

CSci 127: Introduction to Computer Science



hunter.cuny.edu/csci

Announcements



- Each lecture includes a survey of computing research and tech in NYC.

*Today: Prof. Katherine St. John
(computational biology)*

Frequently Asked Questions

From lecture slips & recitation sections.

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 - 1) *it's fundamental, and*
 - 2) *the same ideas are used for accessing formatted data (today's topic).*

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*Yes, we will, since
1) it's fundamental, and
2) the same ideas are used for accessing formatted data (today's topic).*
- Is it okay to work ahead?
*Yes! It's great to try things before lecture/lab (builds a "mental scaffold" to hold new material covered).
All the labs are up for the rest of the semester, and programs open on gradescope 4 weeks before the deadline.*

Today's Topics



- Recap: Logical Expressions & Circuits
- Design: Cropping Images
- Accessing Formatted Data
- CS Survey: Computational Biology

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- **Recap: Logical Expressions & Circuits**
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Recap: Logical Operators

and

in1	and	in2	<i>returns:</i>
False	and	False	False
False	and	True	False
True	and	False	False
True	and	True	True

Recap: Logical Operators

and

in1	in2	<i>returns:</i>
False	and	False
False	and	True
True	and	False
True	and	True

or

in1	in2	<i>returns:</i>
False	or	False
False	or	True
True	or	False
True	or	True

Recap: Logical Operators

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in1		in2	<i>returns:</i>
False	and	False	False
False	and	True	False
True	and	False	False
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or

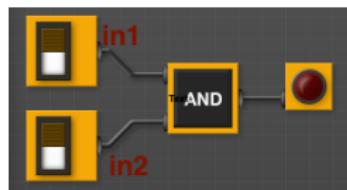
in1		in2	<i>returns:</i>
False	or	False	False
False	or	True	True
True	or	False	True
True	or	True	True

not

	in1	<i>returns:</i>
not	False	True
not	True	False

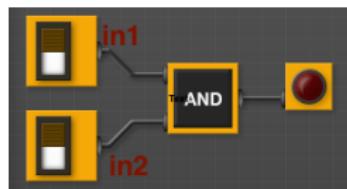
Logical Operators & Circuits

- Each logical operator (and, or, & not) can be used to join together expressions.



Logical Operators & Circuits

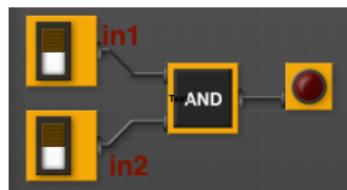
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Example: $\text{in1} \text{ and } \text{in2}$

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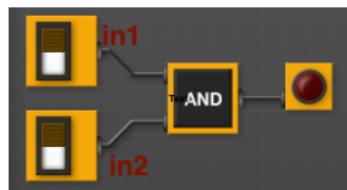


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- Each logical operator (and, or, & not) has a corresponding logical circuit that can be used to join together inputs.

Logical Operators & Circuits

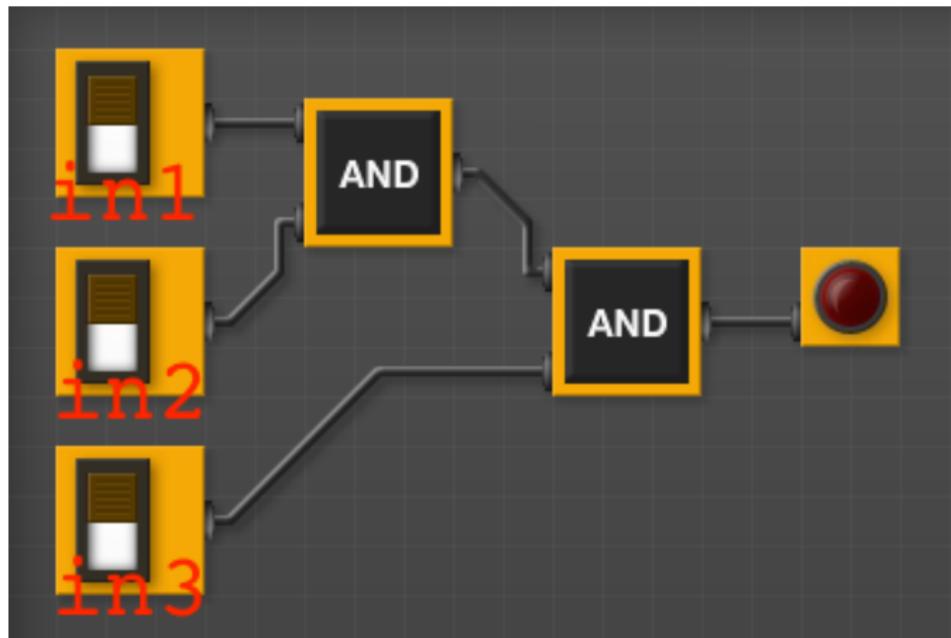
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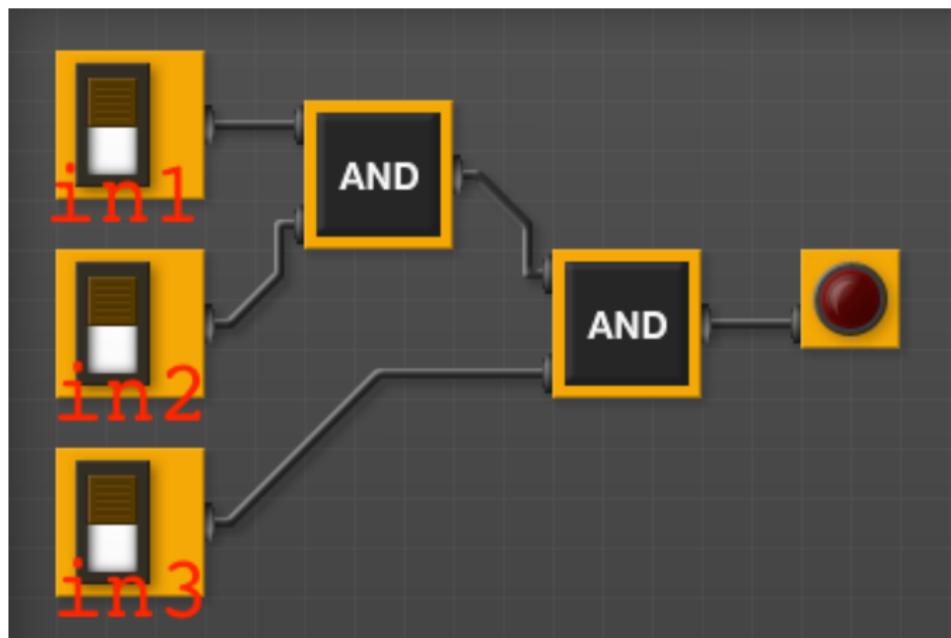
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Examples: Logical Circuit



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$(\text{in1} \text{ and } \text{in2}) \text{ and } \text{in3}$

Examples: Logical Expressions

Examples from last lecture:

```
origin = "Indian Ocean"
winds = 100
if (winds > 74):
    print("Major storm, called a ", end="")
    if origin == "Indian Ocean" or origin == "South Pacific":
        print("cyclone.")
    elif origin == "North Pacific":
        print("typhoon.")
    else:
        print("hurricane.")

visibility = 0.2
winds = 40
conditions = "blowing snow"
if (winds > 35) and (visibility < 0.25) and \
    (conditions == "blowing snow" or conditions == "heavy snow"):
    print("Blizzard!")
```

In Pairs or Triples:

Predict what the code will do:

```
x = 6
y = x % 4
w = y**3
z = w // 2
print(x,y,w,z)
x,y = y,w
print(x,y,w,z)
x = y / 2
print(x,y,w,z)

sports = ["Field Hockey", "Swimming", "Water Polo"]
mess = "Qoauxca BrletRce crcx qvBnqa ocUxk"
result = ""
for i in range(len(mess)):
    if i % 3 == 0:
        print(mess[i])
        result = result + mess[i]
print(sports[1], result)
```

Python Tutor

```
x = 6
y = x % 4
w = y**3
z = w // 2
print(x,y,w,z)      (Demo with pythonTutor)
x,y = y,w
print(x,y,w,z)
x = y / 2
print(x,y,w,z)
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- **Design: Cropping Images**
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In Pairs or Triples: Design Question

From Final Exam, Fall 2017, V4, #6.



Design an algorithm that reads in an image and displays the lower left corner of the image.

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Input:

Output:

Process: (*Brainstorm for a “To Do” list to accomplish this.*)

Design Question

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- Example:
 - ① Import libraries.
 - ② Ask user for an image name.
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 - ⑤ Make a new image that’s half the height and half the width.

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The City University of New York



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- ⑥ Display the new image.

```
plt.imshow(img2) #Load our new image into pyplot  
plt.show() #Show the image (waits until closed to continue)
```

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- CS Survey: Computational Biology

Structured Data

College	Undergraduate		
	Full-time	Part-time	Total
Baruch	11,288	3,922	15,210
Brooklyn	10,198	4,208	14,406
City	10,067	3,250	13,317
Hunter	12,223	4,500	16,723
John Jay	9,831	2,843	12,674
Lehman	6,600	4,720	11,320
Medgar Evers	4,760	2,059	6,819
NYCCT	10,912	6,370	17,282
Queens	11,693	4,633	16,326
Staten Island	9,584	2,948	12,532
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- Next line has the titles for the columns.
- Subsequent lines have a college and attributes about the college.
- Python has several ways to read in such data.

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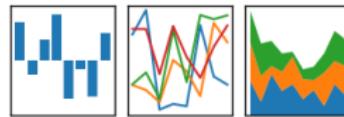
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- Python has several ways to read in such data.
- We will use the popular Python Data Analysis Library (**Pandas**).

Structured Data

pandas

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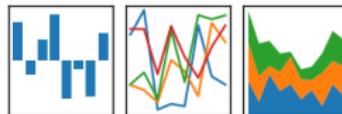


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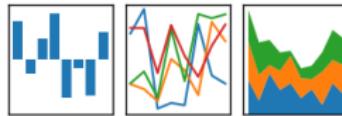


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- Open source and freely available (part of anaconda distribution).

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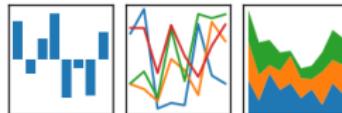


- We will use the popular Python Data Analysis Library (**Pandas**).
- Open source and freely available (part of anaconda distribution).
- Already loaded on the machines in 1001E North.

Structured Data

pandas

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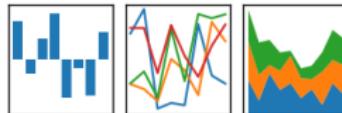


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- See end of Lab 6 for directions on downloading it to your home machine.

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- Already loaded on the machines in 1001E North.
- See end of Lab 6 for directions on downloading it to your home machine.
- To use, add to the top of your file:

```
import pandas as pd
```

CSV Files

College	Undergraduate		
	Full-time	Part-time	Total
Baruch	11,288	3,922	15,210
Brooklyn	10,198	4,208	14,406
City	10,067	3,250	13,317
Hunter	12,223	4,500	16,723
John Jay	9,831	2,843	12,674
Lehman	6,600	4,720	11,320
Medgar Evers	4,760	2,059	6,819
NYCCT	10,912	6,370	17,282
Queens	11,693	4,633	16,326
Staten Island	9,584	2,948	12,532
York	5,066	3,192	8,258

- Excel .xls files have much extra formatting.

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- Excel .xls files have much extra formatting.
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- Each row is a line in the file.
- Columns are separated by commas on each line.

CSV Files

Source: https://en.wikipedia.org/wiki/Demographics_of_New_York_City,
All population figures are consistent with present-day boundaries.
First census after the consolidation of the five boroughs.

Year,Manhattan,Brooklyn,Queens,Bronx,Staten Island,Total
1698,4937,2017,,,727,7681
1771,21863,3623,,,2847,28423
1790,33131,4549,6159,1781,3827,49447
1800,60515,5740,6642,1755,4563,79215
1810,96373,8303,7444,2267,5347,119734
1820,123706,11187,8246,2782,6135,152056
1830,202589,20535,9049,3023,7082,242278
1840,312710,47613,14480,5346,10965,391114
1850,515547,138882,18593,8032,15061,696115
1860,813669,279122,32903,23593,25492,1174779
1870,942292,419921,45468,37393,33029,1478103
1880,1164673,599495,56559,51980,38991,1911698
1890,1441216,838547,87050,88908,51693,2507414
1900,1850093,1166582,152999,200507,67021,3437202
1910,2331542,1634351,284041,430980,85969,4766883
1920,2284103,2018356,469042,732016,116531,5620048
1930,1867312,2560401,1079129,1265258,158346,6930446
1940,1889924,2698285,1297634,1394711,174441,7454995
1950,1960101,2738175,1550849,1451277,191555,7891957
1960,1698281,2627319,1809578,1424815,221991,7781984
1970,1539233,2602012,1986473,1471701,295443,7894862
1980,1428285,2230936,1891325,1168972,352121,7071639
1990,1487536,2300664,1951598,1203789,378977,7322564
2000,1537195,2465326,2229379,1332650,443728,8008278
2010,1585873,2504700,2230722,1385108,468730,8175133
2015,1644518,2636735,2339150,1455444,474558,8550405

nycHistPop.csv

Reading in CSV Files

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Baruch	11,288	3,922	15,210
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- To read in a CSV file: `myVar = pd.read_csv("myFile.csv")`

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- Often abbreviated: `df`.

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- To read in a CSV file: `myVar = pd.read_csv("myFile.csv")`
- Pandas has its own type, **DataFrame**, that is perfect for holding a sheet of data.
- Often abbreviated: `df`.
- It also has **Series**, that is perfect for holding a row or column of data.

Example: Reading in CSV Files

```
Source: https://en.wikipedia.org/wiki/Demographics_of_New_York_City.....  
All population figures are consistent with present-day boundaries.....  
First census after the consolidation of the five boroughs.....  
.....  
Year,Manhattan,Brooklyn,Queens,Bronx,Staten Island,Total  
1890,4937,2017,727,788,111  
1891,21843,3623,2847,28423  
1790,33131,4549,6159,1781,3827,49447  
1800,60515,5740,6442,1755,4543,7595  
1810,65541,5854,6442,1755,4543,7595  
1820,123704,11487,8246,2792,6135,152056  
1830,202589,20535,9049,3023,7082,242278  
1840,312110,18013,14045,5346,10965,39114  
1850,35541,21803,18851,5346,10965,41115  
1860,813449,279122,32903,23593,25492,174777  
1870,942292,419921,45468,37393,33029,1479103  
1880,1164473,59943,5653,51980,33029,1911803  
1890,1364473,65443,5653,51980,33029,2141534  
1900,1850593,116582,152999,200567,67621,2437202  
1910,233342,1634351,284041,430980,8569,476683  
1920,2233103,2018354,446035,446035,732013,116582,593488  
1930,1867128,1867128,1867128,1867128,1867128,4930446  
1940,1889924,2698285,1297634,1394711,174441,7454995  
1950,1960101,2738175,1550849,1451277,191555,7991957  
1960,1690101,2738175,1809049,1451277,191555,7981984  
1970,1539231,2460705,1471071,1471071,135443,7981984  
1980,1426285,2230936,1891325,1168972,352121,7071639  
1990,1487536,2300664,1951598,1203789,378977,7322564  
2000,1537195,2485326,2229379,1332650,419782,8080879  
2010,1583873,2504705,2216722,1385108,474558,8175133  
2015,1444518,2636733,2339150,1459444,474558,8059405
```

nycHistPop.csv

In Lab 6

Example: Reading in CSV Files

```
import matplotlib.pyplot as plt  
import pandas as pd
```

Source: https://en.wikipedia.org/wiki/Demographics_of_New_York_City,
All population figures are consistent with present-day boundaries.....
First census after the consolidation of the five boroughs.....

.....
Year,Manhattan,Brooklyn,Queens,Bronx,Staten Island,Total
1690,4937,2017,...,727,7881
1771,21843,36231,...,2847,28423
1790,33131,4549,6159,1781,3827,49447
1800,60515,5740,6442,1755,4543,75955
1810,65541,6200,6840,2000,4973,85934
1820,123704,11187,8246,2792,6135,152056
1830,202589,20535,9049,3023,7082,242278
1840,311510,11013,14000,5346,10965,391114
1850,355441,12800,14800,5834,12000,45115
1860,813469,279122,32903,23593,25492,174777
1870,942292,419921,45468,37393,33029,1479103
1880,1164473,59943,5653,51980,33091,1911801
1890,1364473,71000,6500,58000,33091,2101514
1900,185093,116582,152999,200567,67621,2437202
1910,223342,1634351,2841,430980,8569,476683
1920,2210103,2018354,44600,720201,116500,500488
1930,1667137,1800000,179000,179000,158000,4930446
1940,1889924,2698285,1297634,1394711,174441,7454995
1950,1960101,2738175,1550949,1451277,191555,7991957
1960,1690000,2319319,1800000,1800000,1800000,781984
1970,1539231,2460700,1471701,135443,798462
1980,1426285,2230936,1891325,1168972,352121,7071639
1990,1487536,2300664,1951598,1320789,378977,7322564
2000,1537195,2485326,2229379,1332450,419728,8080879
2010,1583873,2504705,2272722,1385108,4175133,8175133
2015,1444018,2636733,2339150,1459446,474558,8059405

nycHistPop.csv

In Lab 6

Example: Reading in CSV Files

```
import matplotlib.pyplot as plt  
import pandas as pd
```

```
pop = pd.read_csv('nycHistPop.csv', skiprows=5)
```

```
Source: https://en.wikipedia.org/wiki/Demographics_of_New_York_City.....  
All population figures are consistent with present-day boundaries.....  
First census after the consolidation of the five boroughs.....  
.....  
Year,Bronx,Brooklyn,Queens,Bronx,Staten Island,Totals  
1690,4937,2037,727,788,111,6831  
1771,21843,3623,2847,28423  
1790,33131,4549,6159,1781,3827,49447  
1800,60515,5740,6442,1755,4543,75955  
1810,67500,6240,6840,1755,4543,79334  
1820,123704,11187,8246,2792,6135,152056  
1830,202589,20535,9049,3032,7082,242278  
1840,312110,18013,14000,5346,10965,391114  
1850,355441,21800,18500,5834,11500,44015  
1860,813469,279122,32903,23593,25492,217477  
1870,942292,419921,45468,37393,33029,1479103  
1880,1164473,59943,5653,51980,33091,1911801  
1890,1367000,72000,65000,58000,33091,2141534  
1900,1850993,116582,152999,200567,67621,2437202  
1910,2233142,1634351,2841,430980,8569,476683  
1920,2210110,2018354,44600,44600,73201,11651,50088  
1930,2671110,2210000,579128,579128,55821,4930446  
1940,1889924,2698285,1297634,1394711,174441,7454995  
1950,1960101,2738175,1550949,1451277,191555,7991957  
1960,1690000,2319319,1890000,1400000,1300000,781984  
1970,1539231,2460701,1471701,135443,7901846  
1980,1426285,2230936,1891325,1168972,352121,7071639  
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2010,1583873,2504705,2217722,1385108,419728,8175133  
2015,1444518,2642733,2339150,1459446,474558,8059405
```

nycHistPop.csv

In Lab 6

Example: Reading in CSV Files

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import matplotlib.pyplot as plt
import pandas as pd

pop = pd.read_csv('nycHistPop.csv', skiprows=5)
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```
Source: https://en.wikipedia.org/wiki/Demographics_of_New_York_City.....  
All population figures are consistent with present-day boundaries.....  
First census after the consolidation of the five boroughs.....  
.....  
Year,Population  
1698,203,2037,...,727,71881  
1771,21843,36232,...,2847,28423  
1790,33131,4549,6159,1781,3827,49447  
1800,60515,5740,6442,1755,4543,75955  
1810,70000,62000,68000,18000,49734  
1820,123704,11187,8246,2792,6135,152056  
1830,20589,20535,9049,3032,7082,242278  
1840,31210,10113,14000,5348,10965,391114  
1850,35540,12800,18800,5800,12000,45115  
1860,813469,279122,32903,23593,25492,217477  
1870,942292,419921,45468,37393,33029,1479103  
1880,1164473,59940,5653,51980,33091,1911801  
1890,1370000,650000,600000,518000,350000,210000  
1900,1850093,116582,152999,200567,67621,2437202  
1910,2233142,1634351,2841,430980,8569,476683  
1920,22101103,2018354,44600,72021,11651,50048  
1930,16671112,1579128,1579128,1579128,1579128,4930446  
1940,1889924,2698285,1297634,1394711,174441,7454995  
1950,1960101,2738175,1550949,1451277,191555,7991957  
1960,1696000,2319319,1890900,1460000,1890900,781984  
1970,1539231,2465070,1472701,235443,798462  
1980,1426285,2230936,1891325,1168972,352121,7071639  
1990,1487536,2300664,1951598,1203789,378977,7322564  
2000,1537195,2485326,2229379,1332450,419728,8080879  
2010,1583873,2504705,2216722,1385108,474558,8175133  
2015,1444518,2546733,2339150,1459446,474558,8059405
```

nycHistPop.csv

In Lab 6

Example: Reading in CSV Files

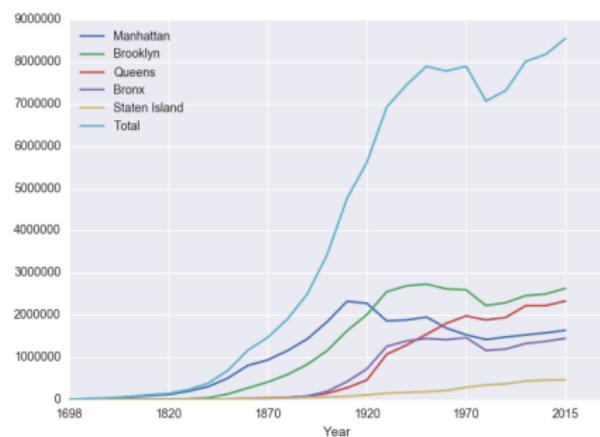
```
import matplotlib.pyplot as plt
import pandas as pd

pop = pd.read_csv('nycHistPop.csv', skiprows=5)
```

