CIS 1100

Nested Data

Python
Fall 2024
University of Pennsylvania

Dicts of Lists of Dicts of Lists of...

Not all data is *tabular*...

- sometimes we have to wrangle messy data into a `DataFrame`-y shape
  - API Responses & Data sent over the web
  - Survey responses
  - Data collected by hand
- other times we deal with data structures that aren't cleanly reducible to tables no matter what
  - family trees
  - certain file formats, like SVGs

Example: Historical Weather API

`open-meteo.com` maintains a service that lets you look up historical weather records for free using programs or a web form.

Unfortunately, when you ask it for some weather data, it looks like this:


```
{"latitude":47.90861,"longitude":-110.44777,"gener
ationtime_ms":21.31497859954834,"utc_offset_second
s":0,"timezone":"GMT","timezone_abbreviation":"GMT
","elevation":786.0,"hourly_units":{"time":"iso860
1","temperature_2m":"°F","precipitation":"inch"},"
hourly":{"time":["1972-01-15T00:00","1972-01-15T01
:00","1972-01-15T02:00","1972-01-15T03:00","1972-0
1-15T04:00","1972-01-15T05:00","1972-01-15T06:00",
"1972-01-15T07:00","1972-01-15T08:00","1972-01-15T
09:00","1972-01-15T10:00","1972-01-15T11:00","1972
-01-15T12:00","1972-01-15T13:00","1972-01-15T14:00
","1972-01-15T15:00","1972-01-15T16:00","1972-01-1
5T17:00","1972-01-15T18:00","1972-01-15T19:00","19
72-01-15T20:00","1972-01-15T21:00","1972-01-15T22:
00","1972-01-15T23:00"],"temperature_2m":[-3.3,-1.
1,2.4,7.4,11.5,14.4,17.4,20.2,23.2,25.6,29.1,31.0,
32.5,33.1,33.1,33.4,34.2,34.8,35.8,37.3,38.4,39.3,
39.5,39.6],"precipitation":[0.000,0.000,0.000,0.00
0,0.000,0.000,0.000,0.000,0.000,0.000,0.000,0.000,
0.000,0.000,0.000,0.000,0.000,0.000,0.000,0.000,0.
000,0.000,0.000,0.000]}}
```

Formatting to the Rescue


```
{
    "latitude": 47.90861,
    "longitude": -110.44777,
    "generationtime_ms": 21.31497859954834,
    "utc_offset_seconds": 0,
    "timezone": "GMT",
    "timezone_abbreviation": "GMT",
    "elevation": 786,
    "hourly_units": {
        "time": "iso8601",
        "temperature_2m": "°F",
        "precipitation": "inch"
    },
    "hourly": {
        "time": ["1972-01-15T00:00", "1972-01-15T01:00", ...],
        "temperature_2m": [-3.3, -1.1, ...],
        "precipitation": [0, 0, ...]
    }
}
```


This is an example of **JSON** data

(**J**avascript **O**bject **N**otation)

JSON

JSON is a common standard for data returned from requests made on the internet.

- Not just for Javascript
- In fact, it looks a lot like a Python dictionary...

```json
{
    "latitude": 47.90861,
    "longitude": -110.44777,
    "generationtime_ms": 21.31497859954834,
    "utc_offset_seconds": 0,
    "timezone": "GMT",
    "timezone_abbreviation": "GMT",
    "elevation": 786,
    "hourly_units": {
        "time": "iso8601",
        "temperature_2m": "°F",
        "precipitation": "inch"
    },
    "hourly": {
        "time": ["1972-01-15T00:00", "1972-01-15T01:00", ...],
        "temperature_2m": [-3.3, -1.1, ...],
        "precipitation": [0, 0, ...]
    }
}
```

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JSON & Python

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json

Python has a built-in JSON encoding and decoding library called `json`.

