Programming IA – algorithms and VBA

How computers think
How to program them to think for you

Computers are dumb but fast

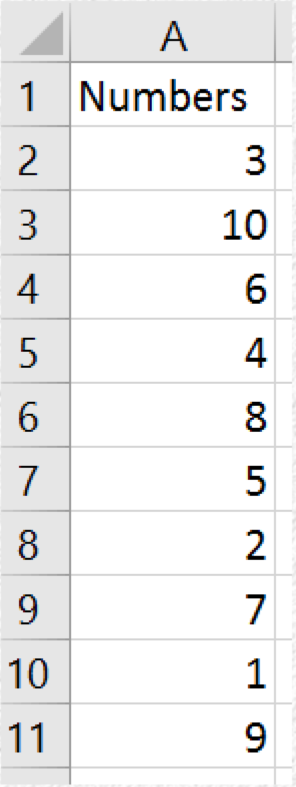
- Computers are literal
  - They will do exactly what you tell them to do
  - They will not do what you don't tell them to do
- Computers are fast
  - They execute millions of instructions millions of times per second
- The trick in programming is telling the computer exactly what it needs to do to accomplish a task

Algorithms

- Computers execute instructions one at a time
- Algorithms are step by step procedures for accomplishing a task
- To get a computer to do a task, we need to:
  - Identify the task to be completed
  - Figure out how to do the task using operations the computer knows how to do
  - Write instructions to the computer to do the steps
- Depending on what we tell the computer to do, it can do it relatively quickly, or really slowly

Example: sorting numbers

- How to sort numbers from 1 to 10 in descending order?
- There are many ways to do this
  - All will accomplish the task
  - Some will take longer than others
- How would we do it?
- Computers do it by making comparisons between adjacent numbers



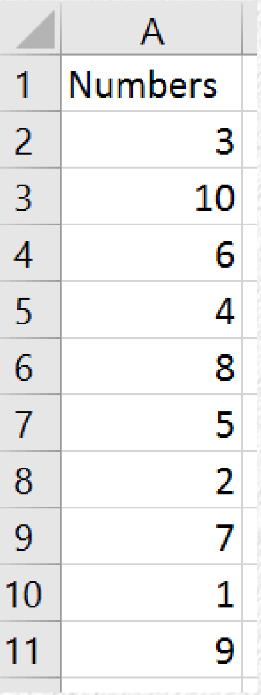
	A
1	Numbers
2	3
3	10
4	6
5	4
6	8
7	5
8	2
9	7
10	1
11	9

A really bad sort algorithm

- Check if the list is in order – if not:
  - Generate random numbers
  - Sort the list
  - Repeat until sorted in order
- Open file “rand_sort.xlsm” and hit CTRL+SHIFT+R to run the sort
- How long will it take?