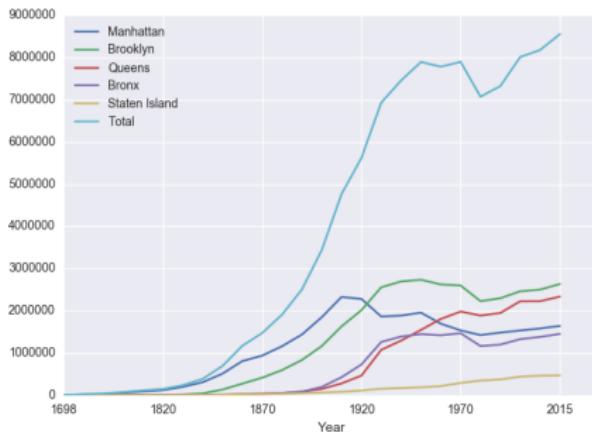
```
Source: https://en.wikipedia.org/wiki/Demographics_of_New_York_City.....  
All population figures are consistent with present-day boundaries.....  
First census after the consolidation of the five boroughs.....  
.....  
Year,Borough,Population  
1698,Manhattan, Brooklyn, Queens, Bronx, Staten Island, Total  
1771,21843,36232,1,2847,28423  
1790,33131,4549,6159,1781,3827,49447  
1800,60515,5740,6442,1755,4543,75935  
1810,67531,6240,7042,1755,4543,79334  
1820,123704,11187,8246,2792,6135,152056  
1830,202589,20535,9049,3023,7082,242278  
1840,312110,18013,14045,5348,10965,391114  
1850,35549,21800,18859,5348,10965,415114  
1860,613469,279122,32903,23593,25492,174777  
1870,942292,419921,45468,37393,33029,1479103  
1880,1164473,59943,5653,51980,33091,1911801  
1890,1387700,72000,6800,5800,33091,2180134  
1900,1850993,1165852,152999,200567,67921,2437202  
1910,223342,1634351,2841,430980,85869,476683  
1920,2210103,2018354,446071,73201,11651,50048  
1930,2667113,2469128,35254,446071,73201,50048  
1940,1889924,2698285,1297634,1394711,174441,7454995  
1950,1960101,2738175,1550849,1451277,191555,7891957  
1960,1696010,2738175,1809009,1451277,191555,7891984  
1970,1539231,2465705,1472705,1235443,7891984  
1980,1426285,2230936,1891325,1168972,352121,7071639  
1990,1487536,2300664,1951598,1203789,378977,7322564  
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2015,1444518,2636733,2339150,1459446,474558,8059405
```

nycHistPop.csv

In Lab 6

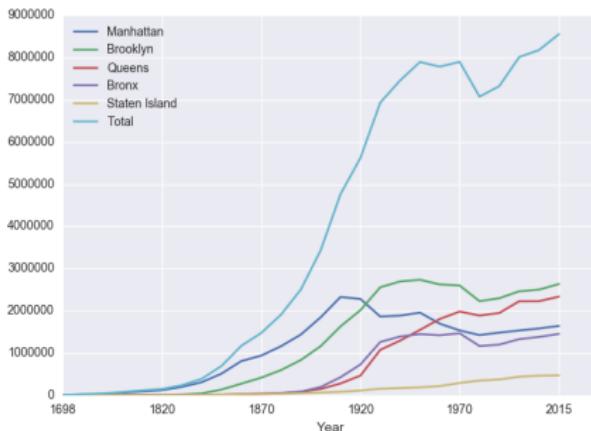


Series in Pandas



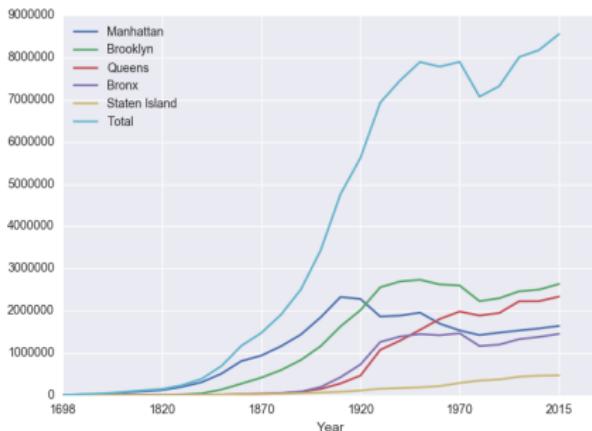
- Series can store a column or row of a DataFrame.

Series in Pandas



- Series can store a column or row of a DataFrame.
- Example: `pop["Manhattan"]` is the Series corresponding to the column of Manhattan data.

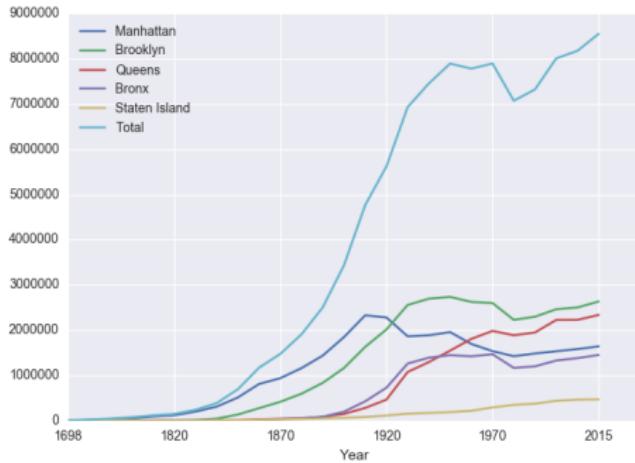
Series in Pandas



- Series can store a column or row of a DataFrame.
- Example: `pop["Manhattan"]` is the Series corresponding to the column of Manhattan data.
- Example:

```
print("The largest number living in the Bronx is",
      pop["Bronx"].max())
```

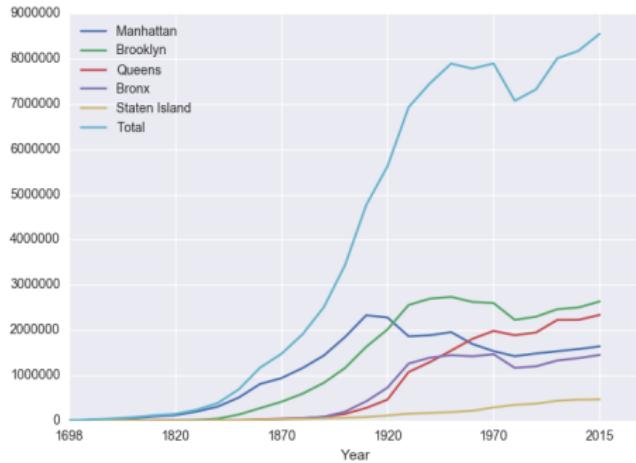
In Pairs or Triples



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`

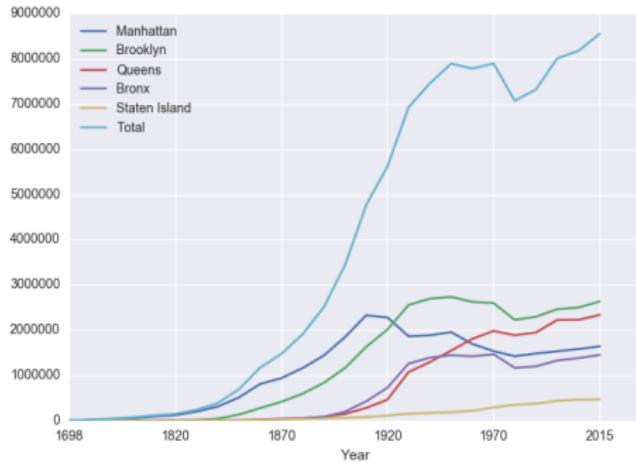
In Pairs or Triples



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`

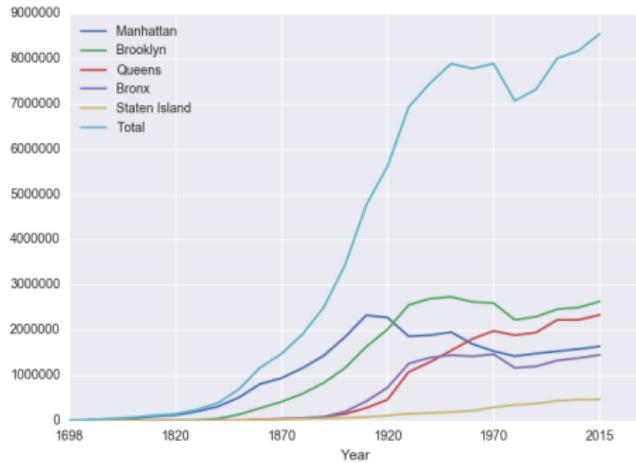
In Pairs or Triples



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`
- `print("S I:", pop["Staten Island"].std())`

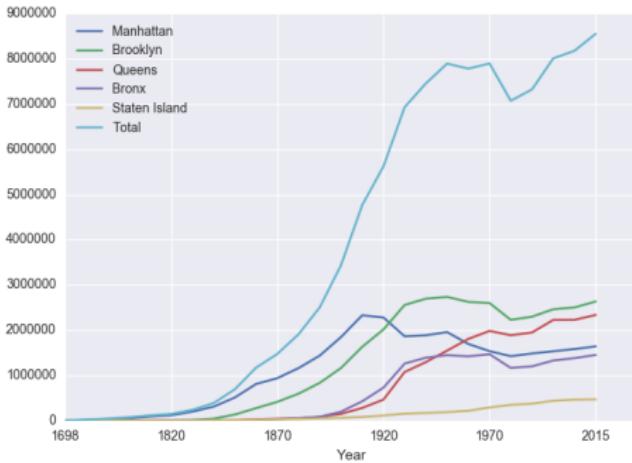
In Pairs or Triples



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`
- `print("S I:", pop["Staten Island"].std())`
- `pop.plot.bar(x="Year")`

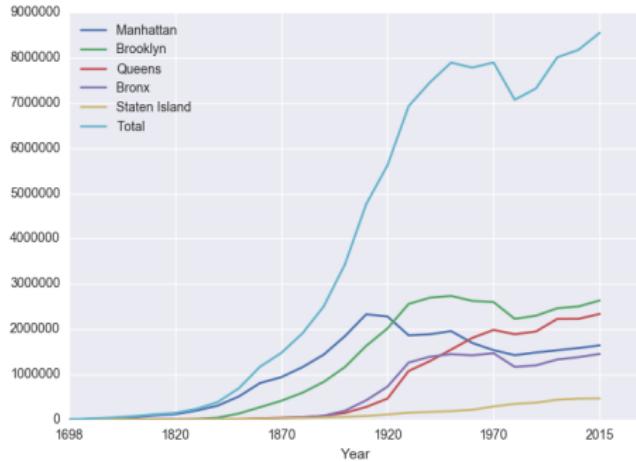
In Pairs or Triples



Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`
- `print("S I:", pop["Staten Island"].std())`
- `pop.plot.bar(x="Year")`
- `pop.plot.scatter(x="Brooklyn", y= "Total")`

In Pairs or Triples



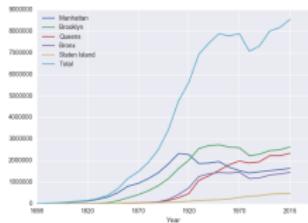
Predict what the following will do:

- `print("Queens:", pop["Queens"].min())`
- `print("S I:", pop["Staten Island"].mean())`
- `print("S I:", pop["Staten Island"].std())`
- `pop.plot.bar(x="Year")`
- `pop.plot.scatter(x="Brooklyn", y= "Total")`
- `pop["Fraction"] = pop["Bronx"]/pop["Total"]`

Solutions

Predict what the following will do:

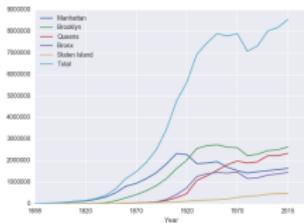
- `print("Queens:", pop["Queens"].min())`



Solutions

Predict what the following will do:

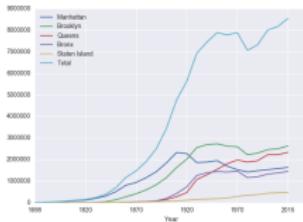
- `print("Queens:", pop["Queens"].min())`
Minimum value in the column with label "Queens".



Solutions

Predict what the following will do:

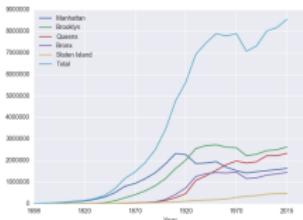
- `print("Queens:", pop["Queens"].min())`
Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`



Solutions

Predict what the following will do:

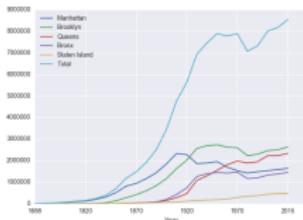
- `print("Queens:", pop["Queens"].min())`
Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`
Average of values in the column "Staten Island".



Solutions

Predict what the following will do:

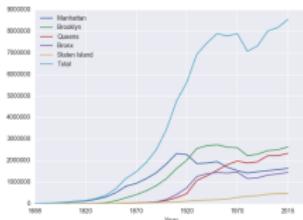
- `print("Queens:", pop["Queens"].min())`
Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`
Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`



Solutions

Predict what the following will do:

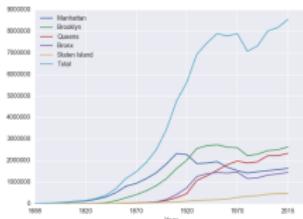
- `print("Queens:", pop["Queens"].min())`
Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`
Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
Standard deviation of values in the column "Staten Island".



Solutions

Predict what the following will do:

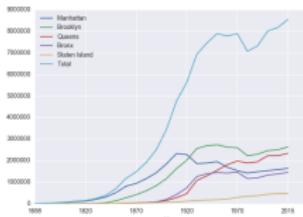
- `print("Queens:", pop["Queens"].min())`
Minimum value in the column with label "Queens".
- `print("S I:", pop["Staten Island"].mean())`
Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`



Solutions

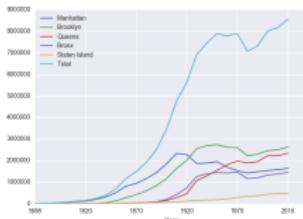
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Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
Bar chart with x-axis "Year".



Solutions

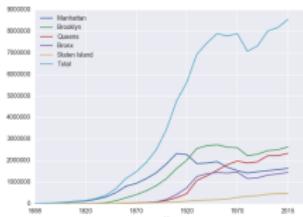
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- `print("Queens:", pop["Queens"].min())`
Minimum value in the column with label "Queens".
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Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
Bar chart with x-axis "Year".
- `pop.plot.scatter(x="Brooklyn", y= "Total")`

Solutions

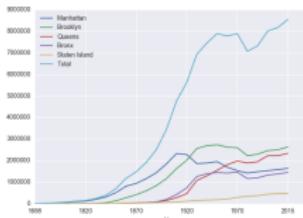
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Minimum value in the column with label "Queens".
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Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
Bar chart with x-axis "Year".
- `pop.plot.scatter(x="Brooklyn", y= "Total")`
Scatter plot of Brooklyn versus Total values.

Solutions

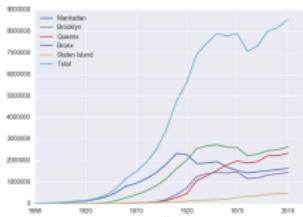
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Standard deviation of values in the column "Staten Island".
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Bar chart with x-axis "Year".
- `pop.plot.scatter(x="Brooklyn", y= "Total")`
Scatter plot of Brooklyn versus Total values.
- `pop["Fraction"] = pop["Bronx"]/pop["Total"]`

Solutions

Predict what the following will do:



- `print("Queens:", pop["Queens"].min())`
Minimum value in the column with label "Queens".
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Average of values in the column "Staten Island".
- `print("S I :", pop["Staten Island"].std())`
Standard deviation of values in the column "Staten Island".
- `pop.plot.bar(x="Year")`
Bar chart with x-axis "Year".
- `pop.plot.scatter(x="Brooklyn", y= "Total")`
Scatter plot of Brooklyn versus Total values.
- `pop["Fraction"] = pop["Bronx"]/pop["Total"]`
New column with the fraction of population that lives in the Bronx.

In Pairs or Triples

Write a complete Python program that reads in the file, `cunyF2016.csv`, and produces a scatter plot of full-time versus part-time enrollment.

College	Undergraduate		
	Full-time	Part-time	Total
Banach	11,288	3,922	15,210
Brooklyn	10,198	4,208	14,406
City	10,087	3,250	13,317
Hunter	12,223	4,500	16,723
John Jay	9,831	2,843	12,674
Lehman	6,600	4,720	11,320
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NYCCT	10,912	6,370	17,282
Queens	11,693	4,833	16,526
Staten Island	9,584	2,948	12,532
York	5,066	3,192	8,258

`cunyF2016.csv`

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Solution:

- 1 *Include pandas & pyplot libraries.*

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Solution:

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Solution:

- ① *Include pandas & pyplot libraries.*
- ② *Read in the CSV file.*
- ③ *Set up a scatter plot.*
- ④ *Display plot.*

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`cunyF2016.csv`

Solution:

- 1 *Include pandas & pyplot libraries.*

```
import matplotlib.pyplot as plt  
import pandas as pd
```

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```

- ③ *Set up a scatter plot.*

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```
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```

- ④ *Display plot.*

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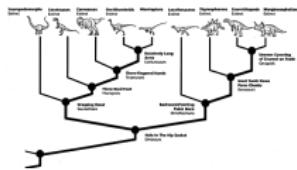
```
plt.show()
```

Today's Topics



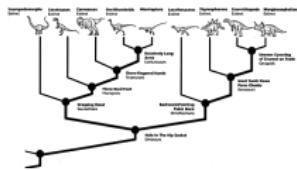
- Recap: Logical Expressions & Circuits
- Design: Cropping Images
- Accessing Formatted Data
- **CS Survey: Computational Biology**

CS Survey: Prof. St. John, computational biology



(American Museum of Natural History)

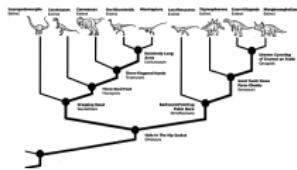
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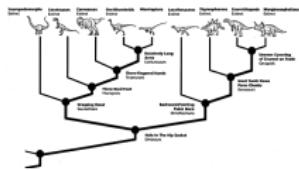
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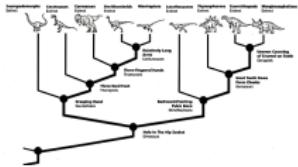


(American Museum of Natural History)

- Finding optimal evolutionary histories for biological data.



