# DATA ABSTRACTION AND TREES

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## 1 Data Abstraction

1. The following is an **Abstract Data Type (ADT)** for elephants. Each elephant keeps track of its name, age, and whether or not it can fly. Given our provided constructor, fill out the selectors:

```
def elephant(name, age, can_fly):
    """
    Takes in a string name, an int age, and a boolean can_fly.
    Constructs an elephant with these attributes.
    >>> dumbo = elephant("Dumbo", 10, True)
    >>> elephant_name(dumbo)
    "Dumbo"
    >>> elephant_age(dumbo)
    10
    >>> elephant_can_fly(dumbo)
    True
    """
    return [name, age, can_fly]
def elephant_name(e):
```

**Solution:**

```
    return e[0]
```

```
def elephant_age(e):
```

**Solution:**
```
    return e[1]
```

```
def elephant_can_fly(e):
```

**Solution:**
```
    return e[2]
```

2. This function returns the correct result, but there's something wrong about its implementation. How do we fix it?

```
def elephant_roster(elephants):
    """
    Takes in a list of elephants and returns a list of their
       names.
    """
    return [elephant[0] for elephant in elephants]
```

**Solution:** `elephant[0]` is a Data Abstraction Violation (DAV). We should use a selector instead. The corrected function looks like:

```
def elephant_roster(elephants):
        return [elephant_name(elephant) for elephant in
           elephants]
```

3. Fill out the following constructor for the given selectors.

```
def elephant(name, age, can_fly):
```

**Solution:**
```
    return [[name, age], can_fly]
```

```
def elephant_name(e):
    return e[0][0]
def elephant_age(e):
    return e[0][1]
def elephant_can_fly(e):
    return e[1]
```

4. How can we write the fixed `elephant_roster` function for the constructors and selectors in the previous question?

**Solution:** No change is necessary to fix `elephant_roster` since using the `elephant` selectors "protects" the roster from constructor definition changes.

5. **(Optional)** Fill out the following constructor for the given selectors.

```
def elephant(name, age, can_fly):
    """
    >>> chris = elephant("Chris Martin", 38, False)
    >>> elephant_name(chris)
        "Chris Martin"
    >>> elephant_age(chris)
        38
    >>> elephant_can_fly(chris)
        False
    """
    def select(command)
```

**Solution:**

```
        if command == "name":
            return name
        elif command == "age":
            return age
        elif command == "can_fly":
            return can_fly
        return "Breaking abstraction barrier!"
```

```
    return select
def elephant_name(e):
    return e("name")
def elephant_age(e):
    return e("age")
def elephant_can_fly(e):
    return e("can_fly")
```

## 2 Trees

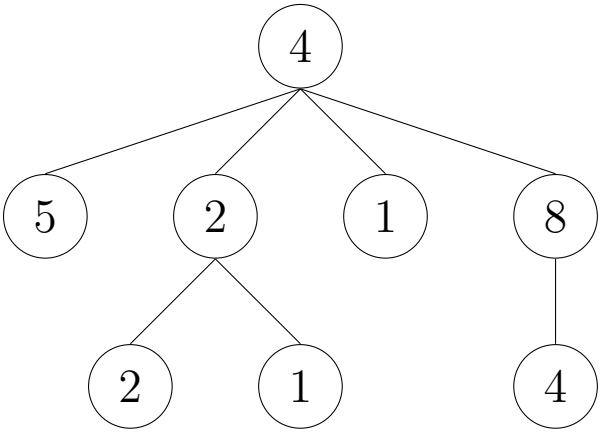
**Things to remember:**

```
def tree(label, branches=[]):
    return [label] + list(branches)

def label(tree):
    return tree[0]

def branches(tree):
    return tree[1:] #returns a list of branches
```

