not a well-formed list!
```
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> (cons 1 (cons 2 nil))  
(1 2)  
> (define x (cons 1 2))  
> x  
(1 . 2)  
> (car x)  
1  
> (cdr x)  

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```
> (cons 1 (cons 2 nil))
(1 2)
> (define x (cons 1 2))
> x
(1 . 2)
> (car x)
1
> (cdr x)
2
```

Not a well-formed list!
Pairs and Lists

In the late 1950s, computer scientists used confusing names

- **cons**: Two-argument procedure that creates a pair
  - (cons 1 2)
  -  

- **car**: Procedure that returns the first element of a pair
  - (cons 2 nil)
  -  

- **cdr**: Procedure that returns the second element of a pair
  - (cons 1 (cons 2 (cons 3 (cons 4 nil))))
  -  

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- A (non-empty) list in Scheme is a pair in which the second element is **nil** or a Scheme list

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  ```scheme
  > (cons 1 (cons 2 nil))
  (1 2)
  > (define x (cons 1 2))
  > x
  (1 . 2)
  > (car x)
  1
  > (cdr x)
  2
  > (cons 1 (cons 2 (cons 3 (cons 4 nil))))
  Not a well-formed list!
  ```
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```scheme
> (cons 1 (cons 2 nil))  
(1 2)  
> (define x (cons 1 2))  
> x  
(1 . 2)  
> (car x)  
1  
> (cdr x)  
2  
> (cons 1 (cons 2 (cons 3 (cons 4 nil)))))
```

Not a well-formed list!
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  (cons 1 2)  
  (1 2)

• **car**: Procedure that returns the first element of a pair

  (cons 1 2)  
  (1 2)

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  (cons 1 2)  
  (1 2)

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  > (cons 1 (cons 2 nil))  
  (1 2)

  > (define x (cons 1 2))  
  > x  
  (1 . 2)

  > (car x)  
  1  

  > (cdr x)  
  2  

  > (cons 1 (cons 2 (cons 3 (cons 4 nil))))  
  (1 2 3 4)

  Not a well-formed list!
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> (cons 1 (cons 2 nil))
(1 2)
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> x
(1 . 2)
> (car x)
1
> (cdr x)
2
> (cons 1 (cons 2 (cons 3 (cons 4 nil))))
(1 2 3 4)
```

Not a well-formed list!
Exceptions
Today's Topic: Handling Errors
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Sometimes, computer programs behave in non-standard ways
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Sometimes, computer programs behave in non-standard ways
• A function receives an argument value of an improper type
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• A function receives an argument value of an improper type
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Grace Hopper's Notebook, 1947, Moth found in a Mark II Computer
Exceptions
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A built-in mechanism in a programming language to declare and respond to exceptional conditions
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Python raises an exception whenever an error occurs
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Exceptions can be handled by the program, preventing the interpreter from halting
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Unhandled exceptions will cause Python to halt execution and print a stack trace
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Mastering exceptions:
Exceptions

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Mastering exceptions:

Exceptions are objects! They have classes with constructors.
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They enable non-local continuations of control
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Mastering exceptions:

Exceptions are objects! They have classes with constructors.

They enable non-local continuations of control

If \( f \) calls \( g \) and \( g \) calls \( h \), exceptions can shift control from \( h \) to \( f \) without waiting for \( g \) to return.
Exceptions

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Mastering exceptions:

Exceptions are objects! They have classes with constructors.

They enable non-local continuations of control

If \texttt{f} calls \texttt{g} and \texttt{g} calls \texttt{h}, exceptions can shift control from \texttt{h} to \texttt{f} without waiting for \texttt{g} to return.

(Exception handling tends to be slow.)
Raising Exceptions
Assert Statements

Assert statements raise an exception of type AssertionError
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```
assert <expression>, <string>
```
Assert Statements

Assert statements raise an exception of type AssertionError

```python
assert <expression>, <string>
```

Assertions are designed to be used liberally. They can be ignored to increase efficiency by running Python with the "-O" flag; "O" stands for optimized
Assert Statements

Assert statements raise an exception of type AssertionError

```
assert <expression>, <string>
```

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```
python3 -O
```
**Assert Statements**

Assert statements raise an exception of type AssertionError

```
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```

Assertions are designed to be used liberally. They can be ignored to increase efficiency by running Python with the "-O" flag; "O" stands for optimized

```
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```

Whether assertions are enabled is governed by a bool __debug__
Assert Statements

Assert statements raise an exception of type AssertionError

```python
assert <expression>, <string>
```

Assertions are designed to be used liberally. They can be ignored to increase efficiency by running Python with the "-O" flag; "O" stands for optimized

```bash
python3 -O
```

Whether assertions are enabled is governed by a bool `__debug__`

(Demo)
Raise Statements
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Exceptions are raised with a raise statement
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\texttt{raise <expression>}

Raise Statements

Exceptions are raised with a raise statement