CS Survey: Prof. St. John, computational biology

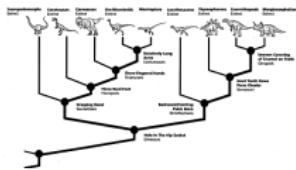


(American Museum of Natural History)

- Finding optimal evolutionary histories for biological data.
 - Computationally hard questions.



CS Survey: Prof. St. John, computational biology



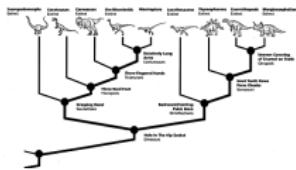
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- Computationally hard questions.
- Collaborate with biologists & anthropologists at AMNH, & team of undergraduate researchers.



CS Survey: Prof. St. John, computational biology



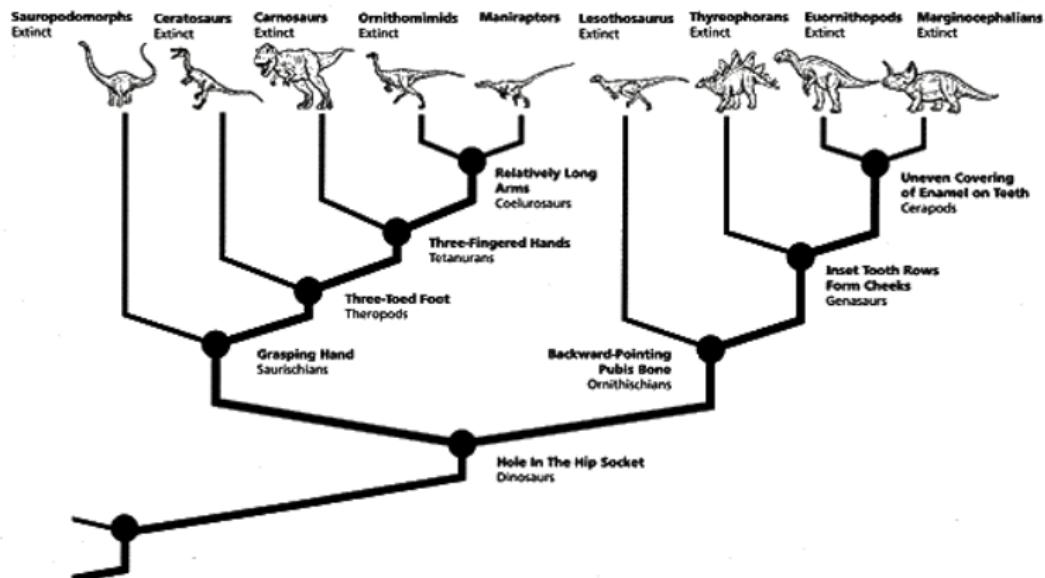
(American Museum of Natural History)



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- Challenge today from BridgeUp:STEM.



Evolutionary History: Dinosaurs



(American Museum of Natural History)

Where Do Turtles Fit in the Tree of Life?



Green Turtle, Kona, Hawai'i (wiki: Inaglory)

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- Lack of consensus about where turtles fit into the tree of life.
- The student project analyzed morphological data (by hand) and then genetic (building scripts on top of bioPython).
- Due to time, we'll focus only on the morphology.
- Recent papers: Lyson *et al.* 2013, Crawford *et al.* 2015, Schoch & Sues 2016

Where Do Turtles Fit in the Tree of Life?

Turtle



(Inaglory, wiki)

Green sea turtle

Chelonia mydas

Squamate



(Bac Luong, wiki)

Tokyō gecko

Gekko gecko

Amphibian



(WA Djatmiko, wiki)

Common tree frog

Polypedates leucomystax

Bird



(S Nygaard, wiki)

Ostrich

Struthio camelus

Mammal



(Proc Zoo London 1863)

Shrew opossum

Caenolestes fuliginosus

Your Turn: Draw an evolutionary history.

Fill in the evolutionary history with the 5 species as tips/leaves of the tree:

Turtle



(Inaglory, wiki)

Squamate



(Bac Luong, wiki)

Amphibian



(WA Djatmiko, wiki)

Bird



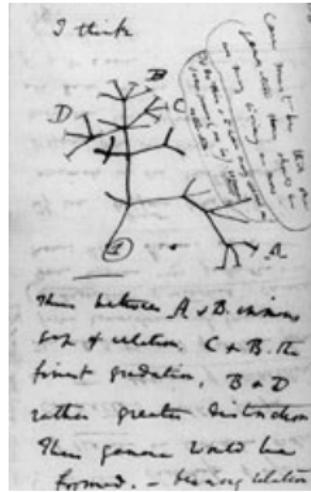
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Mammal



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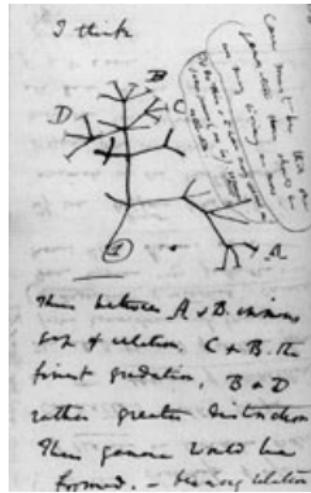
Hands On: Comparing Trees



- Do you have the same tree as your neighbor?

Charles Darwin, 1837

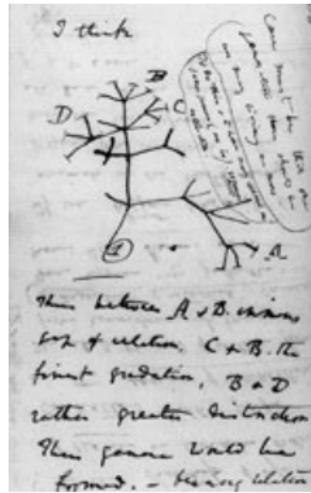
Hands On: Comparing Trees



- Do you have the same tree as your neighbor?
- Why or why not?
Show correspondence or give differences.

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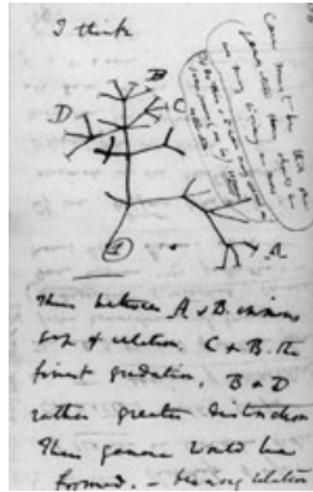
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- The same underlying tree can be drawn in multiple ways.

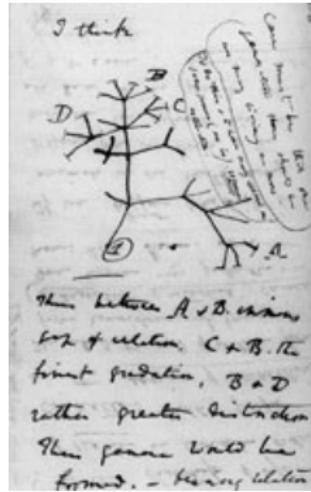
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- Huge number of trees.

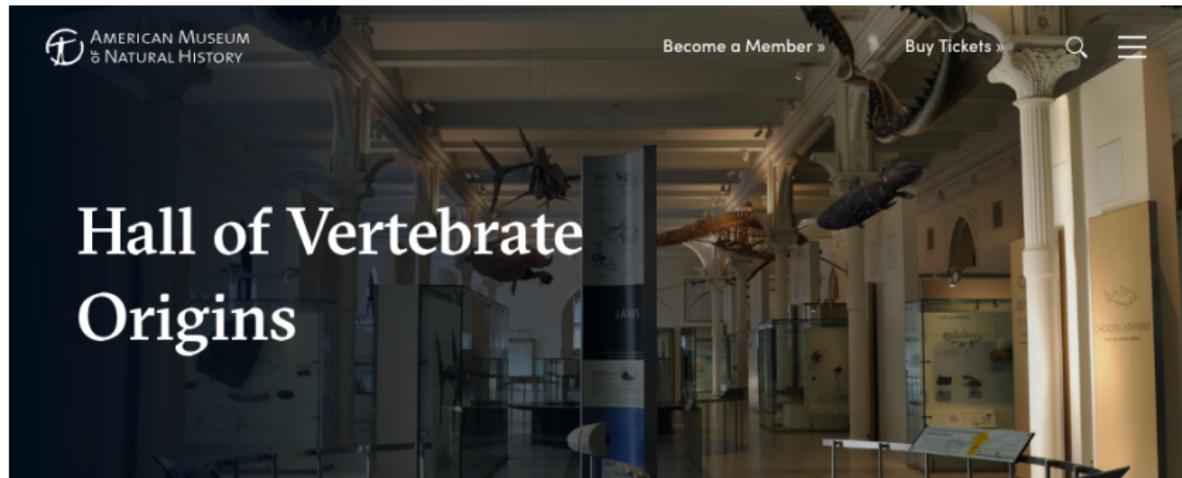
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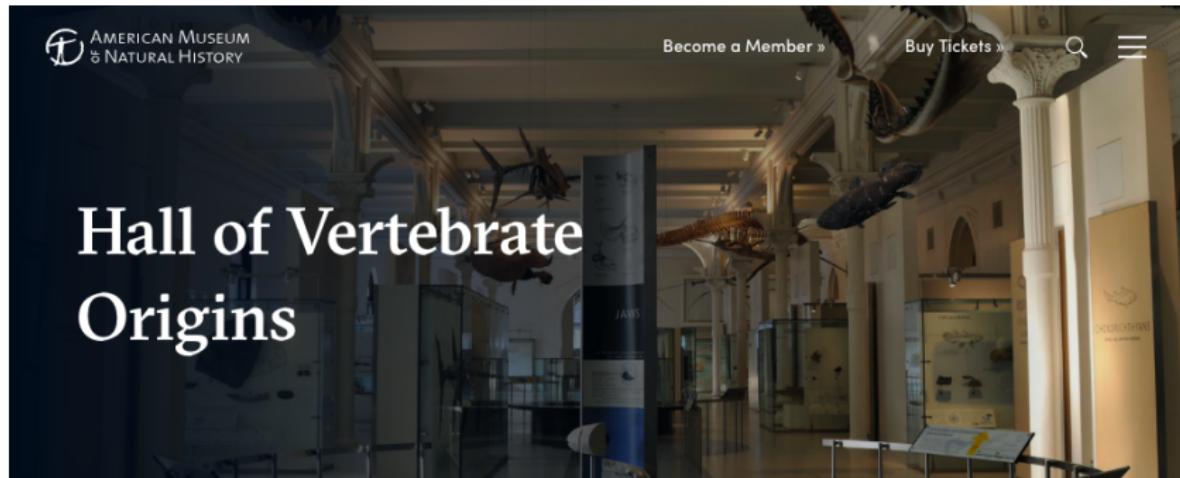
- Do you have the same tree as your neighbor?
- Why or why not?
Show correspondence or give differences.
- The same underlying tree can be drawn in multiple ways.
- Huge number of trees.
- Which one is best?

Collecting Characters



- Before we can evaluate a tree, we need to have a set of characters/traits for our species.

Collecting Characters



- Before we can evaluate a tree, we need to have a set of characters/traits for our species.
- Students visited the AMNH's Hall of Vertebrate Origins to fill in the character matrix.

Collecting Characters

Species →	Higher taxonomy	Sarcopterygii	Testudinata	Lepidosauria	Amphibia	Aves	Mammalia
	Species name	Protopterus dolloi	Chelonia mydas	Gekko gecko	Polypedates leucomystax	Struthio camelus	Caenolestes fuliginosus
	Common name	Lungfish	Green sea turtle	Tokay gecko	Common tree frog	Ostrich	Shrew opossum
Character ↓	Vertebral column						
	Tetrapod (four limbs)						
	Amniotic egg						
	Palatal opening						
	Diapsids (openings in skull for jaw muscles)						
	Feathers						
	Shed skin + specialized ear						
	Fused rib bones form carapace						
	Fur, lactation						
	Gas exchange across skin + large openings in mouth						

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	Palatal opening	0	1	1	0	1	0
	Diapsids (openings in skull for jaw muscles)	0	0	1	0	1	0
	Feathers	0	0	0	0	1	0
	Shed skin + specialized ear	0	0	1	0	0	0
	Fused rib bones form carapace	0	1	0	0	0	0
	Fur, lactation	0	0	0	0	0	1
	Gas exchange across skin + large openings in mouth	0	0	0	1	0	0

Choosing the Best

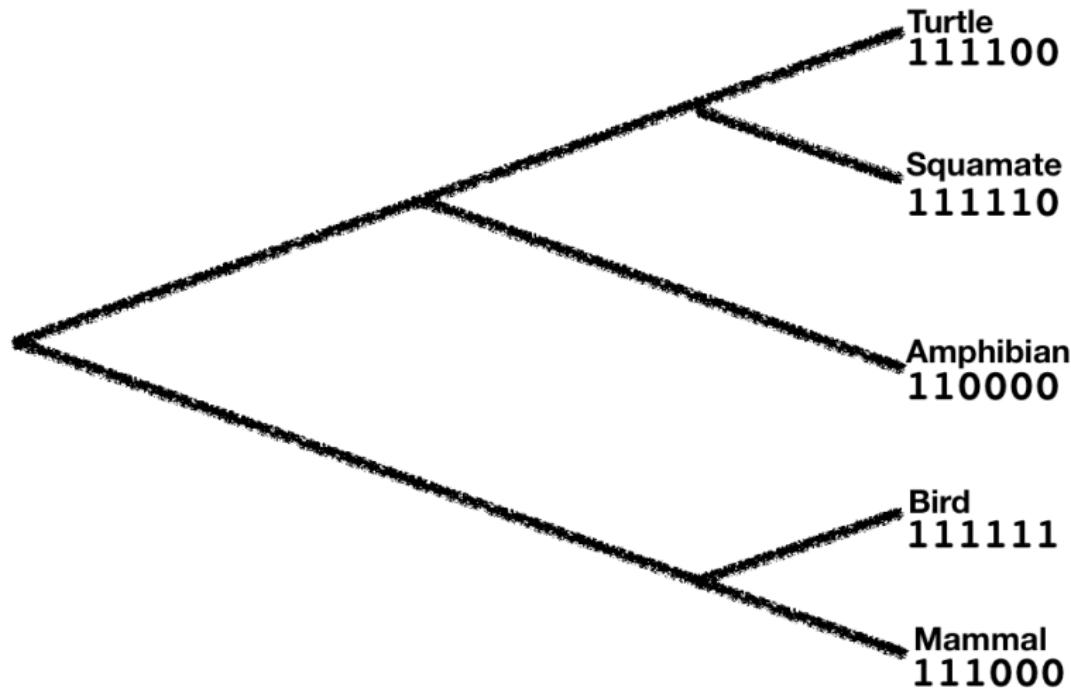


Given a set of organisms, which tree is optimal?

- Two standard criteria for optimality:
 - ▶ Maximum Parsimony: find tree with fewest changes.
 - ▶ Maximum Likelihood: find most likely tree (with respect to a model of evolution)
- Idea: pick a criteria; choose the tree that scores the best under it.

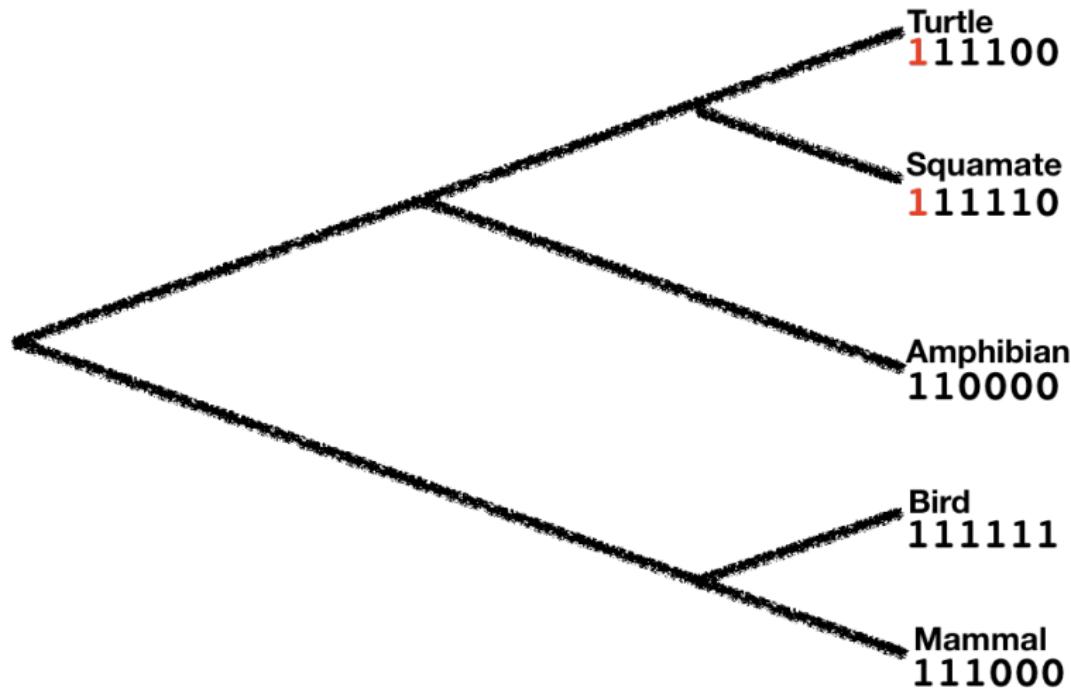
Maximum Parsimony

- For each tree, measure the minimal number of substitutions across branches:



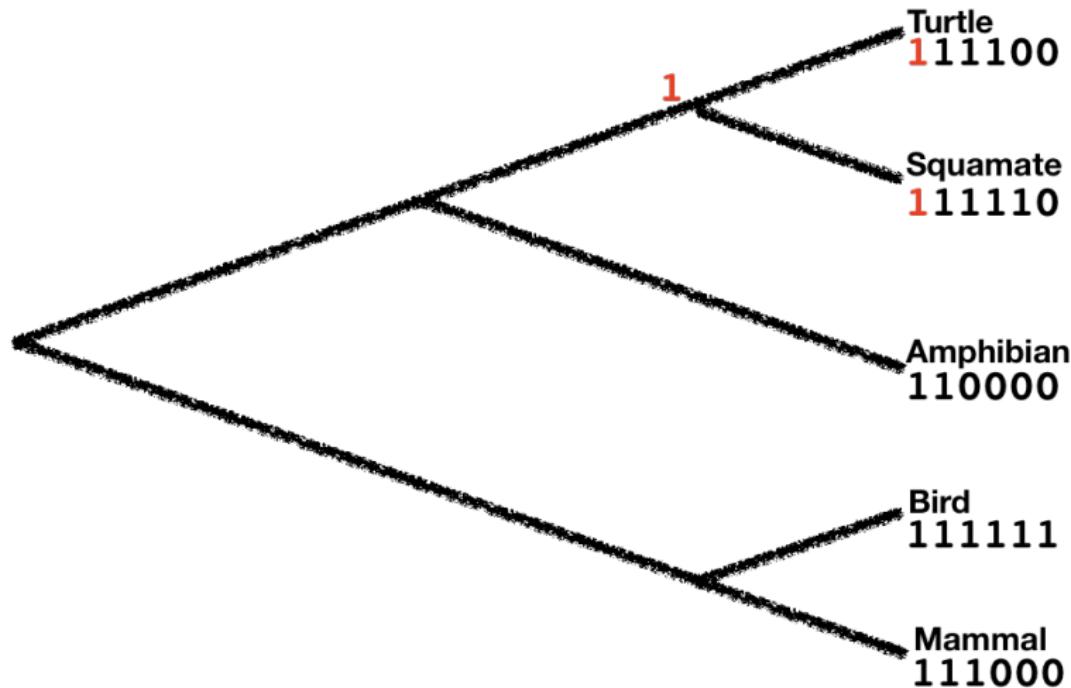
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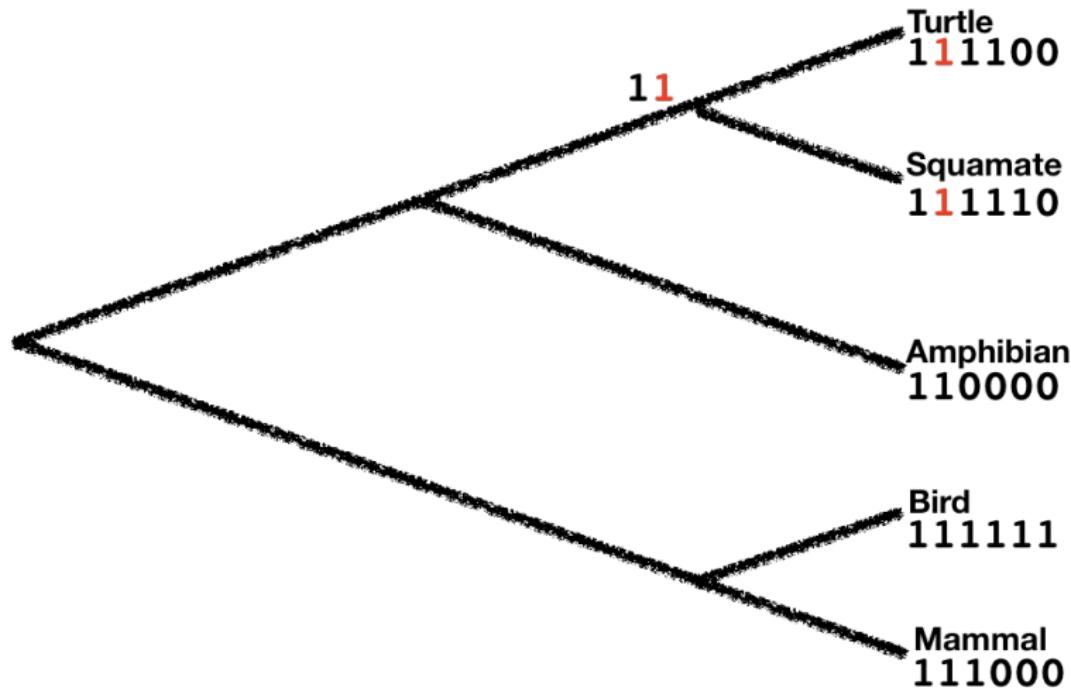
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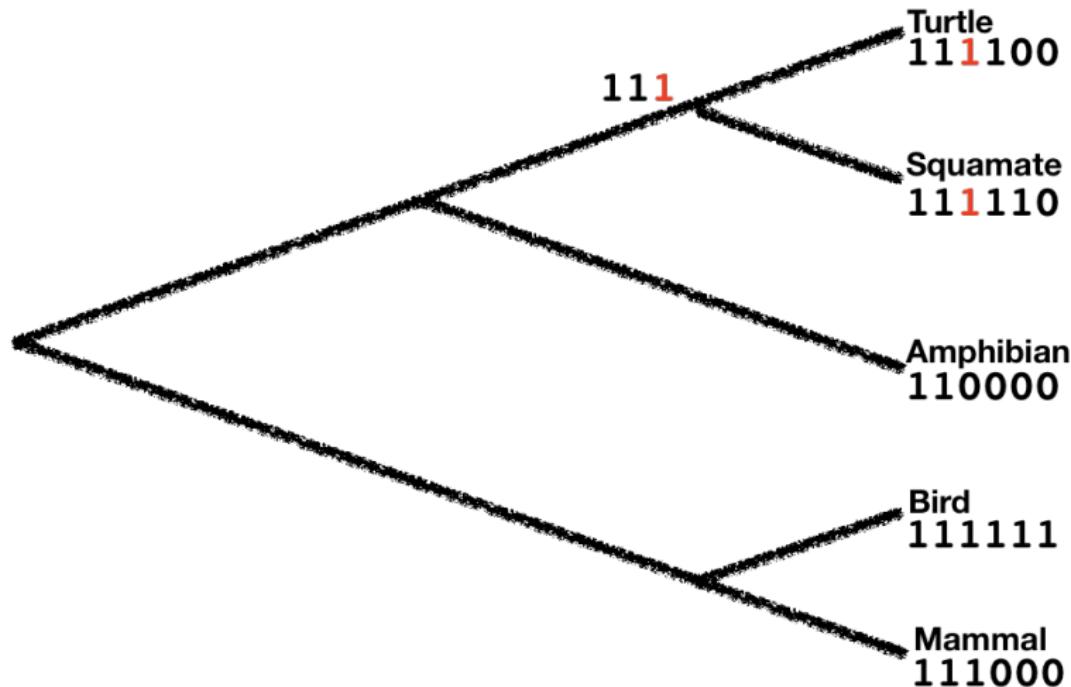
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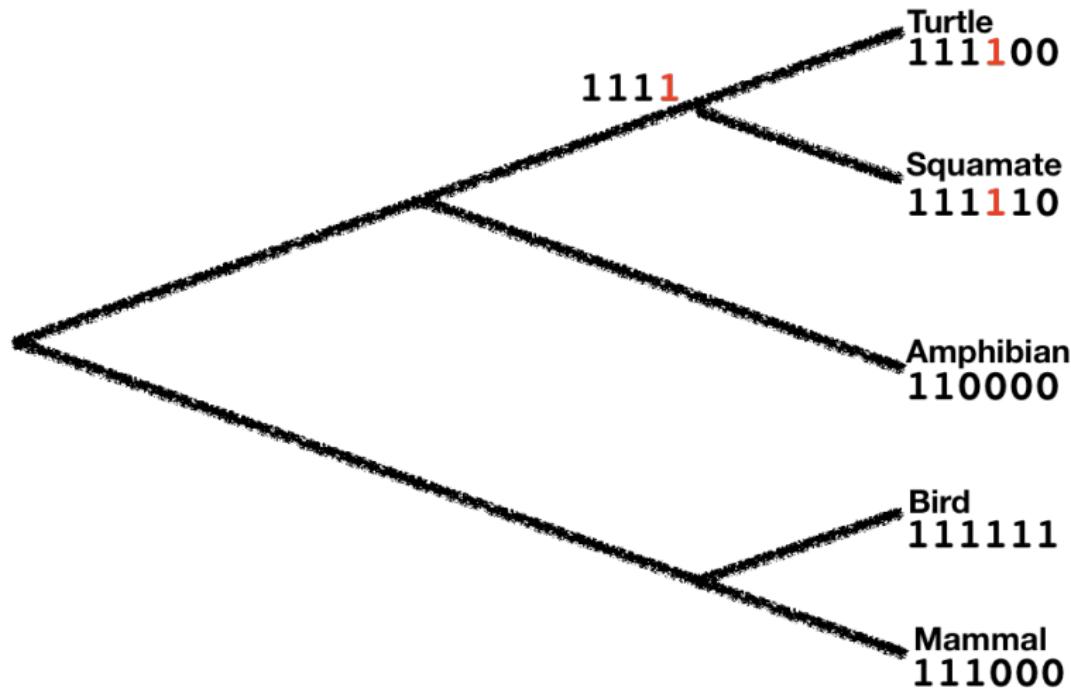
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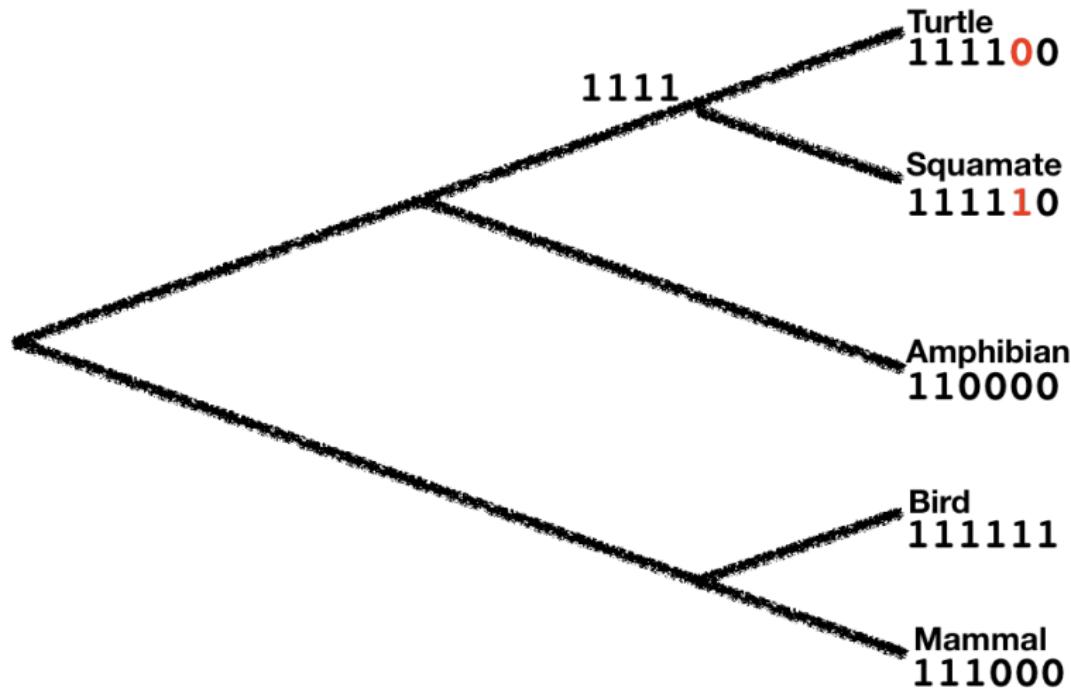
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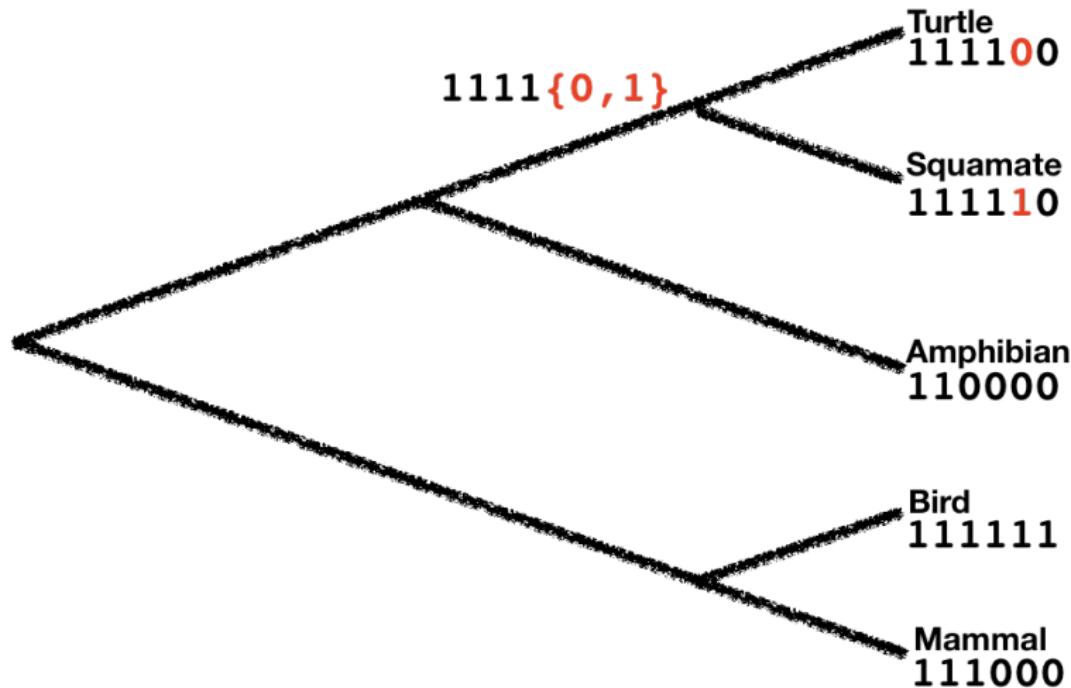
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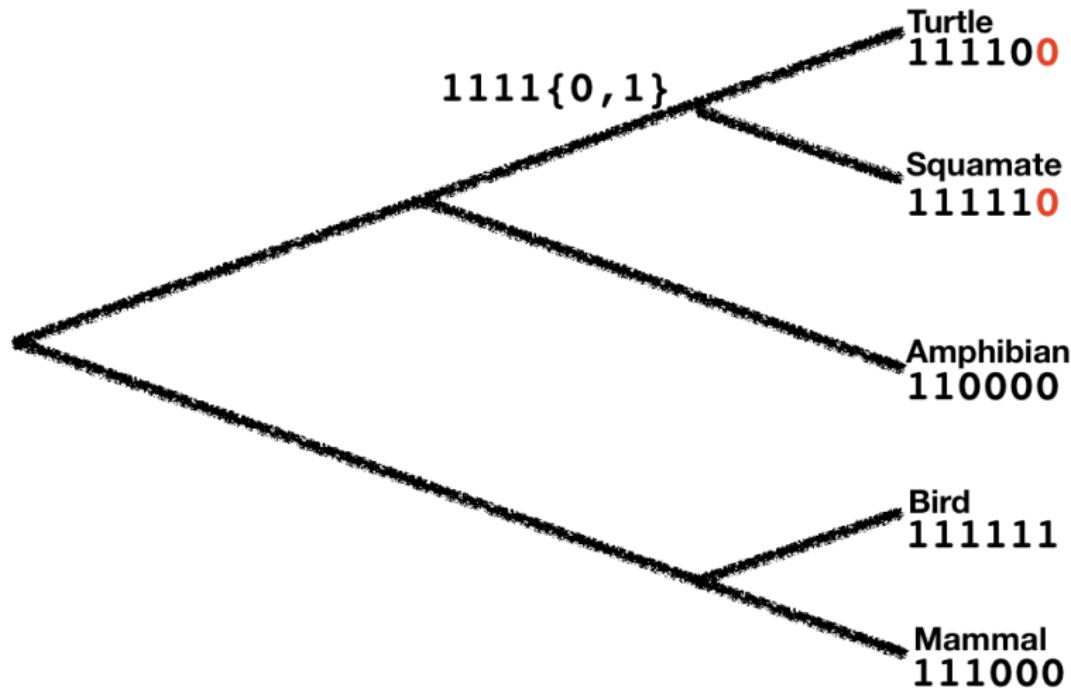
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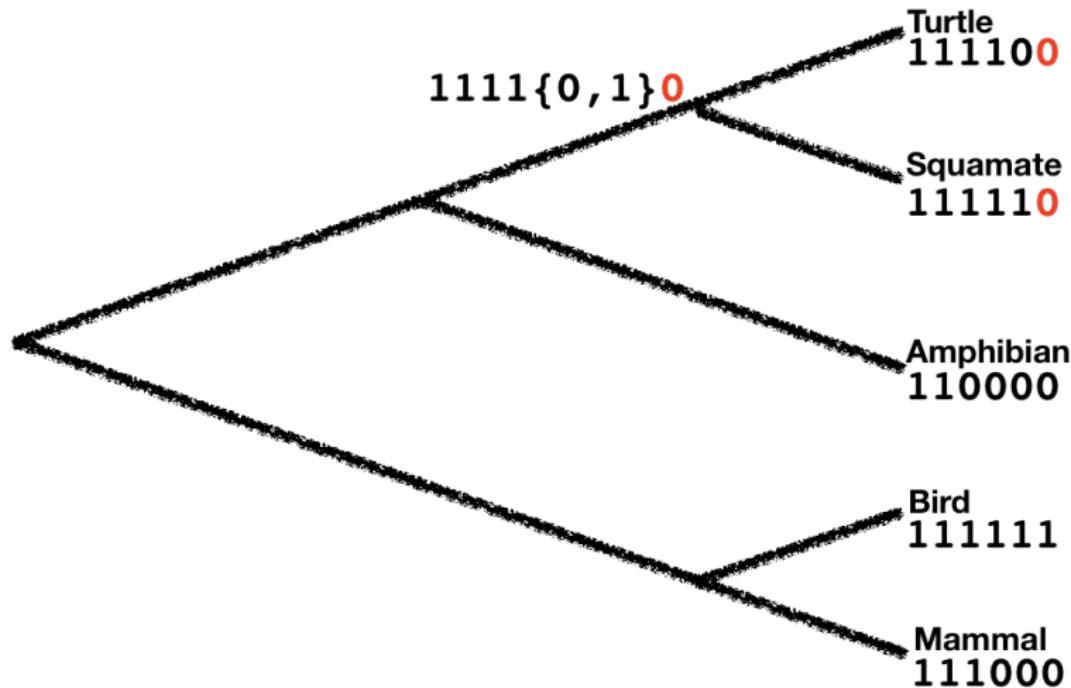
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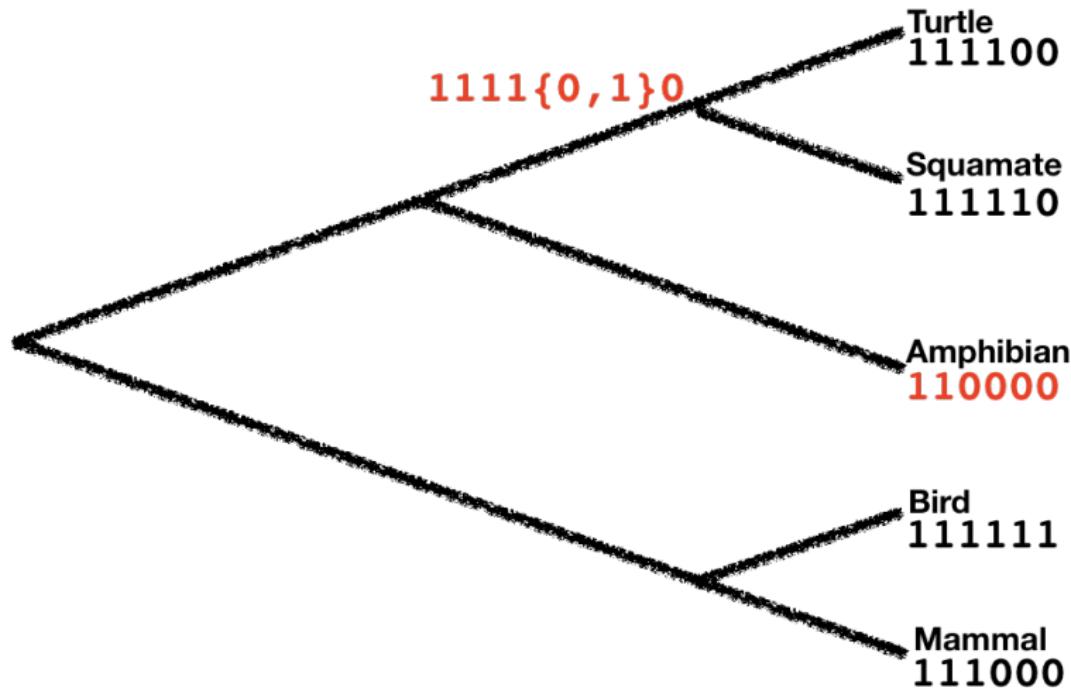
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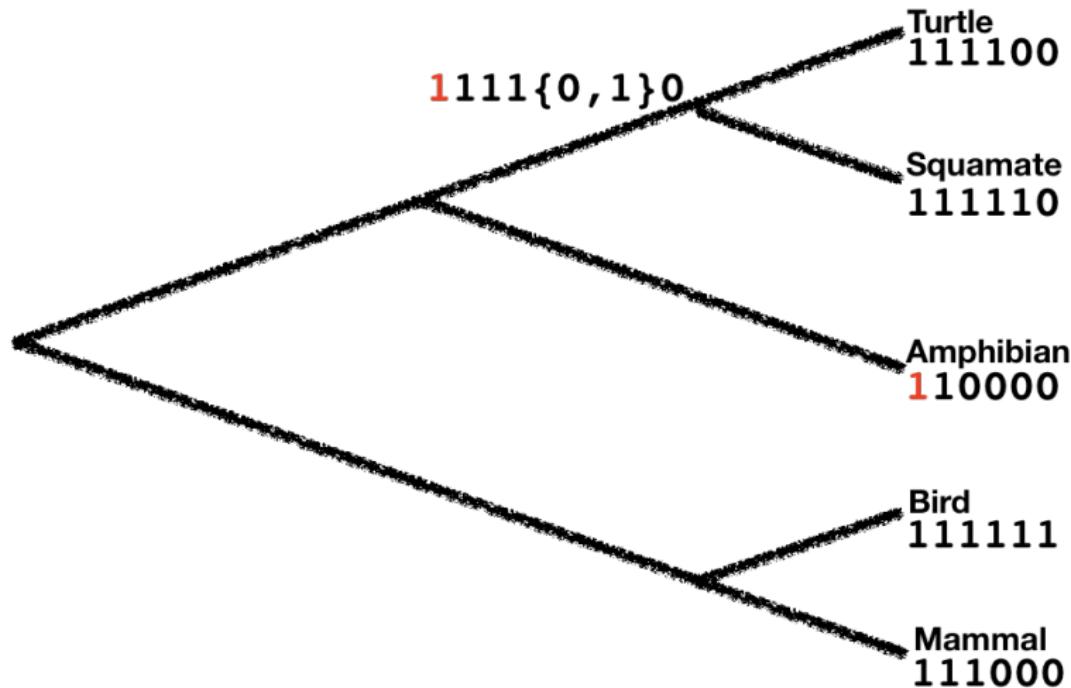