`json.loads()` (*"load string"*) parses a string of JSON data into a dictionary.

```
import json
data_string = '{"name" : "Harry"}'
data_dict = json.loads(data_string)
print(data_dict)
print(data_dict["name"])
```

🖨 👇

```
{'name': 'Harry'}
Harry
```

json

`json.load()` parses a string of JSON data into a dictionary.

```
import json
data_file = open('weather_response.json', 'r')
data_dict = json.load(data_file)
print(data_dict.keys())
```

🖨️ 👇

```
dict_keys(['latitude', 'longitude',
'generationtime_ms', 'utc_offset_seconds',
'timezone', 'timezone_abbreviation',
'elevation', 'hourly_units', 'hourly'])
```

Traversing Through JSON Data

Here are our keys...

```
dict_keys(['latitude', 'longitude',  'generationtime_ms', 'utc_offset_seconds',
'timezone', 'timezone_abbreviation', 'elevation', 'hourly_units', 'hourly'])
```

But how do we read it? And where are time and temperature in the dictionary?

```
{
    "latitude": 47.90861,
    "longitude": -110.44777,
    "generationtime_ms": 21.314978599548340,
    "utc_offset_seconds": 0,
    "timezone": "GMT",
    "timezone_abbreviation": "GMT",
    "elevation": 786,
    "hourly_units": {
        "time": "iso8601",
        "temperature_2m": "°F",
        "precipitation": "inch"
    },
    "hourly": {
        "time": ["1972-01-15T00:00", "1972-01-15T01:00", ...],
        "temperature_2m": [-3.3, -1.1, ...],
        "precipitation": [0, 0, ...]
    }
}
```

Nesting in JSON Data

A JSON Object will often have a nested, hierarchical structure.

- Some keys in the dictionary map to primitives

```
"latitude": 47.90861,
"longitude": -110.44777,
"generationtime_ms": 21.314978599548340,
"utc_offset_seconds": 0,
```

- Other keys map to other dictionaries…

```
"hourly_units": {
    "time": "iso8601",
    "temperature_2m": "°F",
    "precipitation": "inch"
},
```

Nesting in JSON Data

A JSON Object will often have a nested, hierarchical structure.

- And sometimes those dictionaries store other dictionaries or lists themselves!

```
"hourly": {
    "time": ["1972-01-15T00:00", "1972-01-15T01:00", ...],
    "temperature_2m": [-3.3, -1.1, ...],
    "precipitation": [0, 0, ...]
}
```

Working with Nested Structures

Answering questions using nested structures/JSON often requires...

- careful study of the structure by looking at keys, brackets
- list indexing and dictionary lookups, which you already know how to do!

Answering Questions

Where is this weather sample taken from?


```
{
    "latitude": 47.90861,
    "longitude": -110.44777,
    "generationtime_ms": 21.31497859954834,
    "utc_offset_seconds": 0,
    "timezone": "GMT",
    "timezone_abbreviation": "GMT",
    "elevation": 786,
    "hourly_units": {
        "time": "iso8601",
        "temperature_2m": "°F",
        "precipitation": "inch"
    },
    "hourly": {
        "time": ["1972-01-15T00:00", "1972-01-15T01:00", ...],
        "temperature_2m": [-3.3, -1.1, ...],
        "precipitation": [0, 0, ...]
    }
}
```

Answering Questions

Where is this weather sample taken from?

```
data = json.load(weather_file)
lat = data["latitude"]
lon = data["longitude"]
elv = data["elevation"]
print(f"Sample is from coordinates ({lat}, {lon}) at elevation of {elv} feet.")
```

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```
Sample is from coordinates (39.964848, 75.2933) at elevation of 2924.0 feet.
```

Answering Questions

Are the weather samples in Farenheit or Celsius?


```json
{
    "latitude": 47.90861,
    "longitude": -110.44777,
    "generationtime_ms": 21.31497859954834,
    "utc_offset_seconds": 0,
    "timezone": "GMT",
    "timezone_abbreviation": "GMT",
    "elevation": 786,
    "hourly_units": {
        "time": "iso8601",
        "temperature_2m": "°F",
        "precipitation": "inch"
    },
    "hourly": {
        "time": ["1972-01-15T00:00", "1972-01-15T01:00", ...],
        "temperature_2m": [-3.3, -1.1, ...],
        "precipitation": [0, 0, ...]
    }
}
```

Answering Questions

Are the weather samples in Farenheit or Celsius?

```
data = json.load(weather_file)
units = data["temperature_2m"]
```

Answering Questions

Are the weather samples in Farenheit or Celsius?

