Trees and Human Evolution

orangutan  gorilla  human  common chimpanzee  bonobo

~15 MYA  ~7 MYA  ~6 MYA  ~3 MYA

~15 MYA
Learning Goals

- Introduce biological question
- Describe how data is stored in memory (just a peek)
- Describe tree terminology and representation
- Practice writing functions on trees
This week’s homework

• Write memoized version of fold
• Find regions of strong secondary structure in HIV pol gene
• Find pairing interactions
• Drawing secondary structure interactions
• Add steric constraints!

“Care-package” -ization

```python
>>> shortestPath("A", "E", FiveCities, FiveDists)
10
```

```
[10, ['A', 'C', 'D', 'E']]
```
Coming Soon to CS 5 Green

• Phylogenetics
• OOPs
• CS Theory
• End-of-semester projects!

What we are ANTicipating…
Neanderthals and Modern Humans

the old man of La Chapelle

Neanderthal type specimen

https://www.msu.edu/~heslipst/contents/ANP440/images/Neanderthal_1_langle.jpg
http://humanorigins.si.edu/evidence/human-fossils/fossils/la-chapelle-aux-saints
http://anthropologynet.files.wordpress.com/2007/06/neander-valley.jpg
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~15 MYA
Homo erectus: first undisputed world traveler

Sangiran 17, 1.3-1.0 MYA, Sangiran Indonesia
Out of Africa vs. multiregional origin of modern humans

- H. sapiens in Africa
- H. sapiens in Europe
- H. sapiens in Asia

- H. erectus in Africa
- H. erectus in Europe
- H. erectus in Asia

Intermediate species possible
Differing predictions...

Multiregional model

Out of Africa model
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Lists Revisited

```python
>>> L = [4, 5, 7]

>>> M = L

>>> N = L + [9]
```

This is called “shallow copy”
>>> L = [4, 5, 7]
>>> M = L
>>> N = L + [9]

>>> L.append(6)

>>> L
[4, 5, 7, 6]

>>> M

>>> N

Lists Revisited

your computer’s memory

- L: [4, 5, 7] (length is 3)
- M: [4, 5, 7] (length is 3)
- N: [4, 5, 7, 9] (length is 4)
>>> L = [4, 5, 7]
>>> M = L
>>> N = L + [9]

>>> L.append(6)
>>> L
[4, 5, 7, 6]
>>> M
[4, 5, 7, 6]
>>> N
[4, 5, 7, 9]
Strings are **immutable**

```python
>>> F = "Spam"

>>> F.append("!")
BARF!  F.append("!")
AttributeError: 'str' object has no attribute 'append'
```

Python should *really* just say “BARF!”
Tuples are immutable lists

```python
>>> T = (4, 5, 7)
>>> T[0]
4
>>> T[1:]
(5, 7)
>>> len(T)
3
>>> T[0] = 42
BARF!
>>> T.append(42)
BARF!
```
Tuples are immutable lists

```python
>>> T = (4, 5, 7)
>>> U = T + (11, 12)
>>> U
(4, 5, 7, 11, 12)
>>> V = T + (5)
  ← something weird happens here!
BARF!
>>> V = T + (5,)
>>> V
(4, 5, 7, 5)
```
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Phylogenetic Trees

What about the Sontag, South, East, and Atwood Groodies?

How do we represent this in Python?

these are called leaf nodes or leaves or tips of the tree

these are called internal nodes

West Dorm Groody (“W”)
East Dorm Groody (“E”)
Linde Dorm Groody (“L”)
Case Groody (“C”)
RLR (root, left, right) format

groodies = ("X",
            ("Y",
             ("W", (), ()),
             "Z",
             ("E", (), ()),
             "L", (), ()),
            "C", (), ())
Draw this tree...

```
tr = ("Q",
     ("R",
      ("T",
       ("V", (), ()),
       ("Z", (), ()),
      ),
     ("S",
      ("X", (), ()),
      ("W", (), ()),
     ),
     ("Y", (), ()))
)
```
Draw this tree...

```
tr = ('Q',
     ('R',
      ('T',
       ('V', (), ()),
       ('Z', (), ())),
     ('S',
      ('X', (), ()),
      ('W', (), ())),
   ('Y', (), ()))
```
Learning Goals

• Introduce biological question
• Describe how data is stored in memory (just a peek)
• Describe tree terminology and representation
• Practice writing functions on trees
def node_count(tree):
    """Returns the total number of nodes in the given tree."""

>>> node_count(('Yoohoo', (), ()))
1
>>> node_count(groodies)
7

You should always assume that if one child is () then so is the other!