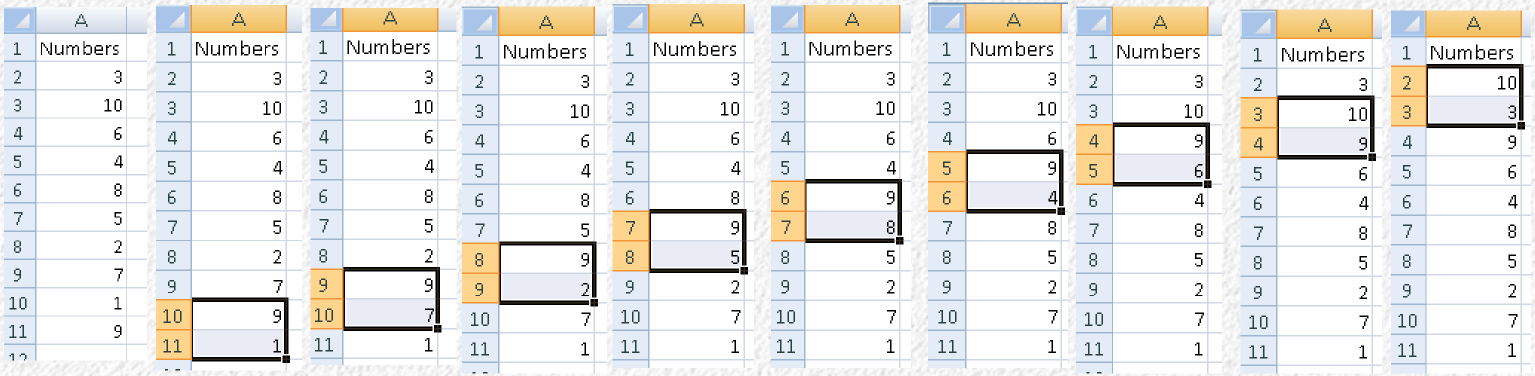
“Bubble” sort

- Start with unsorted numbers
- Compare the bottom two numbers numbers – if they are out of order swap them
- Continue to second and third number, third and fourth, fourth and fifth, etc. until all comparisons have been made
- Repeat from the top until no more swaps are needed



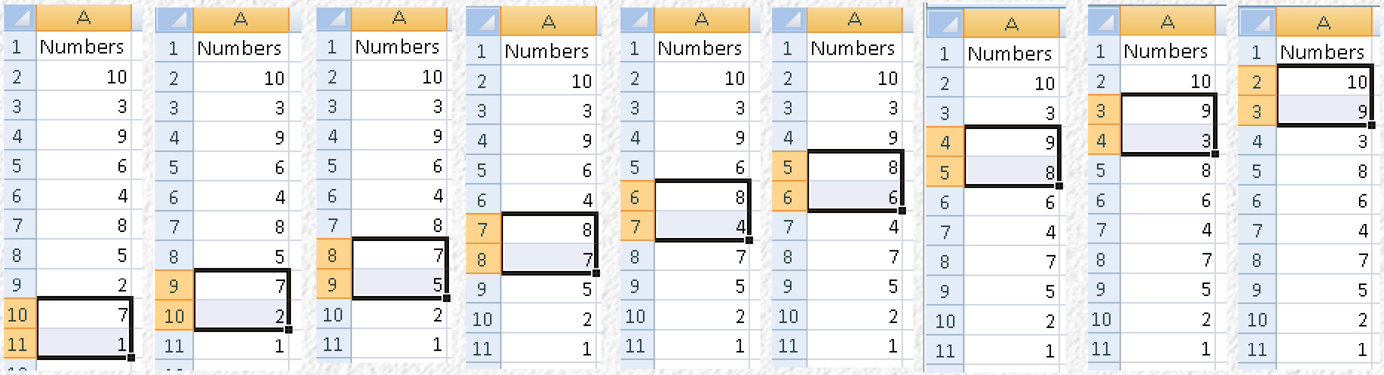
	A
1	Numbers
2	3
3	10
4	6
5	4
6	8
7	5
8	2
9	7
10	1
11	9

First run



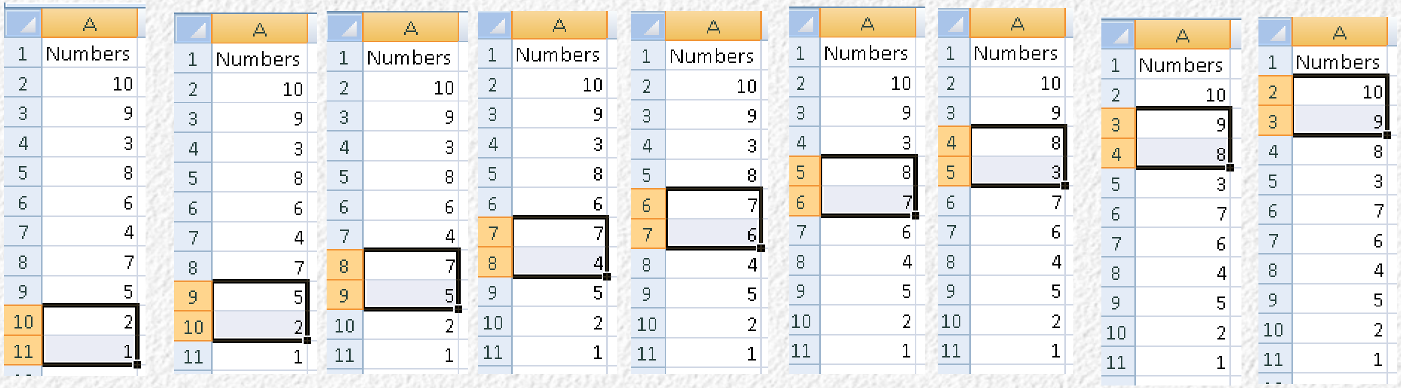
	A	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	3	3	3	3	3	3	3	3	3	10
3	10	10	10	10	10	10	10	10	10	3
4	6	6	6	6	6	6	6	9	9	9
5	4	4	4	4	4	4	9	6	6	6
6	8	8	8	8	8	9	4	4	4	4
7	5	5	5	5	9	8	8	8	8	8
8	2	2	2	9	5	5	5	5	5	5
9	7	7	9	2	2	2	2	2	2	2
10	1	9	7	7	7	7	7	7	7	7
11	9	1	1	1	1	1	1	1	1	1