```
data = json.load(weather_file)
units = data["hourly_units"]
degrees = units["temperature_2m"]
print(f"Temperature given in {degrees}.")
```

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```
Temperature given in °F.
```

Answering Questions

Are the weather samples in Farenheit or Celsius?

```
data = json.load(weather_file)
degrees = data["hourly_units"]["temperature_2m"]
print(f"Temperature given in {degrees}.")
```

🖨️ 👇

```
Temperature given in °F.
```

Answering Questions

How many temperature samples are included?

What was the range of temperatures measured?


```
{
    "latitude": 47.90861,
    "longitude": -110.44777,
    "generationtime_ms": 21.31497859954834,
    "utc_offset_seconds": 0,
    "timezone": "GMT",
    "timezone_abbreviation": "GMT",
    "elevation": 786,
    "hourly_units": {
        "time": "iso8601",
        "temperature_2m": "°F",
        "precipitation": "inch"
    },
    "hourly": {
        "time": ["1972-01-15T00:00", "1972-01-15T01:00", ...],
        "temperature_2m": [-3.3, -1.1, ...],
        "precipitation": [0, 0, ...]
    }
}
```

Answering Questions

How many temperature samples are included?

What was the range of temperatures measured?

```
data = json.load(weather_file)
degrees = data["hourly_units"]["temperature_2m"]
temperatures = data["hourly"]["temperature_2m"]
num_samples = len(temperatures)
low, high = min(temperatures), max(temperatures)
temp_range = high - low
print(f"Over {num_samples} samples,")
print(f"the temperature shifted from {high} to {low}.")
print(f"That's a swing of {temp_range} {degrees}!")
```

