Announcements
Pairs Review
Pairs and Lists
Pairs and Lists

In the late 1950s, computer scientists used confusing names
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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

```lisp
(cons 1 2)  
1 2
```
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
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(cons 1 2)  
\[
\begin{array}{c}
1 \\
2 \\
\end{array}
\]

(cons 2 nil)  
\[
\begin{array}{c}
2 \\
\end{array} \rightarrow \text{nil}
\]
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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)  \[\begin{array}{c}
1 \\
2
\end{array}\]
```

```
(cons 2 nil) \[\begin{array}{c}
2 \rightarrow \text{nil}
\end{array}\]
```
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(cons 1 2)  
(cons 2 nil)
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\[
\text{> (cons 1 (cons 2 nil))}
\]
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A (non-empty) list in Scheme is a pair in which the second element is *nil* or a Scheme list.

**Important!** Scheme lists are written in parentheses separated by spaces.

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

\[
\textbf{Important!} \quad \text{Scheme lists are written in parentheses separated by spaces} \\
\]

\[
> (\text{cons} \ 1 \ (\text{cons} \ 2 \ \text{nil})) \\
(1 \ 2)
\]
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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

\[
\text{> (cons 1 (cons 2 nil))} \\
\text{(1 2)}
\]
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```scheme
> (cons 1 (cons 2 nil))
(1 2)
> (define x (cons 1 2))
```

```
1 2
2

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

```
1
\|\-----------\---------> nil
\___________
```

```
1
\|\---------> 2
\___________
```

```
1
\|\---------> 2
\___________
```

```
Not a well-formed list!
```

```
1
\|\---------> 2
\___________
```
Pairs and Lists

In the late 1950s, computer scientists used confusing names

- **cons**: Two-argument procedure that creates a pair
  
  \[ (\text{cons} \; 1 \; 2) \]

- **car**: Procedure that returns the first element of a pair
  
  \[ (\text{car} \; x) \]

- **cdr**: Procedure that returns the second element of a pair
  
  \[ (\text{cdr} \; x) \]

- **nil**: The empty list
  
  \[ \text{nil} \]

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

**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.

\[ (1 \; 2) \]

\[ (\text{define} \; x \; (\text{cons} \; 1 \; 2)) \]

\[ (1.2) \]

\[ (\text{car} \; x) \]

\[ 1 \]

\[ (\text{cdr} \; x) \]

\[ 2 \]

\[ (\text{cons} \; 1 \; (\text{cons} \; 2 \; (\text{cons} \; 3 \; (\text{cons} \; 4 \; \text{nil}))))) \]
**Pairs and Lists**

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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)))))
(1 2 3 4)
```

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```scheme
> (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
Today's Topic: Handling Errors

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- 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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- A network connection is lost in the middle of data transmission
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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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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 \( f \) calls \( g \) and \( g \) calls \( h \), exceptions can shift control from \( h \) to \( f \) without waiting for \( g \) 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>
```
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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
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; "0" stands for optimized

```bash
python3 -O
```
### 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

```
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```

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

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(Demo)
Raise Statements
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Exceptions are raised with a raise statement
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```
raise <expression>
```
Raise Statements

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```
raise <expression>
```

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

Exceptions are raised with a raise statement

\[
\text{raise } \langle \text{expression} \rangle
\]

\langle \text{expression} \rangle \text{ must evaluate to a subclass of BaseException or an instance of one}

Exceptions are constructed like any other object. E.g., \texttt{TypeError('Bad argument!')}
Raise Statements

Exceptions are raised with a raise statement

```python
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
Raise Statements

Exceptions are raised with a raise statement

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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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```python
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

```python
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
- **RuntimeError** — Catch-all for troubles during interpretation
Raise Statements

Exceptions are raised with a raise statement

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

\<expression>\ must evaluate to a subclass of \text{BaseException} or an instance of one

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

\text{TypeError} -- A function was passed the wrong number/type of argument
\text{NameError} -- A name wasn't found
\text{ KeyError} -- A key wasn't found in a dictionary
\text{ 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

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except <exception class> as <name>:
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...
```

Execution rule:
Try Statements

Try statements handle exceptions

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

**Execution rule:**

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

Try statements handle exceptions

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try:
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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
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Try statements handle exceptions

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

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

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
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Exception handling can prevent a program from terminating

```python
>>> 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:
```
Handling Exceptions

Exception handling can prevent a program from terminating

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

Exception handling can prevent a program from terminating

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

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

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

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```python
>>> try:
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        x = 0

handling a <class 'ZeroDivisionError'>
```

```python
>>> x
0
```
Handling Exceptions

Exception handling can prevent a program from terminating

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

```python
>>> x
0
```

**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?
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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def invert(x):
    inverse = 1/x  # Raises a ZeroDivisionError if x is 0
    print('Never printed if x is 0')
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    try:
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    except ZeroDivisionError as e:
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>>> invert_safe(1/0)
```

WWPD?
**WWPD: What Would Python Display?**

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def invert(x):
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    try:
        return invert(x)
    except ZeroDivisionError as e:
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>>> invert_safe(1/0)
>>> try:
```
**WWPD: What Would Python Display?**

How will the Python interpreter respond?

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def invert(x):
    inverse = 1/x  # Raises a ZeroDivisionError if x is 0
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def invert_safe(x):
    try:
        return invert(x)
    except ZeroDivisionError as e:
        return str(e)
```

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

**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:
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>>> invert_safe(1/0)
>>> try:
    ...
        invert_safe(0)
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except ZeroDivisionError as e:
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>>> invert_safe(1/0)
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>>> try:
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...     print('Hello!')
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```python
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WWPD: What Would Python Display?

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```
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)
    64
    """
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    reduce(pow, [1, 2, 3, 4], 2)
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\[
\text{reduce}(\text{pow}, [1, 2, 3, 4], 2)
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- `f` is ...  
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`reduce(pow, [1, 2, 3, 4], 2)`
Sierpinski's Triangle

(Demo)