Second run



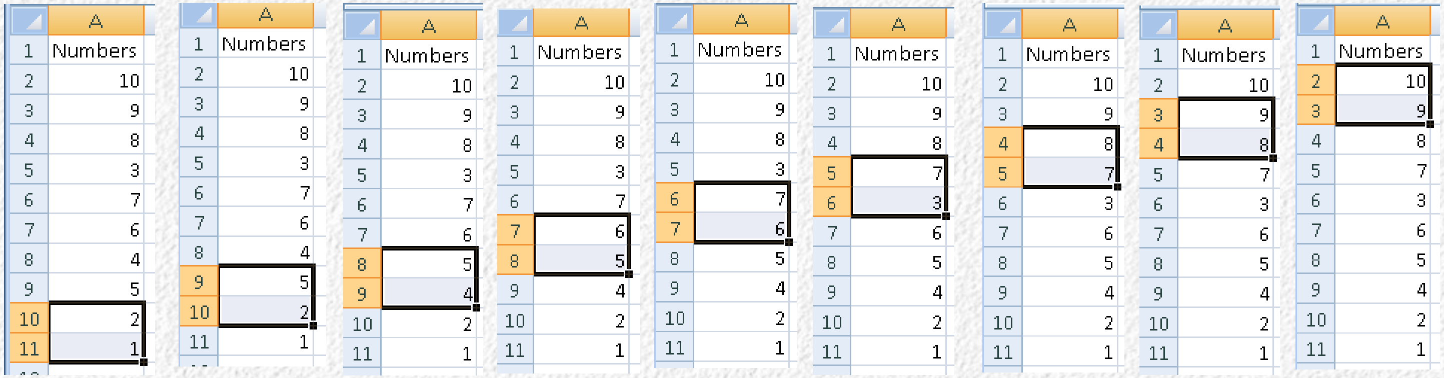
	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	3	3	3	3	3	3	3	9	9
4	9	9	9	9	9	9	9	3	3
5	6	6	6	6	6	8	8	8	8
6	4	4	4	4	8	6	6	6	6
7	8	8	8	8	4	4	4	4	4
8	5	5	7	7	7	7	7	7	7
9	2	7	5	5	5	5	5	5	5
10	7	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Third run



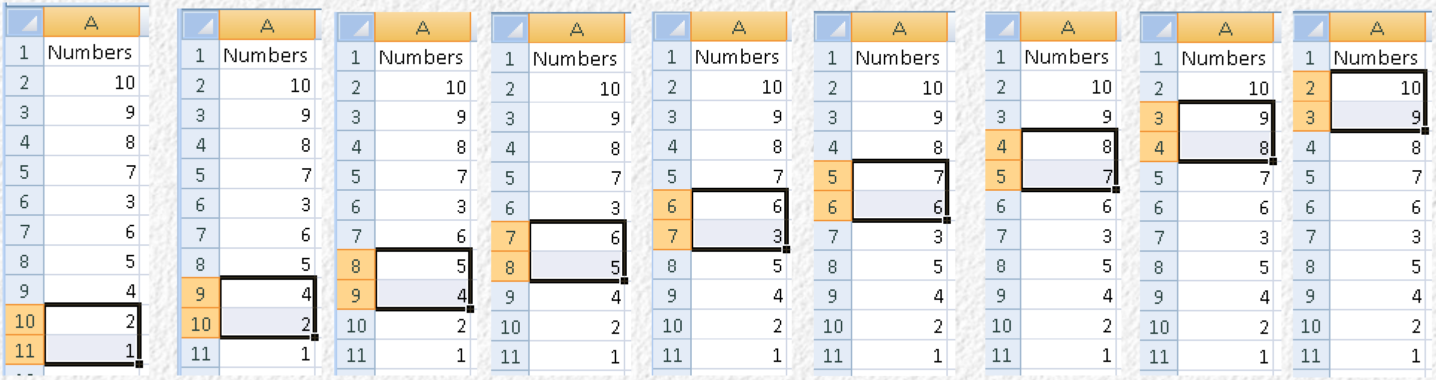
	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	3	3	3	3	3	3	8	8	8
5	8	8	8	8	8	8	3	3	3
6	6	6	6	6	7	7	7	7	7
7	4	4	4	7	6	6	6	6	6
8	7	7	7	4	4	4	4	4	4
9	5	5	5	5	5	5	5	5	5
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Fourth run