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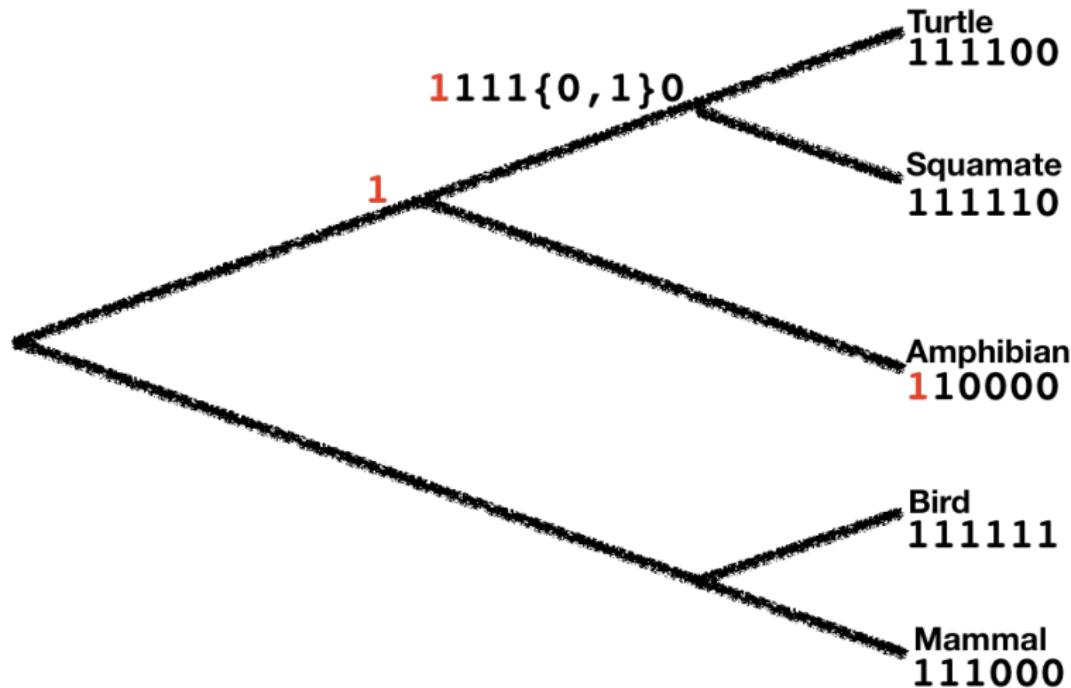
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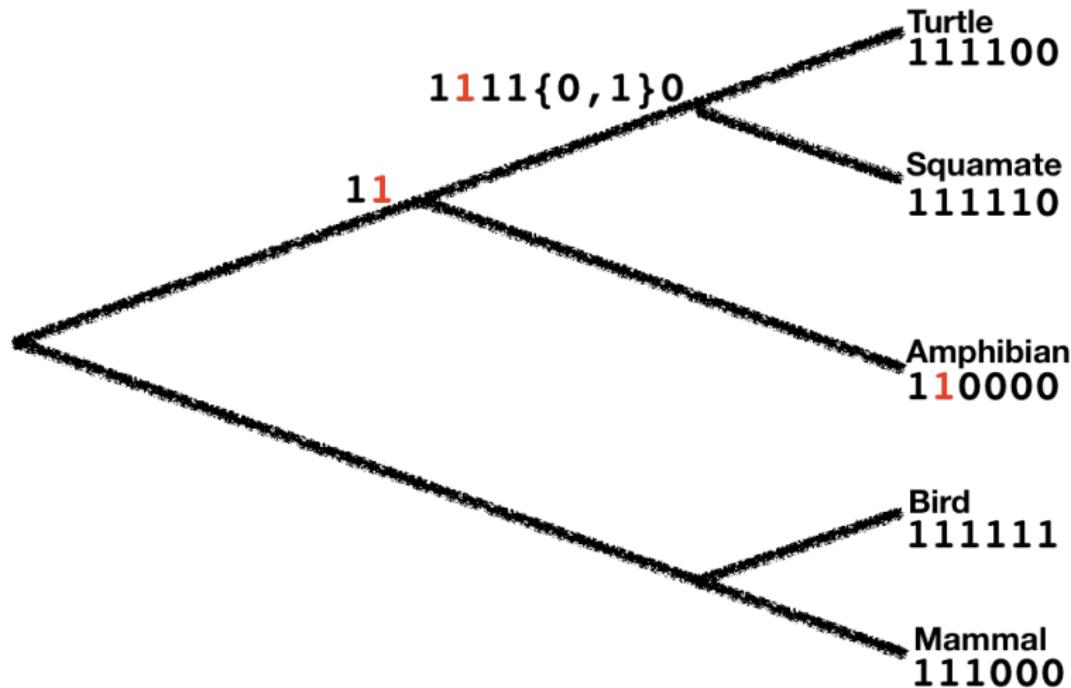
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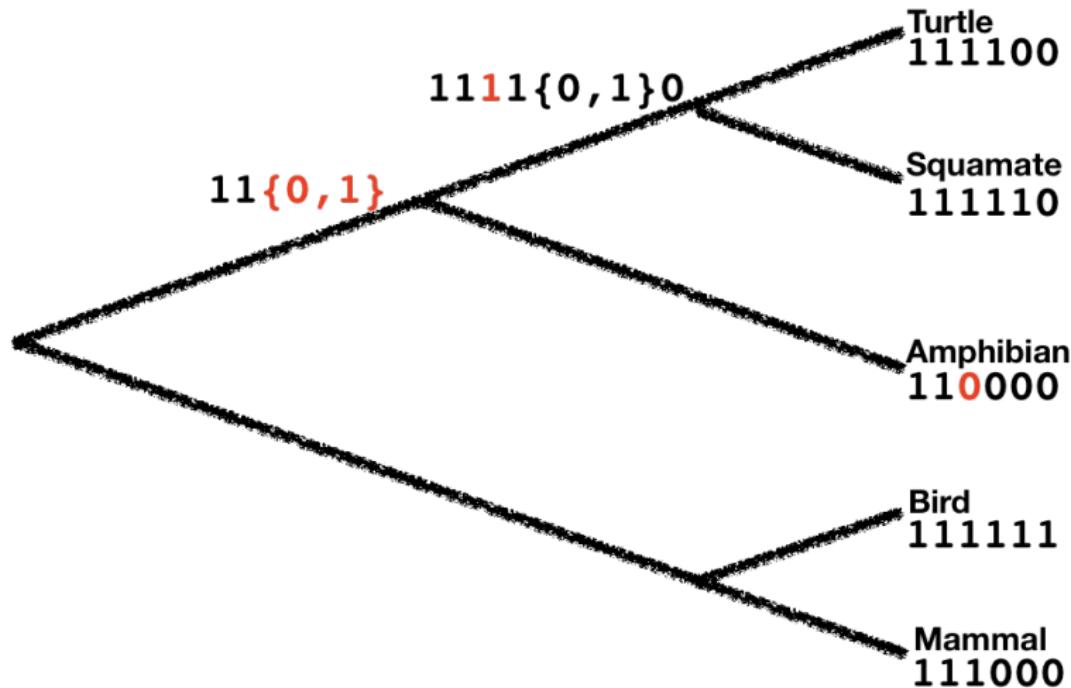
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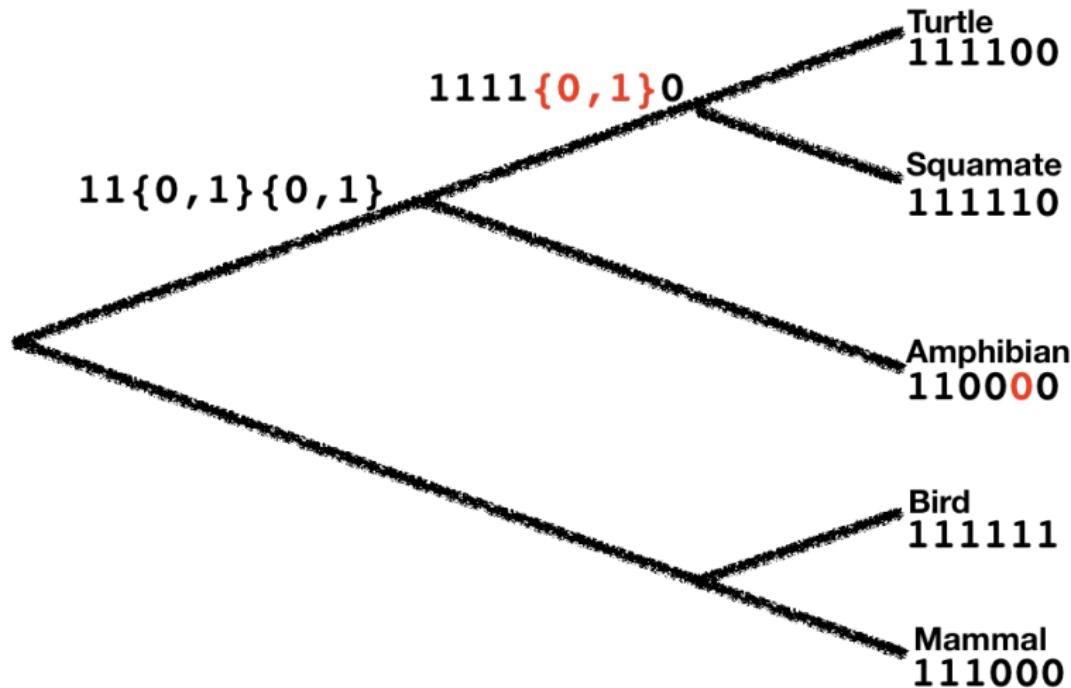
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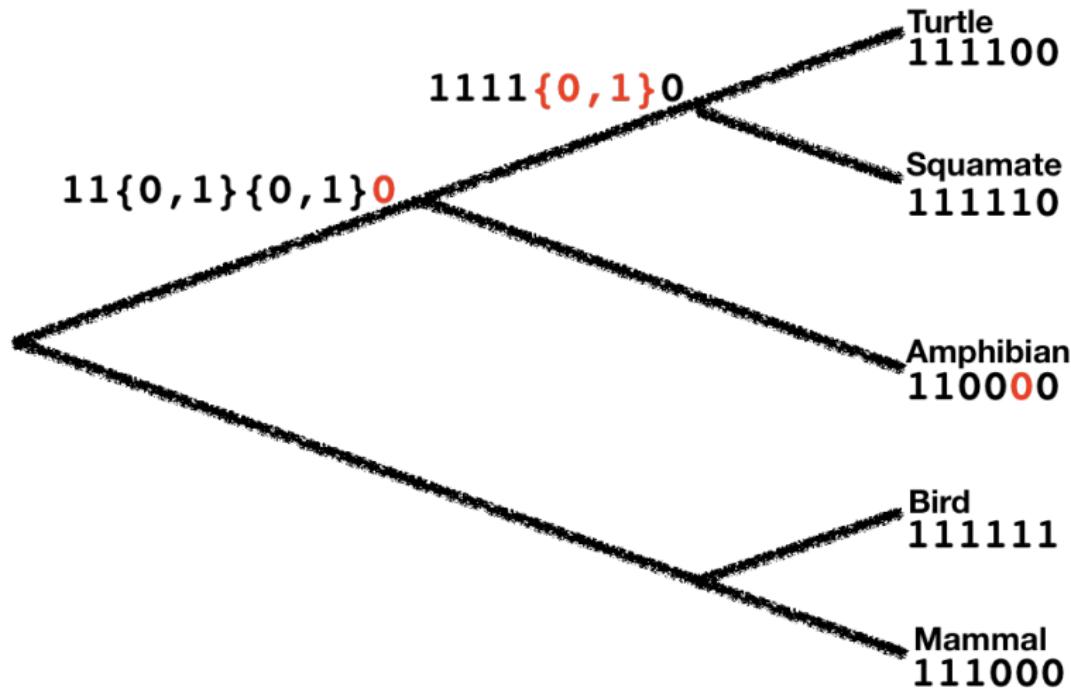
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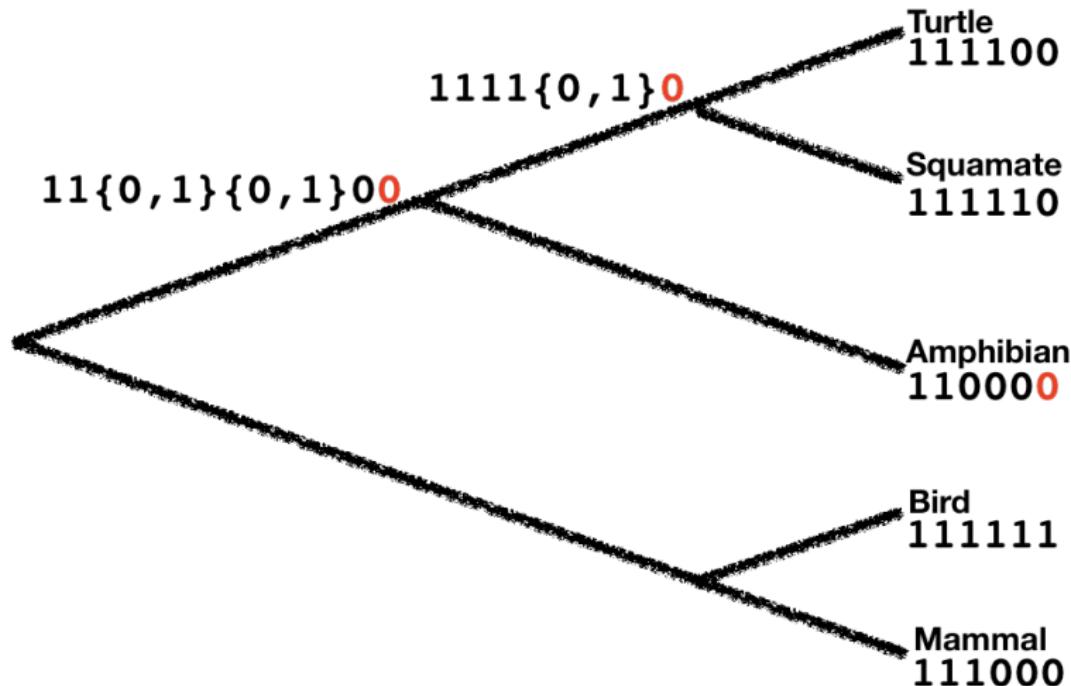
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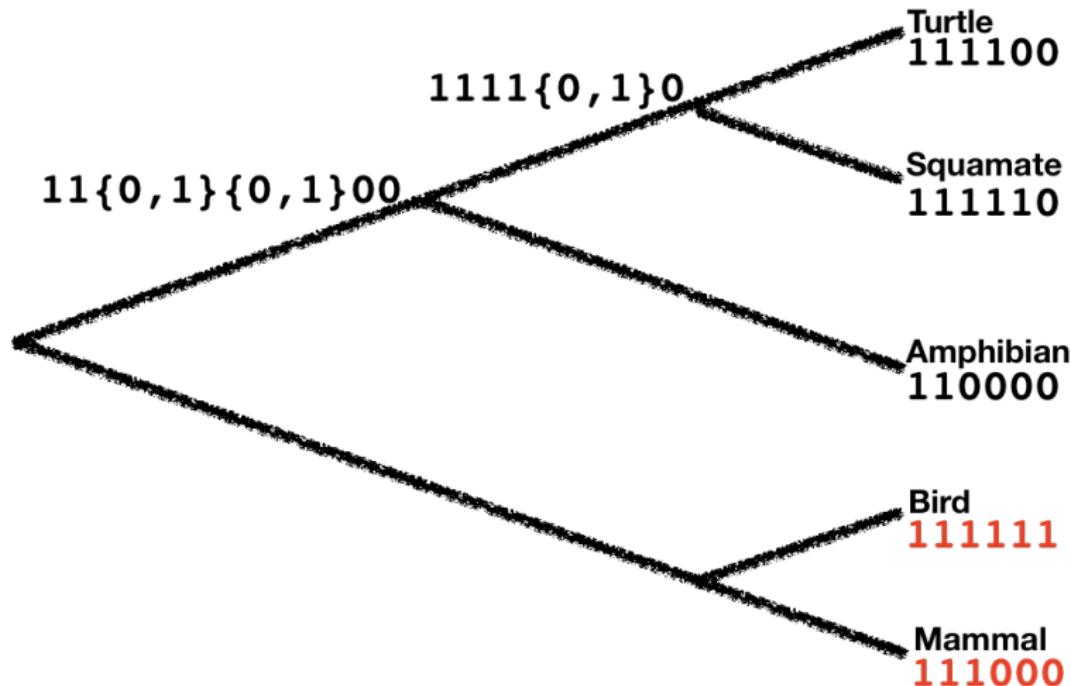
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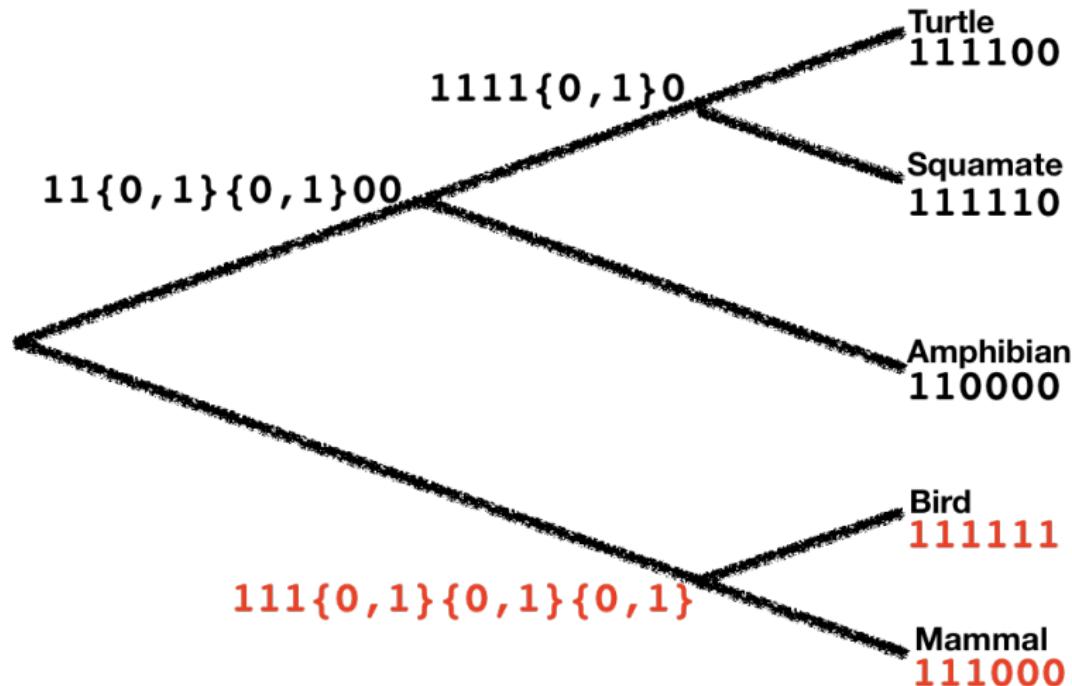
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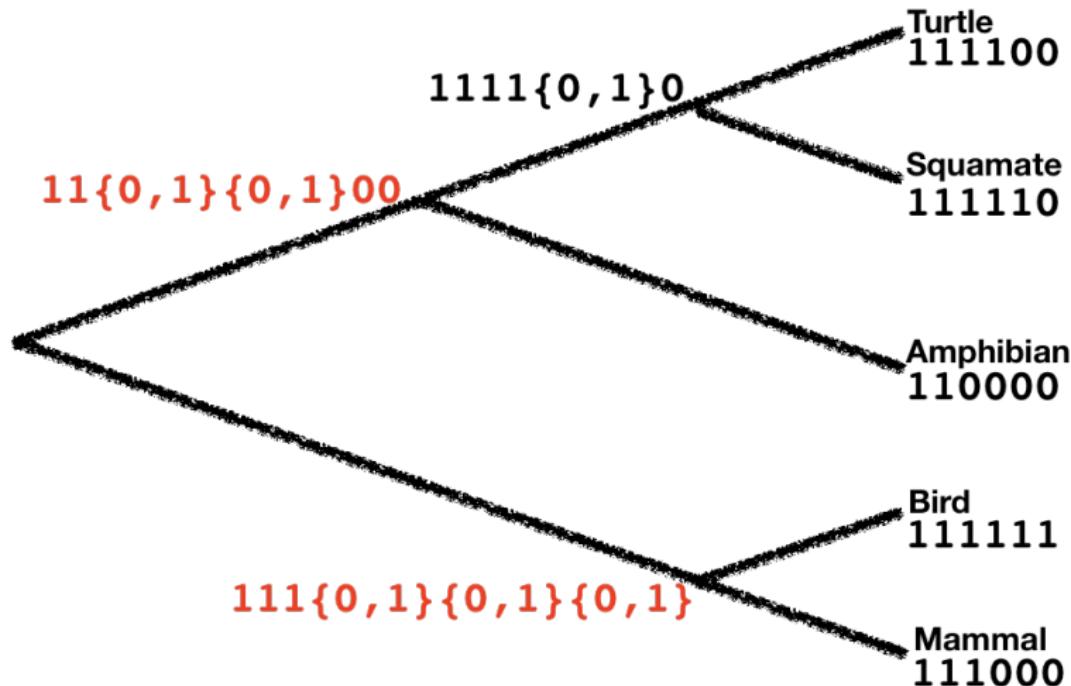
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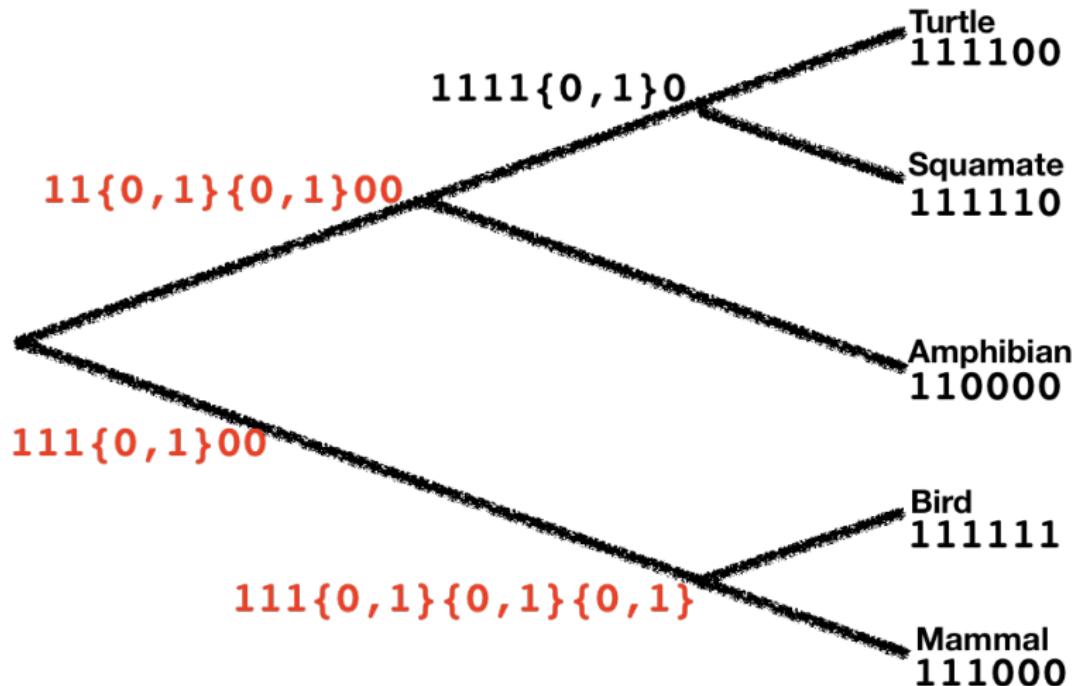