```
raise <expression>
```

<expression> must evaluate to a subclass of BaseException or an instance of one
Raise Statements

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```
raise <expression>
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Exceptions are constructed like any other object. E.g., `TypeError('Bad argument!')`
Raise Statements

Exceptions are raised with a raise statement

\[ \text{raise} \ <\text{expression}> \]

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Exceptions are constructed like any other object. E.g., `TypeError('Bad argument!')`

`TypeError` -- A function was passed the wrong number/type of argument
Raise Statements

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Exceptions are constructed like any other object. E.g., `TypeError('Bad argument!')`

`TypeError` — A function was passed the wrong number/type of argument

`NameError` — A name wasn't found
Raise Statements

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```
raise <expression>
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Exceptions are constructed like any other object. E.g., `TypeError('Bad argument!')`

- **TypeError** — A function was passed the wrong number/type of argument
- **NameError** — A name wasn't found
- **KeyError** — A key wasn't found in a dictionary
Raise Statements

Exceptions are raised with a raise statement

   raise <expression>

<expression> must evaluate to a subclass of BaseException or an instance of one

Exceptions are constructed like any other object. E.g., TypeError('Bad argument!')

TypeError -- A function was passed the wrong number/type of argument

NameError -- A name wasn't found

KeyError -- A key wasn't found in a dictionary

RuntimeError -- Catch-all for troubles during interpretation
Raise Statements

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- **RuntimeError** — Catch-all for troubles during interpretation

(Demo)
Try Statements
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Try statements handle exceptions
Try Statements

Try statements handle exceptions

```python
try:
    <try suite>
except <exception class> as <name>:
    <except suite>
...
```
Try Statements

Try statements handle exceptions

```
try:
    <try suite>
except <exception class> as <name>:
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```

Execution rule:
Try Statements

Try statements handle exceptions

```python
try:
    <try suite>
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    <except suite>
...
```

**Execution rule:**

The `<try suite>` is executed first
Try Statements

Try statements handle exceptions

try:
    <try suite>
    except <exception class> as <name>:
        <except suite>
    ...

Execution rule:

The <try suite> is executed first

If, during the course of executing the <try suite>, an exception is raised that is not handled otherwise, and
Try Statements

Try statements handle exceptions

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try:
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If the class of the exception inherits from `<exception class>`, then
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Try statements handle exceptions

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try:
    <try suite>
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        <except suite>
...
```

**Execution rule:**

The `<try suite>` is executed first

If, during the course of executing the `<try suite>`, an exception is raised that is not handled otherwise, and

If the class of the exception inherits from `<exception class>`, then

The `<except suite>` is executed, with `<name>` bound to the exception
Handling Exceptions
Handling Exceptions

Exception handling can prevent a program from terminating
Handling Exceptions

Exception handling can prevent a program from terminating

>>> try:
Handling Exceptions

Exception handling can prevent a program from terminating

```python
>>> try:
    x = 1/0
```
Handling Exceptions

Exception handling can prevent a program from terminating

```python
>>> try:
    x = 1/0
except ZeroDivisionError as e:
```
Exception handling can prevent a program from terminating

```python
>>> try:
    x = 1/0
  except ZeroDivisionError as e:
    print('handling a', type(e))
```
Handling Exceptions

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```python
>>> try:
    x = 1/0
except ZeroDivisionError as e:
    print('handling a', type(e))
    x = 0
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Handling Exceptions

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>>> try:
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handling a <class 'ZeroDivisionError'>
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Handling Exceptions

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handling a <class 'ZeroDivisionError'>
>>> x
0
```
Handling Exceptions

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        x = 0

handling a <class 'ZeroDivisionError'>
```

```
>>> x
0
```

**Multiple try statements:** Control jumps to the except suite of the most recent try statement that handles that type of exception
Handling Exceptions

Exception handling can prevent a program from terminating

```python
>>> try:
    x = 1/0
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handling a <class 'ZeroDivisionError'>
>>> x
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**Multiple try statements:** Control jumps to the except suite of the most recent try statement that handles that type of exception

(Demo)
WWPD: What Would Python Display?

How will the Python interpreter respond?
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How will the Python interpreter respond?

```python
def invert(x):
    inverse = 1/x  # Raises a ZeroDivisionError if x is 0
    print('Never printed if x is 0')
    return inverse

def invert_safe(x):
    try:
        return invert(x)
    except ZeroDivisionError as e:
        return str(e)
```
**WWPD: What Would Python Display?**

How will the Python interpreter respond?

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>>> invert_safe(1/0)
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>>> invert_safe(1/0)
>>> try:
```
**WWPD: What Would Python Display?**

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>>> invert_safe(1/0)
>>> try:
    ...    invert_safe(0)
```

WWPD?
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>>> try:
    ...   invert_safe(0)
    ... except ZeroDivisionError as e:
```
WWPD: What Would Python Display?

How will the Python interpreter respond?

```python
def invert(x):
    inverse = 1/x  # Raises a ZeroDivisionError if x is 0
    print('Never printed if x is 0')
    return inverse

def invert_safe(x):
    try:
        return invert(x)
    except ZeroDivisionError as e:
        return str(e)

>>> invert_safe(1/0)
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    ...     print('Hello!')
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`invert` function raises a `ZeroDivisionError` if `x` is 0, and `invert_safe` handles this exception by returning a string representation of the error.
Example: Reduce
Reducing a Sequence to a Value
Reducing a Sequence to a Value

```python
def reduce(f, s, initial):
    """Combine elements of s pairwise using f, starting with initial.

    E.g., reduce(mul, [2, 4, 8], 1) is equivalent to mul(mul(mul(1, 2), 4), 8).

    >>> reduce(mul, [2, 4, 8], 1)
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f is ...

*a two-argument function*
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