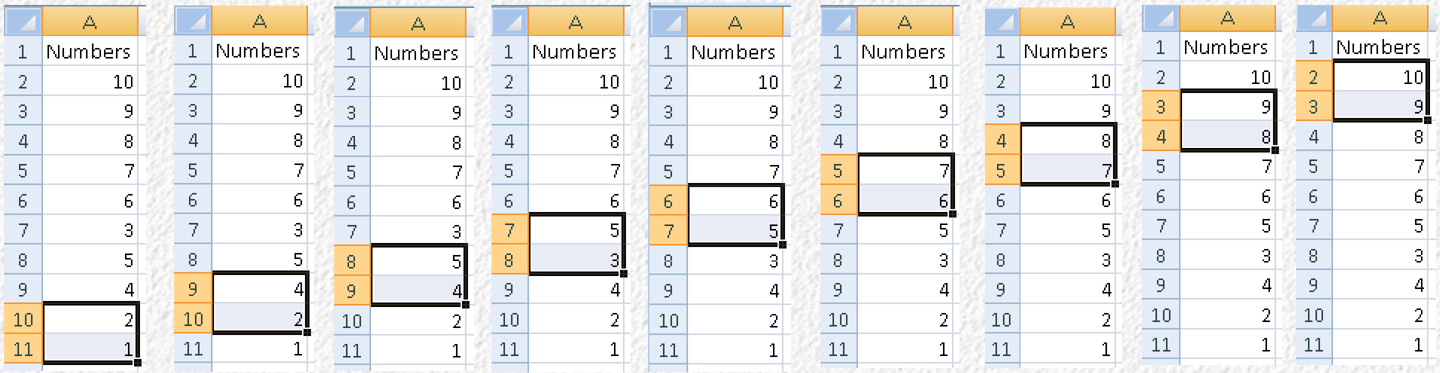
	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	8	8	8	8	8	8	8	8	8
5	3	3	3	3	3	7	7	7	7
6	7	7	7	7	7	3	3	3	3
7	6	6	6	6	6	6	6	6	6
8	4	4	5	5	5	5	5	5	5
9	5	5	4	4	4	4	4	4	4
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Fifth run