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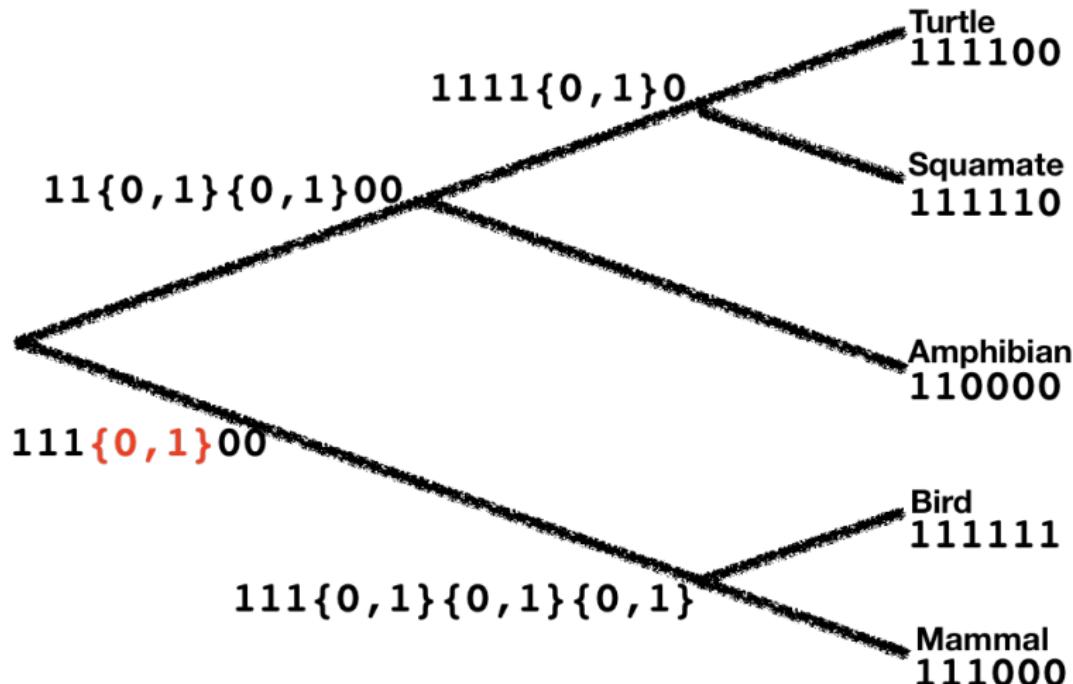
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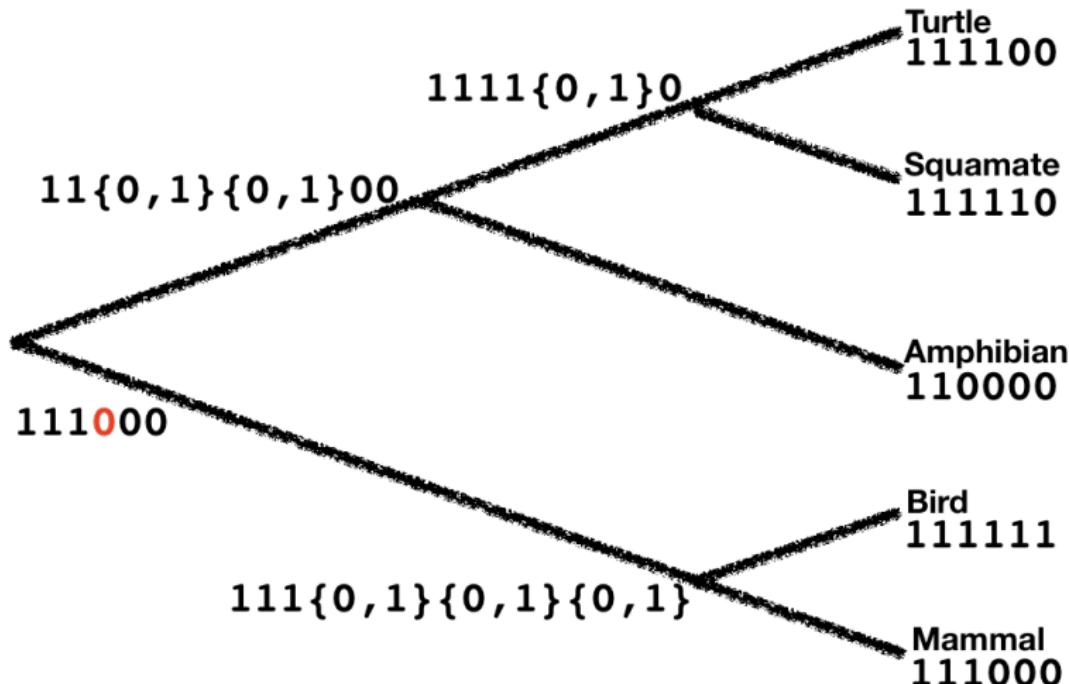
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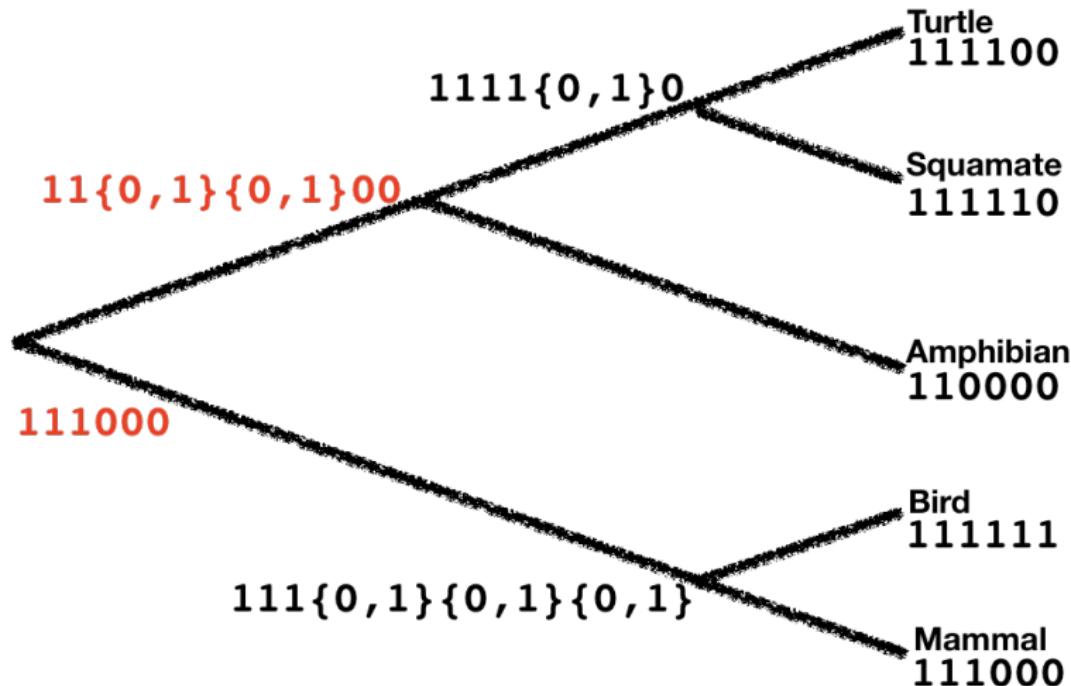
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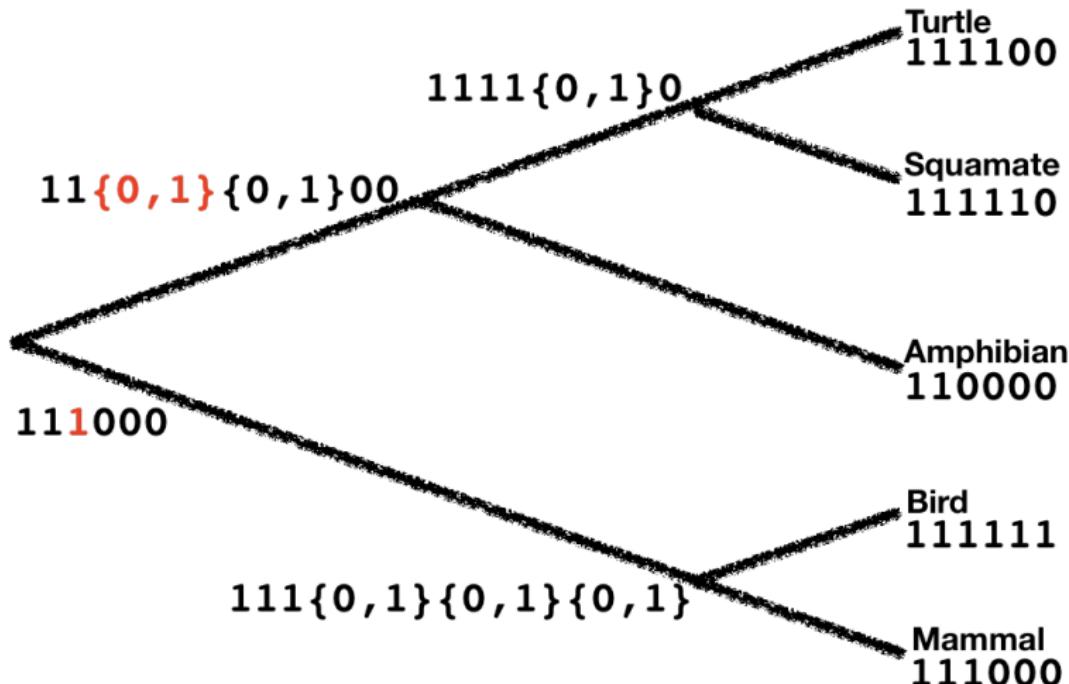
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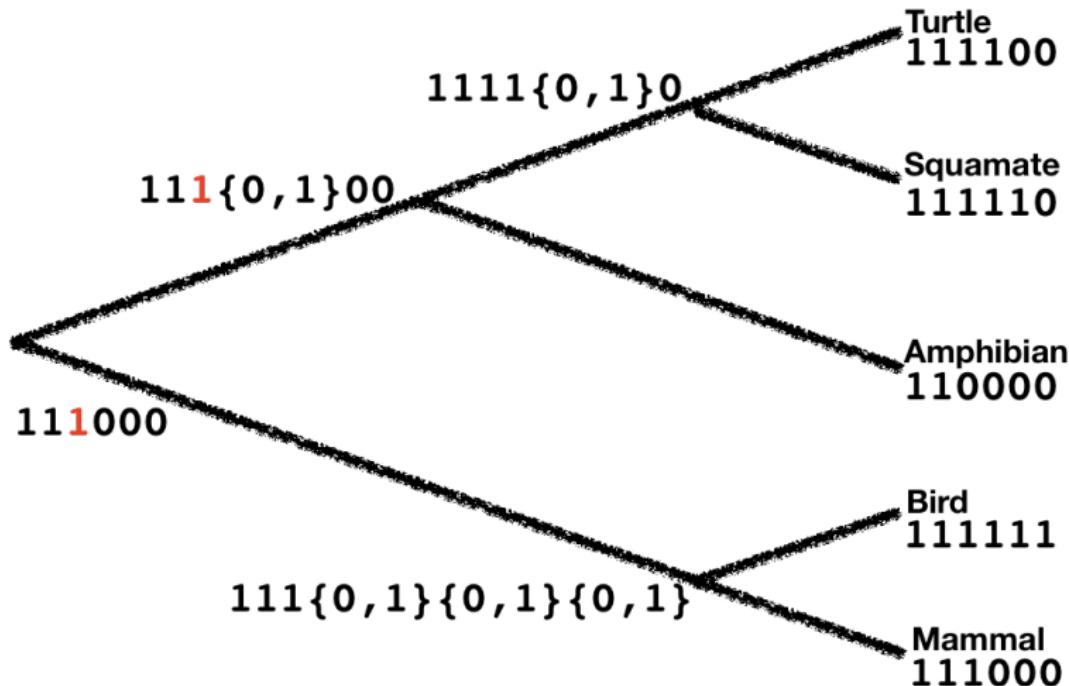
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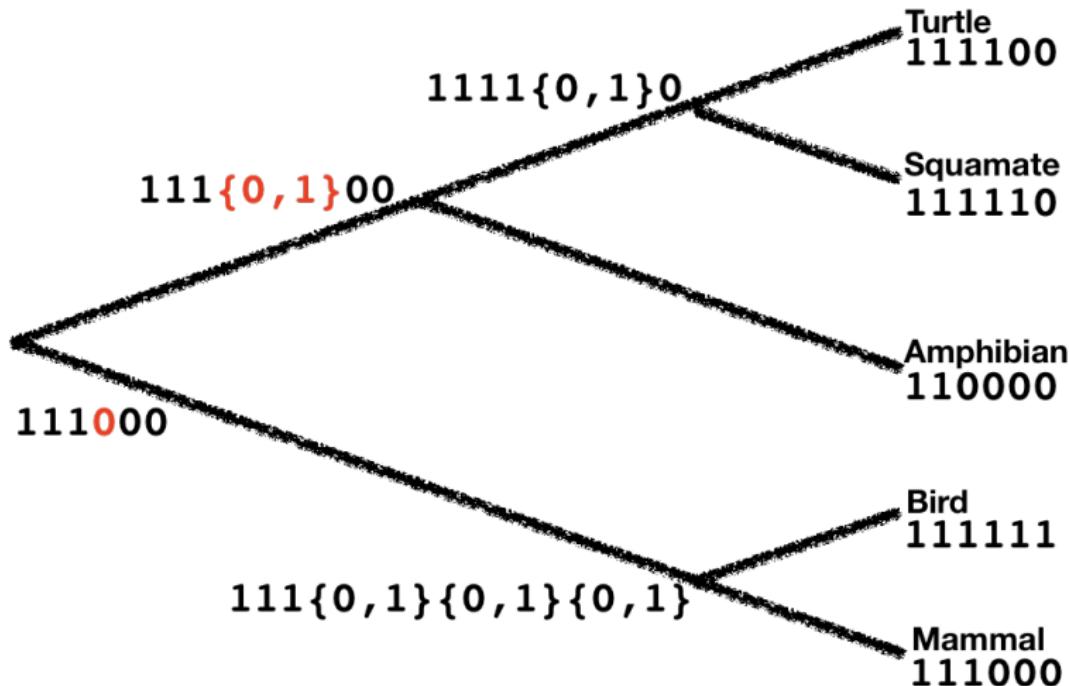
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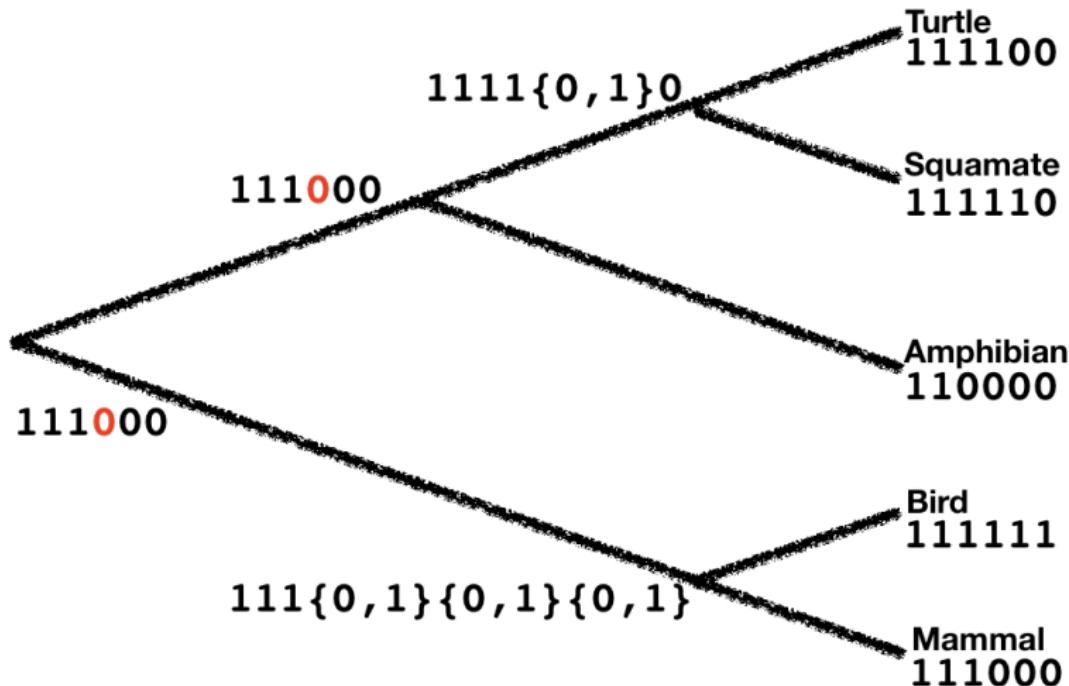
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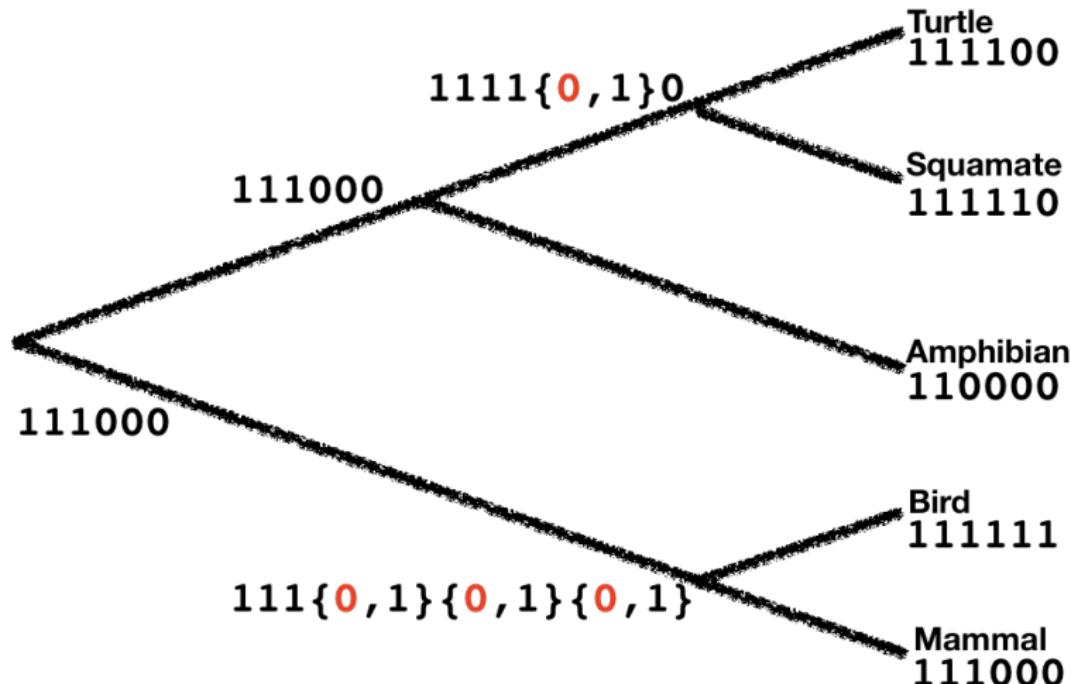
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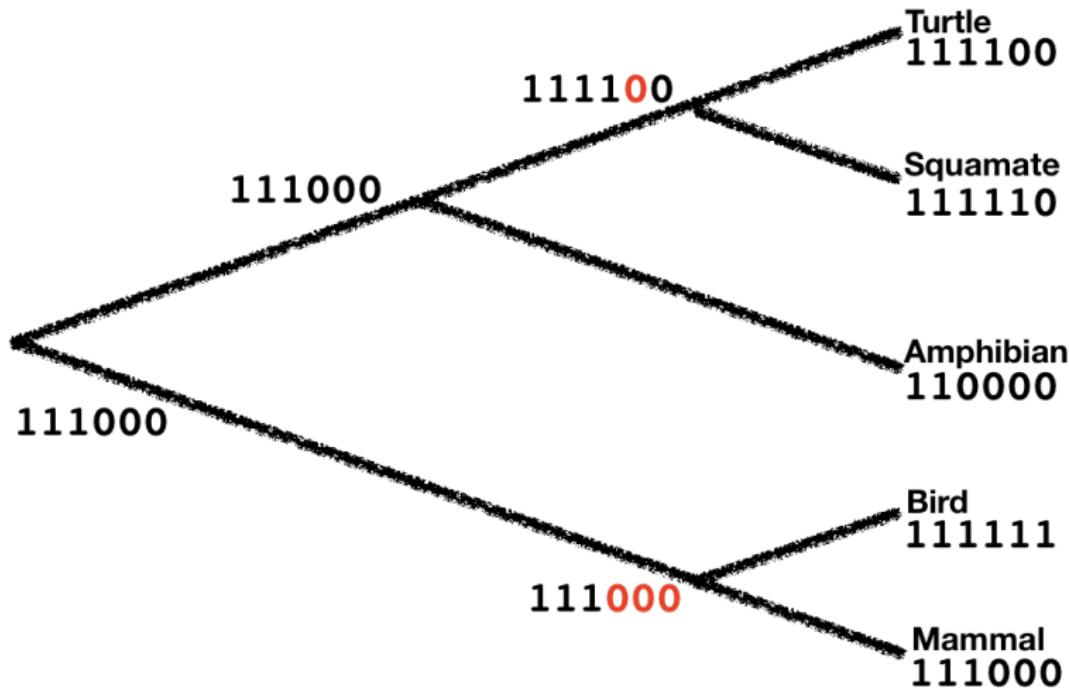
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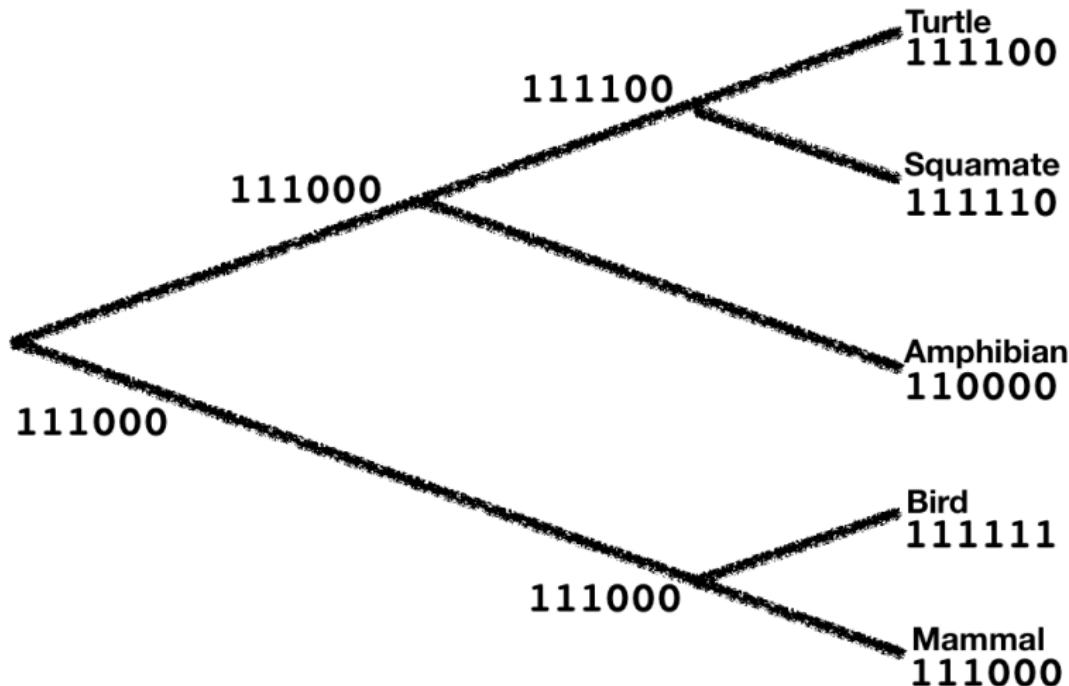