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```
Over 360 samples,
the temperature shifted from 59.0 to 31.2.
That's a swing of 27.8 °F!
```

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Trees & XML

Python

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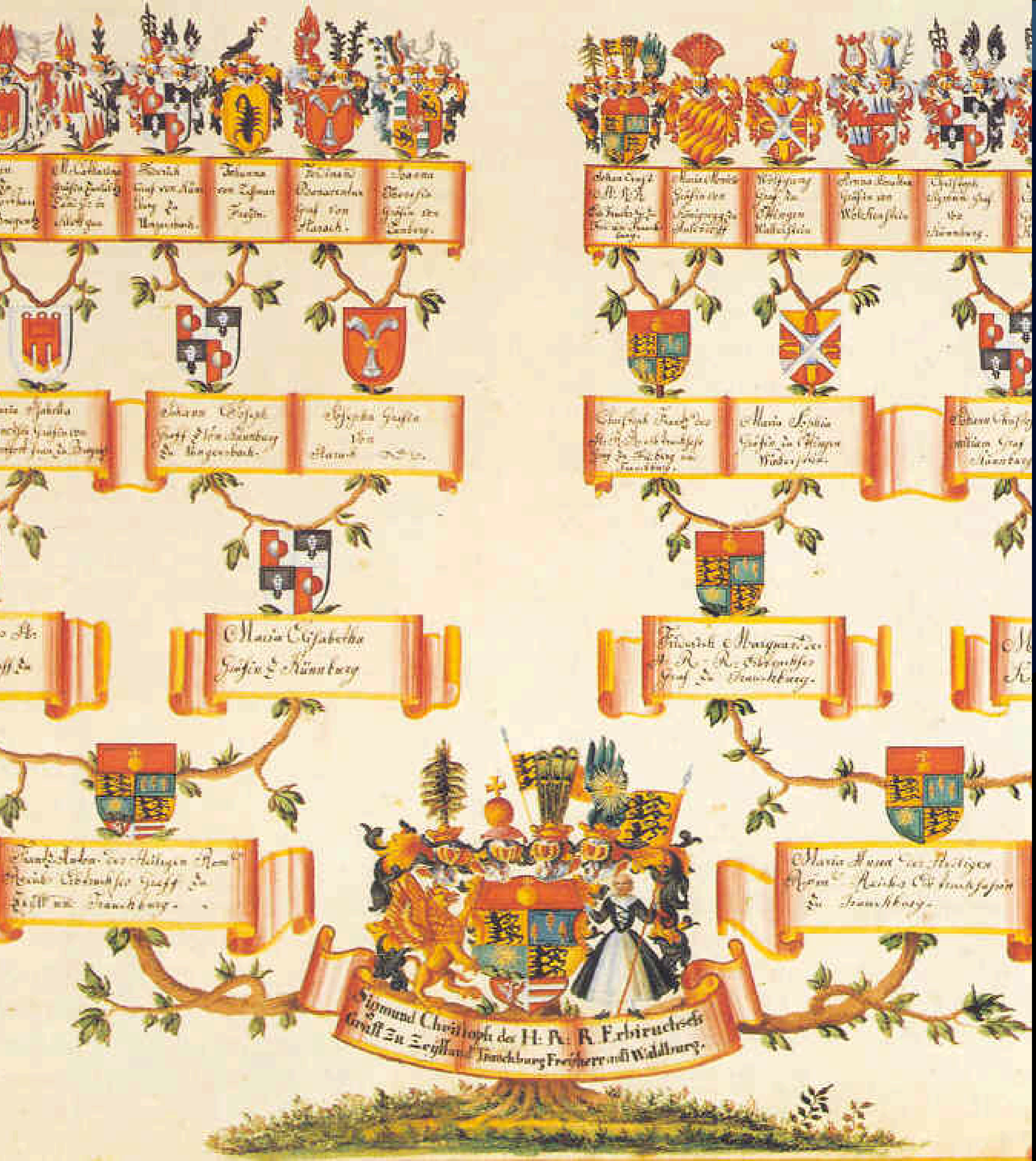


Tree Data

Trees in computer science are hierarchical collections of data elements (often called **nodes**) that have connections between them.

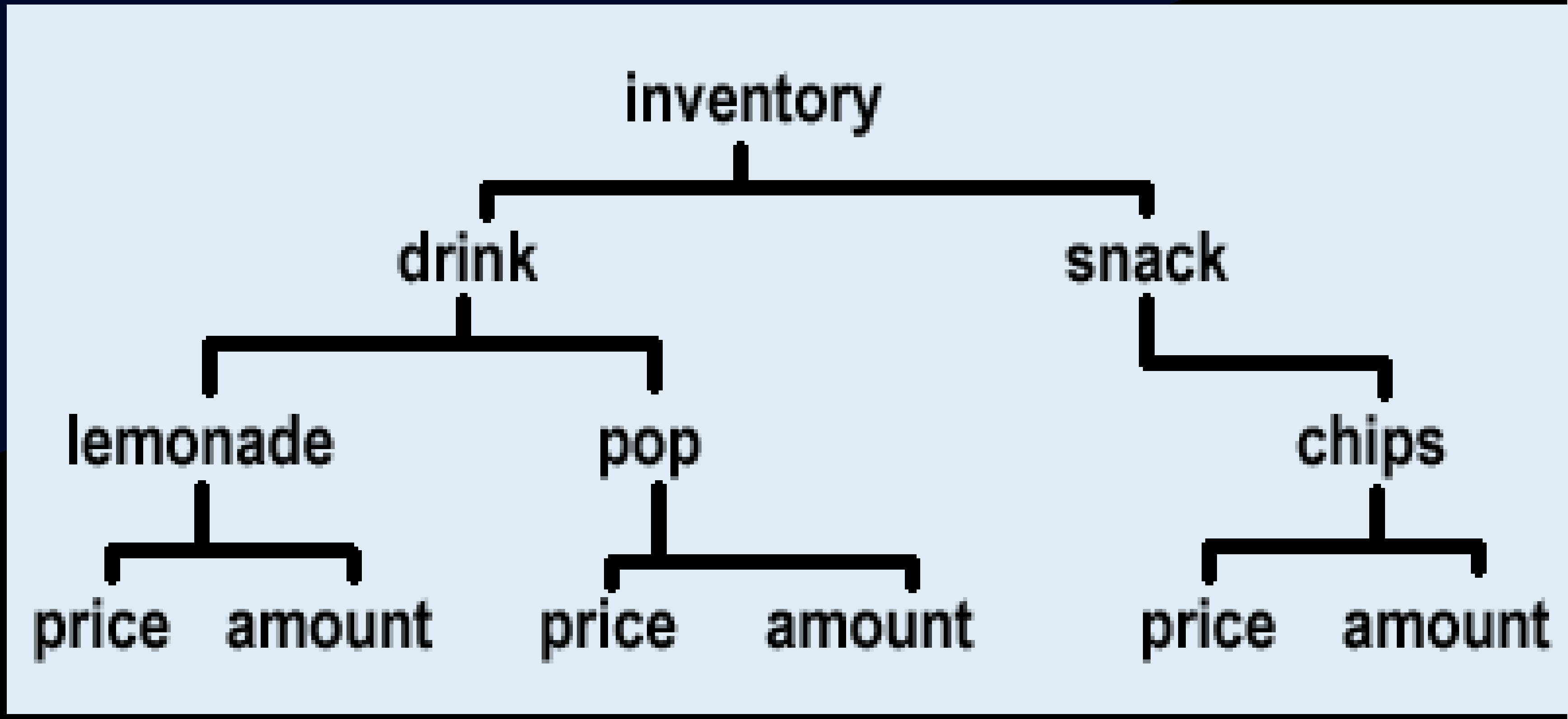
- e.g. family trees

XML

XML is a data document format that allows us to represent data nested inside of other data.