Fill this in (in your notes)!
How many nodes are in this tree?

```python
def node_count(tree):
    """Returns the total number of nodes in the given tree."""
    root, left, right = tree  # root = tree[0], left = tree[1], right = tree[2]
    if left == (): return 1  # a leaf
    else:                     # an internal node
        return 1 + node_count(left) + node_count(right)
```

```python
>>> node_count(('Yoohoo', (), ()))
1
>>> node_count(groodies)
7
```

Fill this in (in your notes)!

You should always assume that if one child is () then so is the other!

It would be a shame to "leaf" out the base case!
Is my favorite species in this tree?

```python
def find(species, tree):
    #"Returns True if species is in tree and False otherwise.""
    root, left, right = tree
    if root == species: return True  # found it at the root!

>>> find("E", Groodies)
True
>>> find("Sontag", Groodies)
False
```

```
West Dorm Groody ("W")
East Dorm Groody ("E")
Linde Dorm Groody ("L")
Case Groody ("C")
```

```
"X"
  "Y"
  "Z"
```

```
```

```
```
Is my favorite species in this tree?

```python
def find(species, tree):
    """Returns True if species is in tree and False otherwise."""
    root, left, right = tree
    if root == species: return True  # found it at the root!
    if left == (): return False
    else:
        return find(species, left) or find(species, right)
```

>>> find("E", Groodies)
True
>>> find("Sontag", Groodies)
False
def height(tree):
    """Returns the height of the given Tree."""
    root, left, right = tree

>>> height(groodies)
3
>>> height(("spam", (), ()))
0

The height of a tree is the length of the path from the root to the deepest node in the tree.

Worksheet
def height(tree):
    """Returns the height of the given Tree."""
    root, left, right = tree
    if left == (): return 0  # a leaf
    else:  # an internal node
        return 1 + max(height(left), height(right))

>>> height(groodies)
3
>>> height(("spam", (), ()))
0

The height of a tree is the length of the path from the root to the deepest node in the tree.

Worksheet
node_list

>>> node_list(groodies)
['X', 'Y', 'W', 'Z', 'E', 'L', 'C']

```
def node_list(tree):
    """Returns the list of nodes in a given tree.""
    root, left, right = tree
```
def node_list(tree):
    """Returns the list of nodes in a given tree."""
    root, left, right = tree
    if left == (): return [root]
    else:
        return [root] + node_list(left) + node_list(right)
def leaf_list(tree):
    """Returns the list of leaves in a given Tree."""
    root, left, right = tree

>>> leaf_list(groodies)
['W', 'E', 'L', 'C']
def leaf_list(tree):
    """Returns the list of leaves in a given Tree."""
    root, left, right = tree
    if left == ():
        return [root]
    else:
        return leaf_list(left) + leaf_list(right)
Isomorphic Trees

Consider three trees

T1
("Anc",
("W", ( ), ( )),
("Anc",
("L", ( ), ( )),
("E", ( ), ( ))
)

E

L

W

T2
("Anc",
("Anc",
("E", ( ), ( )),
("L", ( ), ( ))
),
("W", ( ), ( ))
)

E

L

W

T3
("Anc",
("L", ( ), ( )),
("Anc",
("W", ( ), ( )),
("E", ( ), ( ))
)

L

W

E

We often use "Anc" to represent internal (ancestor) nodes that do not have unique labels.

Two trees are isomorphic if they imply the same underlying phylogenetic relationships

- T1 and T2 are isomorphic
- T3 is not isomorphic either with T1 or T2
Isomorphic Trees

>>> isomorphic(('A',(),()),('A',(),()))
True
>>> isomorphic(('A',(),()),T1)
False
>>> isomorphic(('A',(),()),('B',(),()))
False

>>> isomorphic(T1,T2)
True
>>> isomorphic(T1,T3)
False
>>> isomorphic(T2,T3)
False

def isomorphic(tree1, tree2):
    """Returns boolean indicating if tree1 and tree2 are isomorphic."""
Isomorphic Trees

```python
def isomorphic(tree1, tree2):
    """Returns boolean indicating if tree1 and tree2 are isomorphic."""
    if tree1 == tree2: return True
    elif tree1[1] == () or tree2[1] == (): return False
    else:
        option1 = isomorphic(tree1[1], tree2[1]) and \
                isomorphic(tree1[2], tree2[2])
        option2 = isomorphic(tree1[1], tree2[2]) and \
                isomorphic(tree1[2], tree2[1])
    return option1 or option2

>>> isomorphic(('A',(),()),('A',(),()))
True
>>> isomorphic(('A',(),()),T1)
False
>>> isomorphic(('A',(),()),('B',(),()))
False
>>> isomorphic(T1,T2)
True
>>> isomorphic(T1,T3)
False
>>> isomorphic(T2,T3)
False
```