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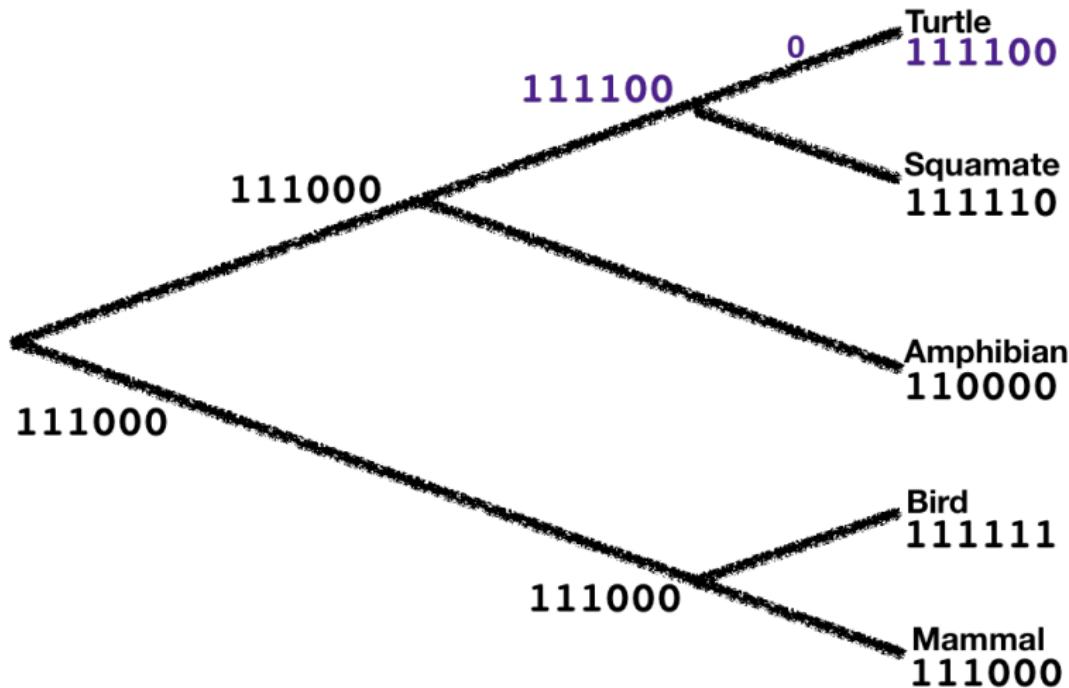
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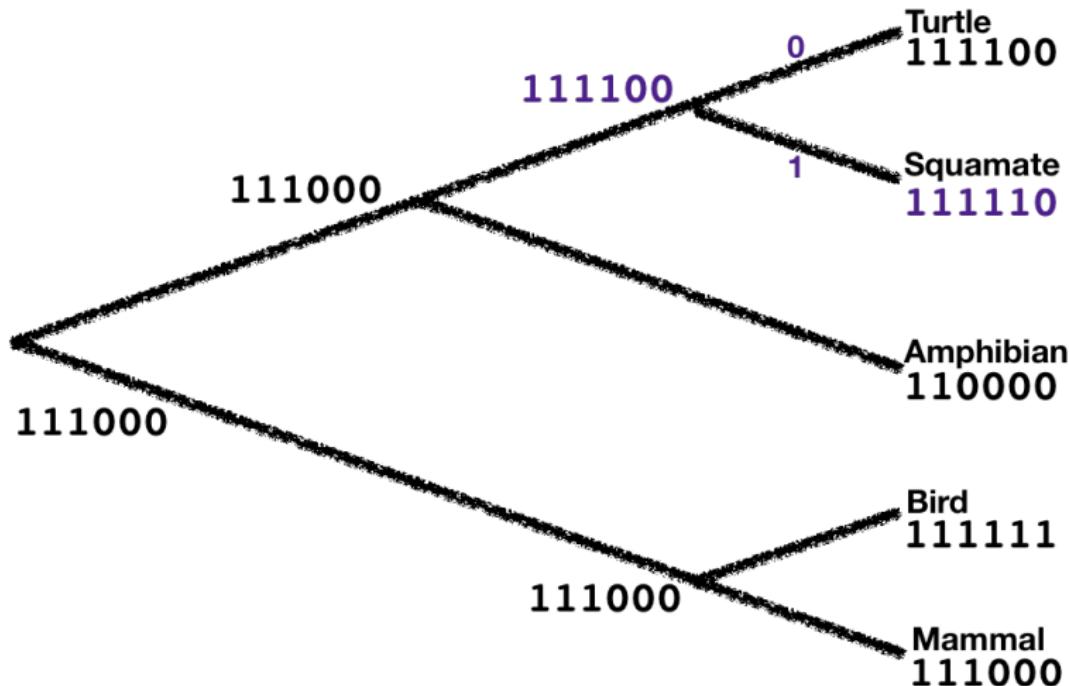
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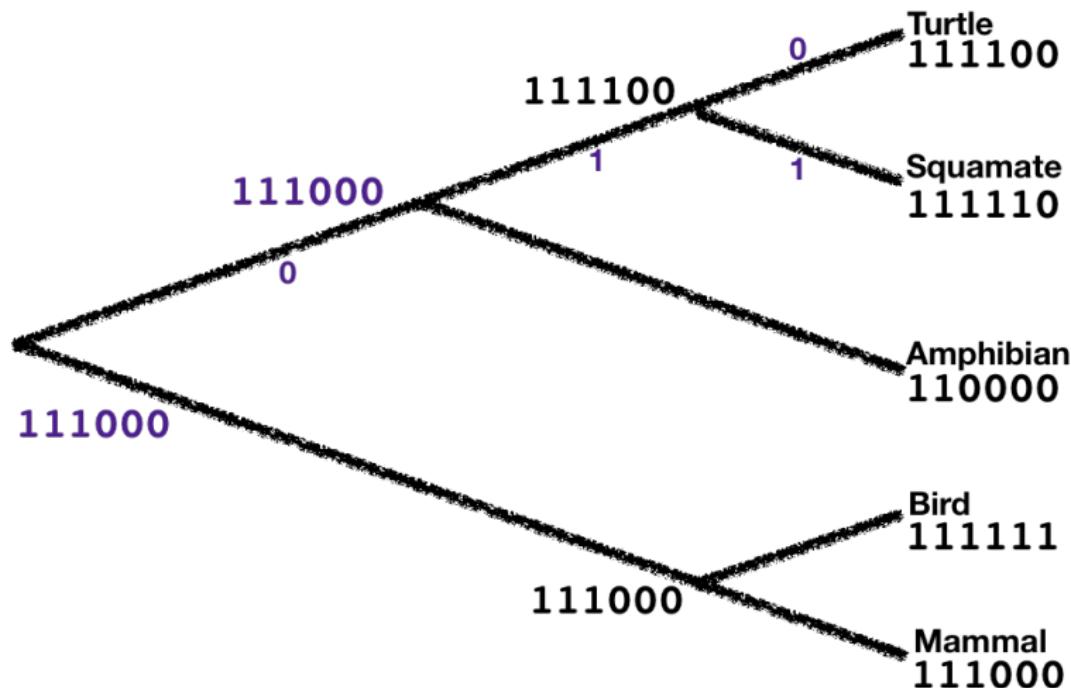
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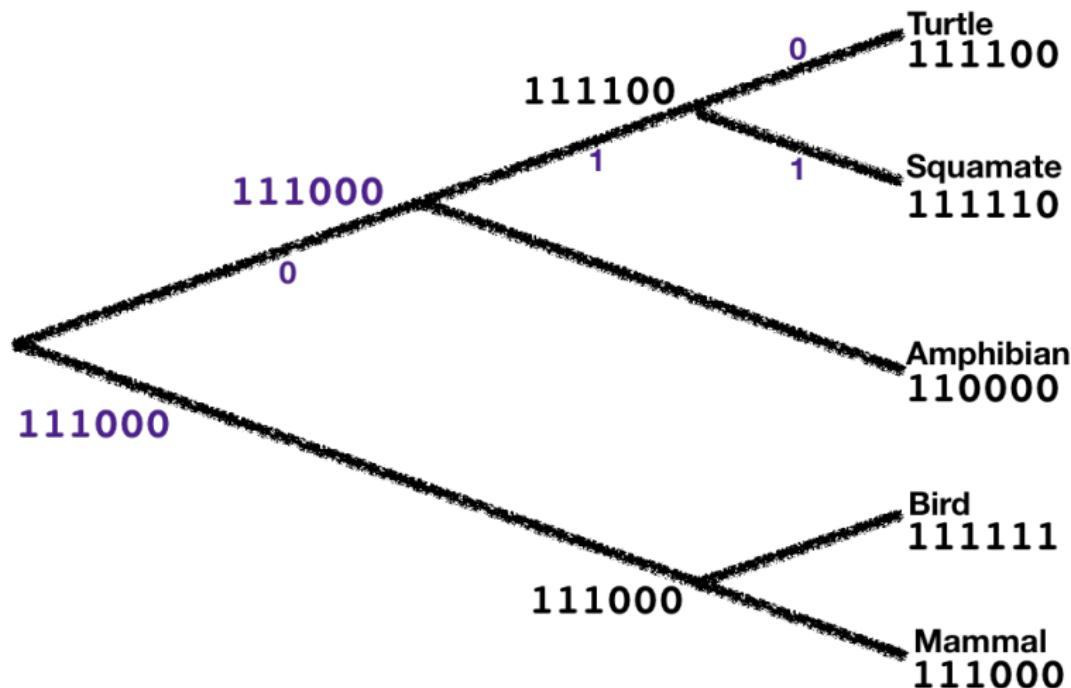
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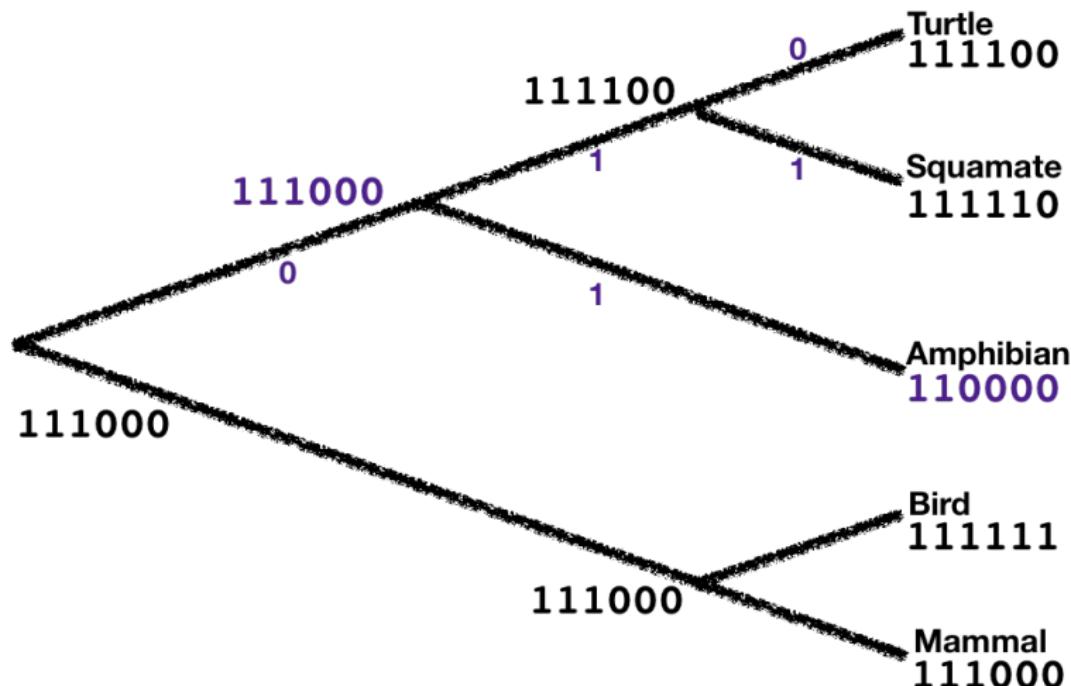
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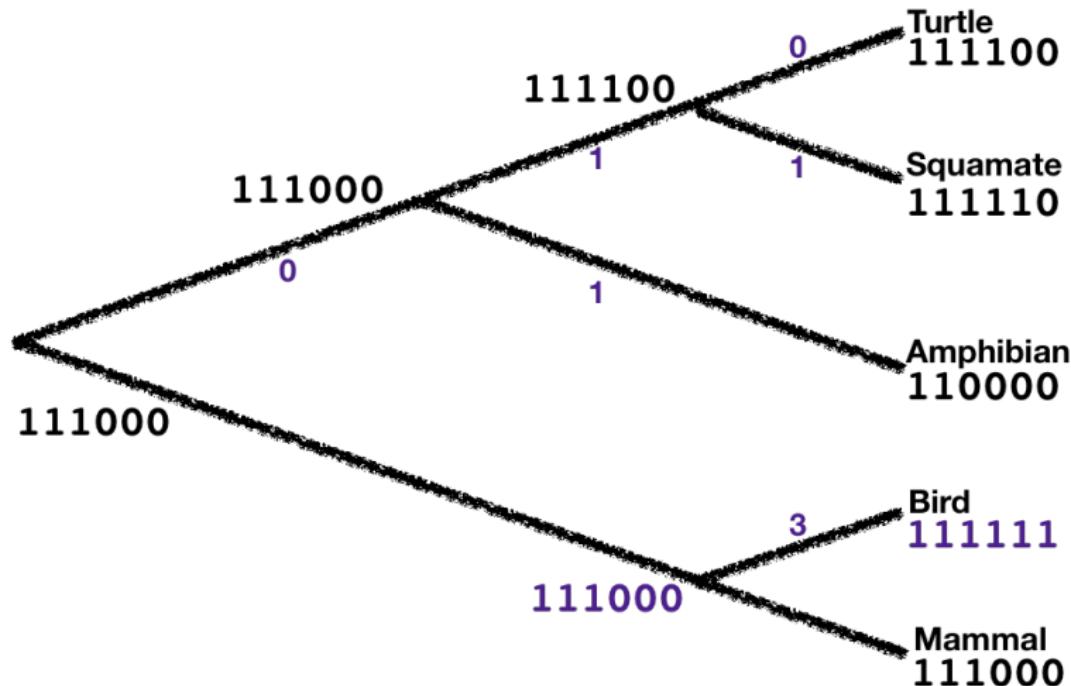
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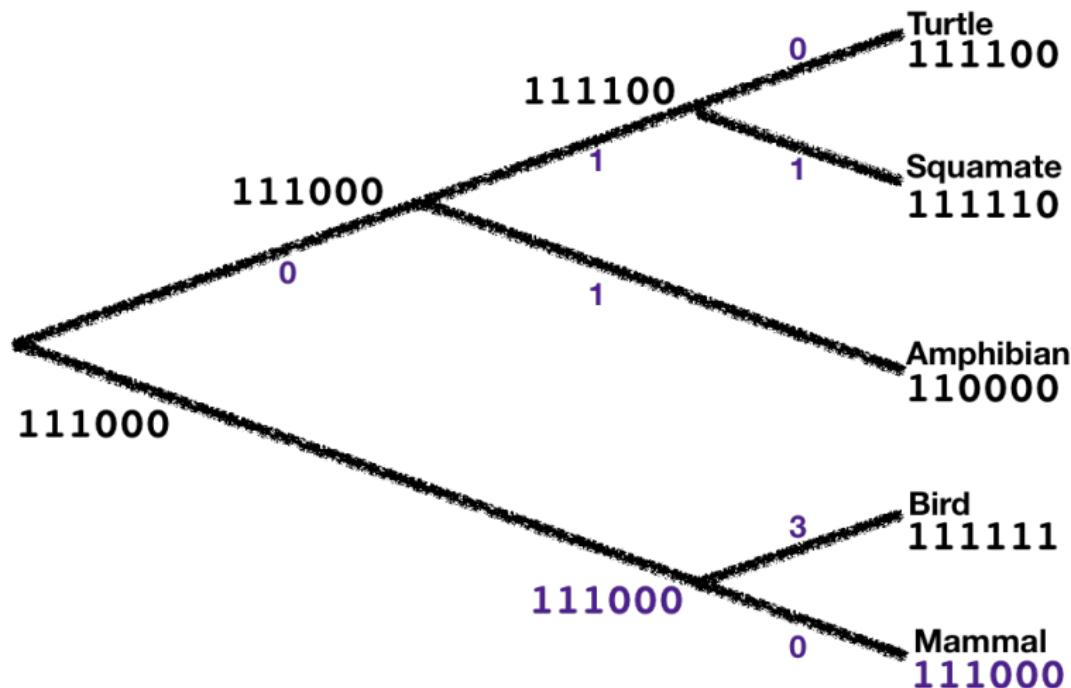
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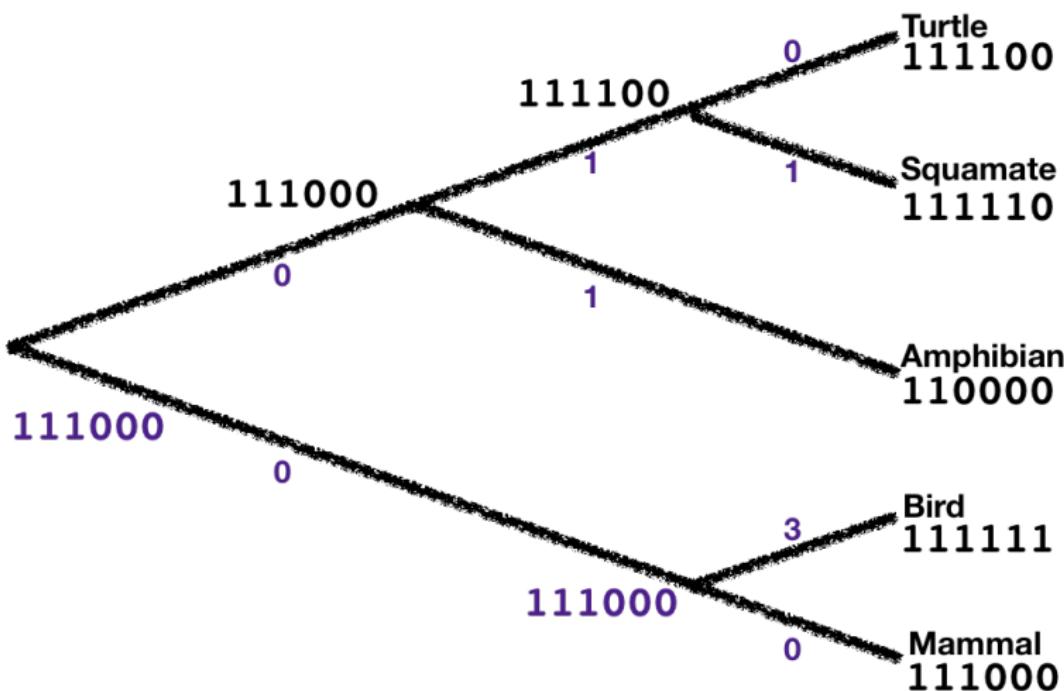
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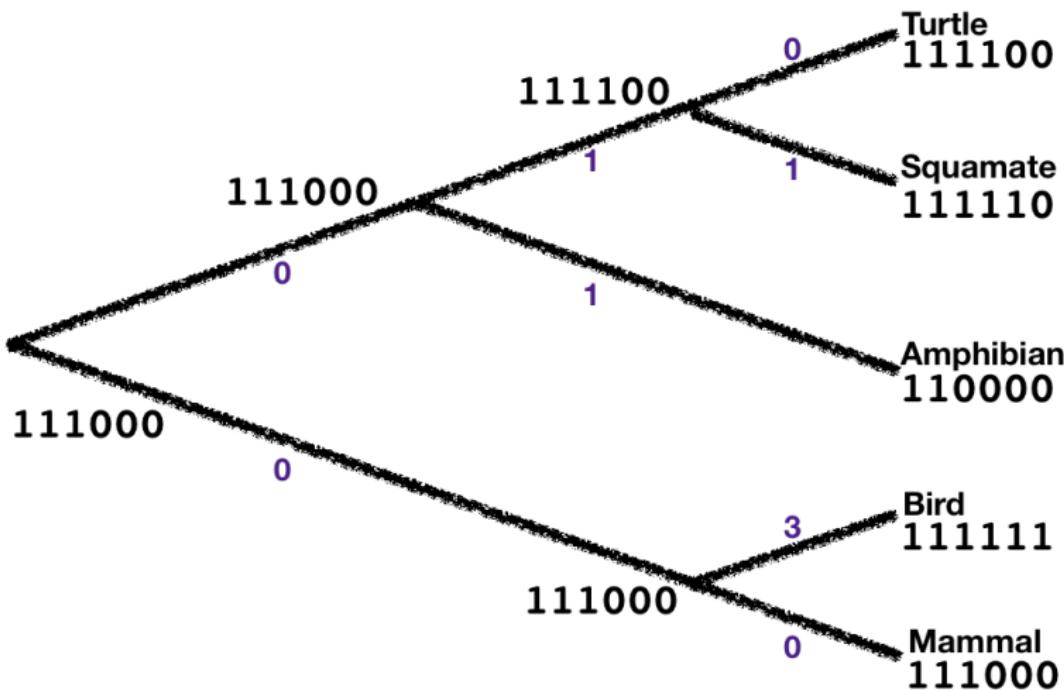
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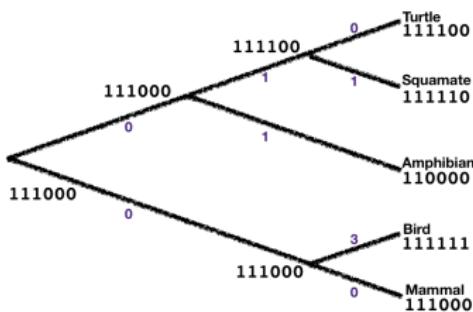