```
<inventory>
        <drink>
                <lemonade>
                        <price>$2.50</price>
                        <amount>20</amount>
                </lemonade>
                <pop brand="Pepsi">
                        <price>$1.50</price>
                        <amount>10</amount>
                </pop>
        </drink>

        <snack>
                <chips flavor="BBQ">
                        <price>$4.50</price>
                        <amount>60</amount>
                </chips>
        </snack>
</inventory>
```



http://www.tizag.com/xmlTutorial/xmltree.php

Some XML Terminology

- **Elements** are the entities being represented in the XML tree, e.g. an inventory or a price.
- **Tags** are the names that we give to the elements, e.g. `<inventory>` or `<price>`
- **Attributes** are properties that individual elements can have, stored in the tags
  - If the pop element is specifically a Pepsi, we could have its tag be `<pop brand="Pepsi">`.

```xml
<inventory>
        <drink>
                <lemonade>
                        <price>$2.50</price>
                        <amount>20</amount>
                </lemonade>
                <pop brand="Pepsi">
                        <price>$1.50</price>
                        <amount>10</amount>
                </pop>
        </drink>

        <snack>
                <chips flavor="BBQ">
                        <price>$4.50</price>
                        <amount>60</amount>
                </chips>
        </snack>
</inventory>
```

Some Tree Terminology

- The **tree** is the collection of elements being represented and the connections between them
- The **root** is the element of the tree that has no ancestors.
- An **ancestor** is an element that contains another element.
  - A **parent** is a direct ancestor.
- A **descendant** is an element that is contained by another element.
  - A **child** is a direct descendant.

```xml
<inventory>
        <drink>
                <lemonade>
                        <price>$2.50</price>
                        <amount>20</amount>
                </lemonade>
                <pop brand="Pepsi">
                        <price>$1.50</price>
                        <amount>10</amount>
                </pop>
        </drink>

        <snack>
                <chips flavor="BBQ">
                        <price>$4.50</price>
                        <amount>60</amount>
                </chips>
        </snack>
</inventory>
```

Why XML?

It's a convenient standard for representing hierarchy.

- Family trees, inventory systems
- Degree requirements & course dependencies

Many visual elements are best represented as hierarchical data

- PowerPoints and Word Documents are actually just XML documents rendered in a fancy way
  - Slides, which have boxes, which have images & text, which each have properties...
- Some image formats are XML, like SVG

```
<ns0:svg xmlns:ns0="http://www.w3.org/2000/svg" id="emoji" viewBox="0 0 72 72">
  <ns0:g id="color">
    <ns0:path fill="#d0cfce" d="m56..." />
    <ns0:path fill="#9b9b9a" d="m36.."/>
  </ns0:g>
  <ns0:g id="line">
    <ns0:path fill="none" stroke="#000" stroke-linecap="round" ... />
    <ns0:path fill="none" stroke="#000" stroke-miterlimit="10" ... />
  </ns0:g>
</ns0:svg>
```

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Parsing XML with Python

`BeautifulSoup` is a library we can use to parse or modify XML. Need to install it!