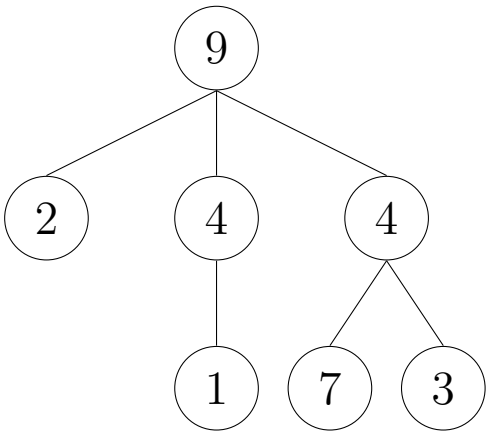
As shown above, the tree constructor takes in a label and a list of branches (which are themselves trees).

```
tree(4,
    [tree(5),
     tree(2,
        [tree(2),
         tree(1)]),
     tree(1),
     tree(8,
        [tree(4)])])
```

This creates a tree that looks like this:



1. Construct the following tree and save it to the variable `t`.




**Solution:**
```
t = tree(9, [tree(2, []),
             tree(4, [tree(1, [])]),
             tree(4, [tree(7, []),
                      tree(3, [])])])
```

2. What do the following expressions evaluate to? If the expressions evaluates to a tree, format your answer as `tree(... , ...)`. (Note that the python interpreter wouldn't display trees like this. We ask you to do this in order to think about trees as an ADT instead of worrying about their implementation.)

```
>>> label(t)
```

**Solution:** 9

```
>>> branches(t)[2]
```

**Solution:**
```
tree(4, [tree(7), tree(3)])
```

```
>>> branches(branches(t)[2])[0]
```

**Solution:**
```
tree(7)
```

3. Write the Python expression to return the integer 2 from t.

**Solution:**
```
label(branches(t)[0])
```

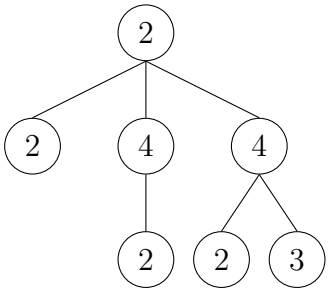
4. Write the function `sum_of_nodes` which takes in a tree and outputs the sum of all the elements in the tree.

```
def sum_of_nodes(t):
    """
    >>> t = tree(...) # Tree from question 2.
    >>> sum_of_nodes(t) # 9 + 2 + 4 + 4 + 1 + 7 + 3 = 30
    30
    """
```

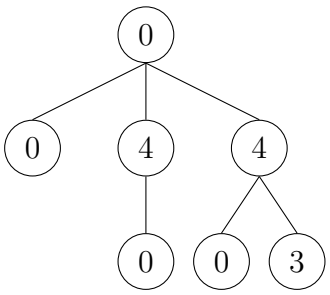
**Solution:**
```
    total = label(t)
    for branch in branches(t):
        total += sum_of_nodes(branch)
    return total

    Alternative solution:
    return label(t) +\
           sum([sum_of_nodes(b) for b in branches(t)])
```

5. Write a function, `replace_x` that takes in a tree, `t`, and returns a new tree with all labels `x` replaced with 0.

   For example, if we called `replace_x(t, 2)` on the following tree:




   We would expect it to return




```
def replace_x(t, x):
```

**Solution:**

```
    new_label = label(t)
    if new_label == x:
        new_label = 0
    new_branches = [replace_x(b, x) for b in branches(t)]
    return tree(label, new_branches)
```

6. Challenge: Write a function that returns true only if there exists a path from root to leaf that contains at least `n` instances of `elem` in a tree `t`.

```
def contains_n(elem, n, t):
    """
    >>> t1 = tree(1, [tree(1, [tree(2)])])
    >>> contains(1, 2, t1)
    True
    >>> contains(2, 2, t1)
    False
    >>> contains(2, 1, t1)
    True
    >>> t2 = tree(1, [tree(2), tree(1, [tree(1), tree(2)])])
    >>> contains(1, 3, t2)
    True
    >>> contains(2, 2, t2) # Not on a path
    False
    """
    if n == 0:

        return True

    elif _____________________________________________:

        return _____________________________________

    elif label(t) == elem:

        return _____________________________________

    else:

        return _____________________________________
```

**Solution:**

```
if n == 0:
    return True
elif is_leaf(t):
    return n == 1 and label(t) == elem
elif label(t) == elem:
    return True in [contains_n(elem, n - 1, b) for b in
      branches(t)]
else:
    return True in [contains_n(elem, n, b) for b in
      branches(t)]
```