Maximum Parsimony

- Count the number of changes across each branch: 6 changes.



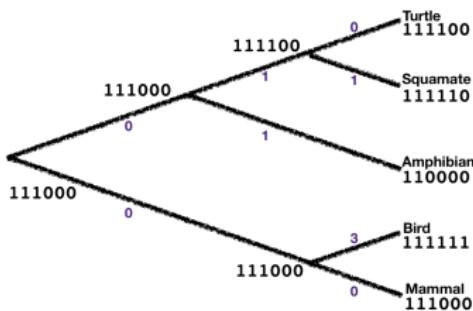
Your turn: score your tree



Species	Characters					
	1	1	0	0	0	0
Amphibian	1	1	0	0	0	0
Bird	1	1	1	1	1	1
Mammal	1	1	1	0	0	0
Squamate	1	1	1	1	1	0
Turtle	1	1	1	1	0	0

- ① Score the tree you drew.

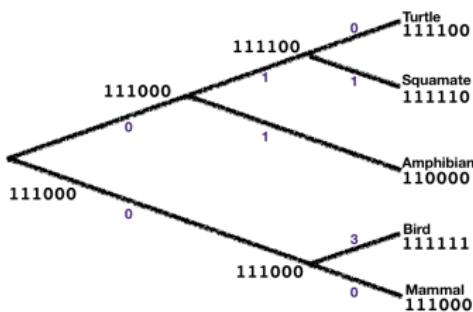
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- ① Score the tree you drew.
- ② Is there a better scoring tree?

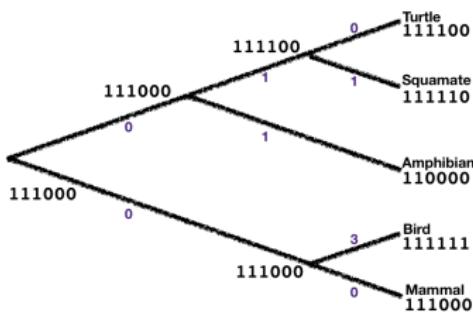
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Wrap-up



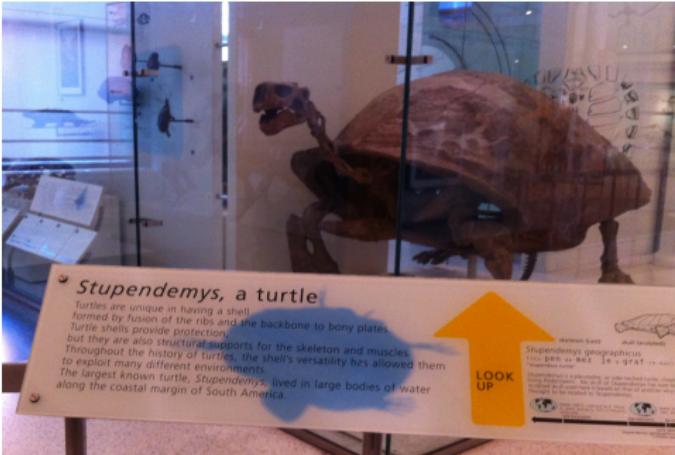
- For 6 taxa, there are 105 possible trees.

Wrap-up



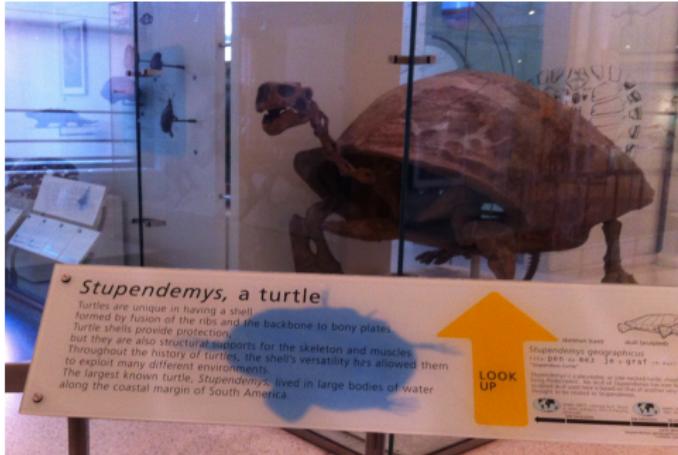
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- Finding the best tree is computationally hard (NP-hard).

Wrap-up



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Wrap-up



- For 6 taxa, there are 105 possible trees.
General formula: for n taxa, # trees = $(2n - 5)!!$
- Finding the best tree is computationally hard (NP-hard).
- But, for small number of taxa, can exhaustively search.
- With high schoolers, we did both:
 - ▶ by hand for morphological data, and
 - ▶ using bioPython and student-written code to download genetic sequences, score trees, and choose the best.

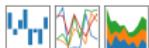
Recap

- On lecture slip, write down a topic you wish we had spent more time (and why).

pandas 
 $y_t = \beta' x_t + \mu_t + \epsilon_t$

Recap

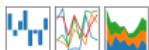
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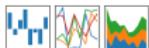
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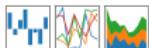
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pandas 

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- Accessing Formatted Data:
 - ▶ Pandas library has elegant solutions for accessing & analyzing structured data.
 - ▶ Can manipulate individual columns or rows ('Series').

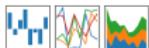
Recap

pandas 

$$y_t = \beta' x_t + \mu_t + \epsilon_t$$

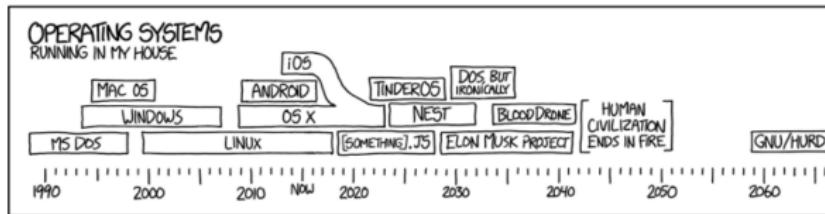
- On lecture slip, write down a topic you wish we had spent more time (and why).
- Recap: Logical Expressions & Circuits
- Accessing Formatted Data:
 - ▶ Pandas library has elegant solutions for accessing & analyzing structured data.
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- Pass your lecture slips to the aisles for the UTAs to collect.

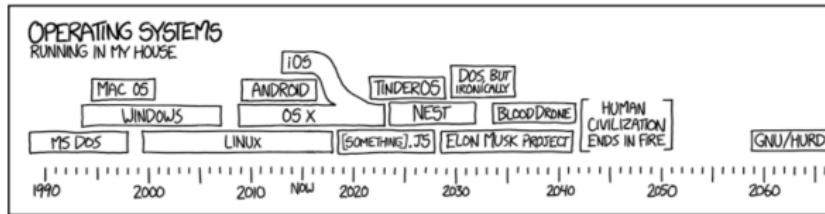
Practice Quiz & Final Questions



xkcd #1508

- Since you must pass the final exam to pass the course, we end every lecture with final exam review.

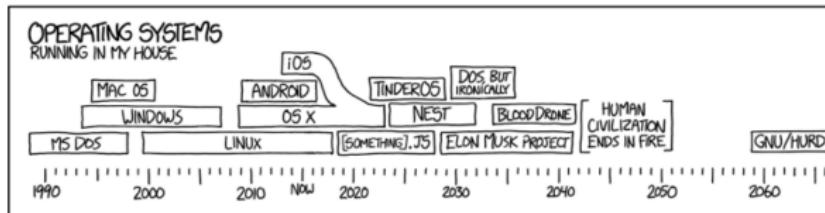
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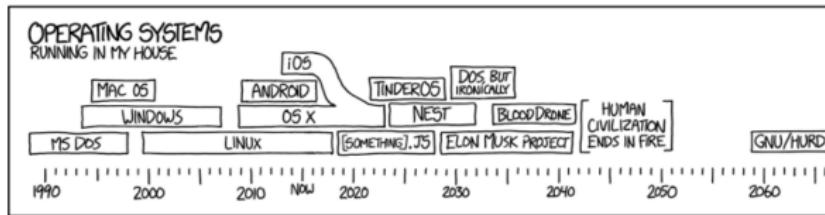
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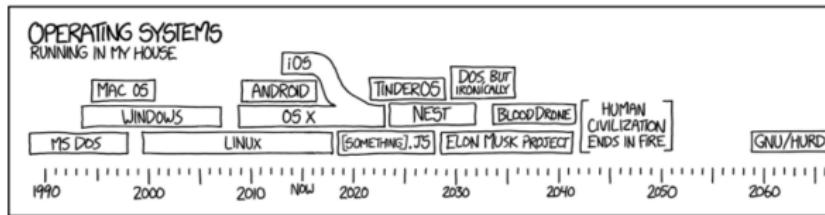
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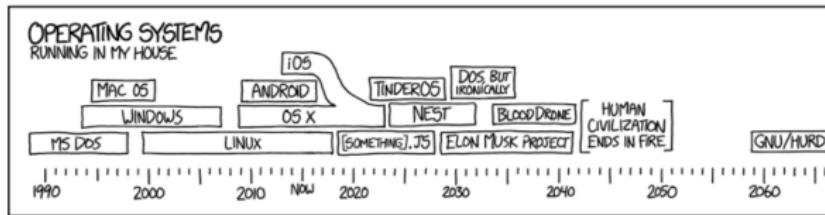
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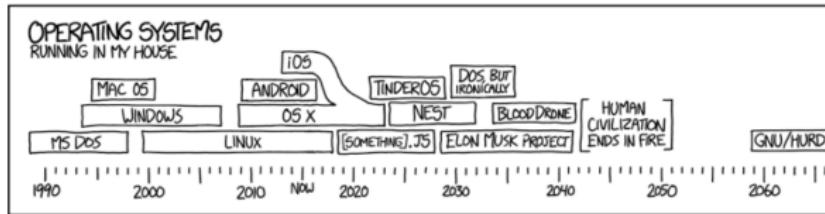
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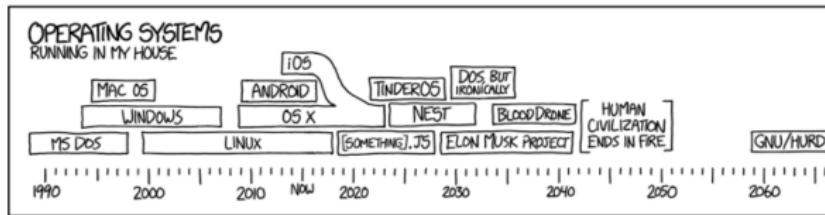
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- Theme: Unix commands!

Writing Boards



- Return writing boards as you leave...