```
pip install bs4
```

```python
from bs4 import BeautifulSoup
data_file = open('country_data.xml', 'r')
tree = BeautifulSoup(data_file, 'xml')
data_file.close()
```

`tree` now stores the full XML structure!

Demo XML

This is `country_data.xml`:

```xml
<data>
    <country name="Liechtenstein">
        <rank>1</rank>
        <year>2008</year>
        <gdppc>141100</gdppc>
        <neighbor name="Austria" direction="E"/>
        <neighbor name="Switzerland" direction="W"/>
    </country>
    <country name="Singapore">
        <rank>4</rank>
        <year>2011</year>
        <gdppc>59900</gdppc>
        <neighbor name="Malaysia" direction="N"/>
    </country>
    <country name="Panama">
        <rank>68</rank>
        <year>2011</year>
        <gdppc>13600</gdppc>
        <neighbor name="Costa Rica" direction="W"/>
        <neighbor name="Colombia" direction="E"/>
    </country>
</data>
```

https://docs.python.org/3/library/xml.etree.elementtree.html

Parsing XML with Python

The `tree` is "rooted" at a `data` tag, so we could access that tag with:

```
root = tree.data
```

`root` stores its tag name and a dictionary of its attributes:

```
>>> root.name
'data'
>>> root.attrs
{}
```

"The root is a 'data' element that stores no attributes."

Look at the Children

You can iterate over all of the children of an element using `.find_all(recursive=False)`

```python
for child in root.find_all(recursive=False):
    print(child.name, child.attrs)
```

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```
country {'name': 'Liechtenstein'}
country {'name': 'Singapore'}
country {'name': 'Panama'}
```

```xml
<data>
    <country name="Liechtenstein">
        <rank>1</rank>
        <year>2008</year>
        <gdppc>141100</gdppc>
        <neighbor name="Austria" direction="E"/>
        <neighbor name="Switzerland" direction="W"/>
    </country>
    <country name="Singapore">
        <rank>4</rank>
        <year>2011</year>
        <gdppc>59900</gdppc>
        <neighbor name="Malaysia" direction="N"/>
    </country>
    <country name="Panama">
        <rank>68</rank>
        <year>2011</year>
        <gdppc>13600</gdppc>
        <neighbor name="Costa Rica" direction="W"/>
        <neighbor name="Colombia" direction="E"/>
    </country>
</data>
```

Looking Further

You can search over all descendants of an element that have a specific tag using `.find_all(tag_name)`

```python
for neighbor in root.find_all('neighbor'):
    print(neighbor.attrs)
```

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```
{'name': 'Austria', 'direction': 'E'}
{'name': 'Switzerland', 'direction': 'W'}
{'name': 'Malaysia', 'direction': 'N'}
{'name': 'Costa Rica', 'direction': 'W'}
{'name': 'Colombia', 'direction': 'E'}
```

```xml
<data>
    <country name="Liechtenstein">
        <rank>1</rank>
        <year>2008</year>
        <gdppc>141100</gdppc>
        <neighbor name="Austria" direction="E"/>
        <neighbor name="Switzerland" direction="W"/>
    </country>
    <country name="Singapore">
        <rank>4</rank>
        <year>2011</year>
        <gdppc>59900</gdppc>
        <neighbor name="Malaysia" direction="N"/>
    </country>
    <country name="Panama">
        <rank>68</rank>
        <year>2011</year>
        <gdppc>13600</gdppc>
        <neighbor name="Costa Rica" direction="W"/>
        <neighbor name="Colombia" direction="E"/>
    </country>
</data>
```

Filtering Children

`.find_all(tag_name)` gives all children of a given element that have a matching tag.

`.find(tag_name)` or just `.tag_name` gives the first child of a given element that have a matching tag.

```python
for country in root.find_all('country'):
    rank = country.find('neighbor')
    print(rank)
```

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```
<neighbor direction="E" name="Austria"/>
<neighbor direction="N" name="Malaysia"/>
<neighbor direction="W" name="Costa Rica"/>
```

```xml
<data>
    <country name="Liechtenstein">
        <rank>1</rank>
        <year>2008</year>
        <gdppc>141100</gdppc>
        <neighbor name="Austria" direction="E"/>
        <neighbor name="Switzerland" direction="W"/>
    </country>
    <country name="Singapore">
        <rank>4</rank>
        <year>2011</year>
        <gdppc>59900</gdppc>
        <neighbor name="Malaysia" direction="N"/>
    </country>
    <country name="Panama">
        <rank>68</rank>
        <year>2011</year>
        <gdppc>13600</gdppc>
        <neighbor name="Costa Rica" direction="W"/>
        <neighbor name="Colombia" direction="E"/>
    </country>
</data>
```