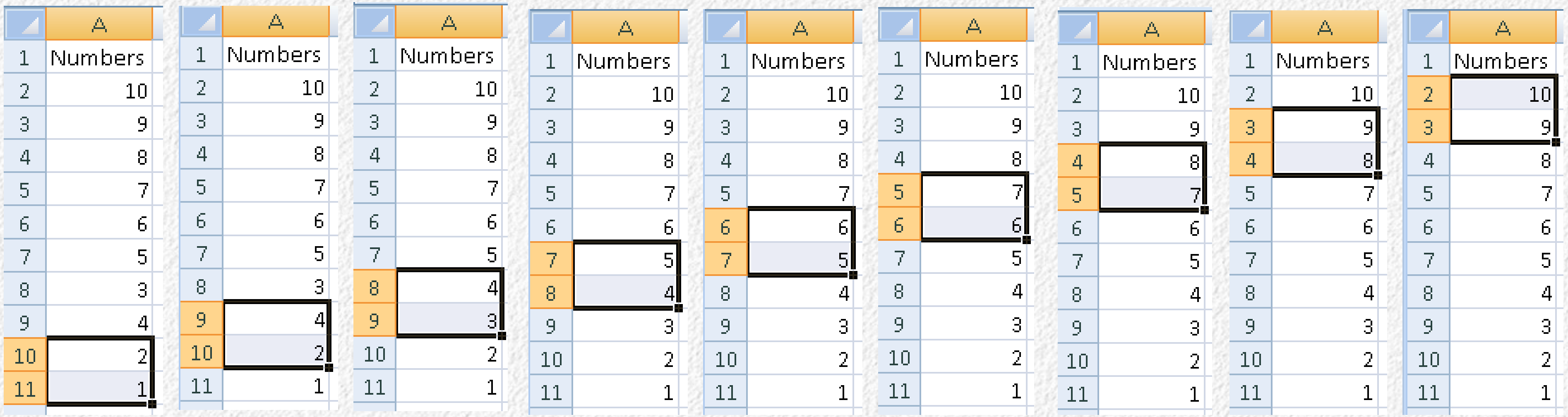
	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	8	8	8	8	8	8	8	8	8
5	7	7	7	7	7	7	7	7	7
6	3	3	3	3	6	6	6	6	6
7	6	6	6	6	3	3	3	3	3
8	5	5	5	5	5	5	5	5	5
9	4	4	4	4	4	4	4	4	4
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Sixth run



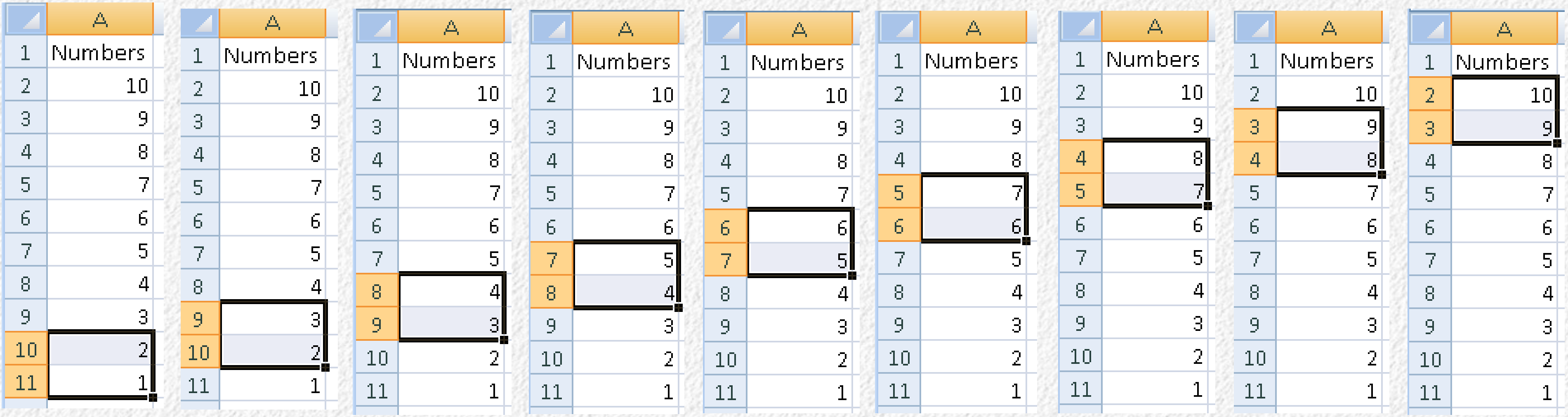
	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	8	8	8	8	8	8	8	8	8
5	7	7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6	6	6
7	3	3	3	5	5	5	5	5	5
8	5	5	5	3	3	3	3	3	3
9	4	4	4	4	4	4	4	4	4
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Seventh run



	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	8	8	8	8	8	8	8	8	8
5	7	7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6	6	6
7	5	5	5	5	5	5	5	5	5
8	3	3	4	4	4	4	4	4	4
9	4	4	3	3	3	3	3	3	3
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Eighth run



	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	8	8	8	8	8	8	8	8	8
5	7	7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6	6	6
7	5	5	5	5	5	5	5	5	5
8	4	4	4	4	4	4	4	4	4
9	3	3	3	3	3	3	3	3	3
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

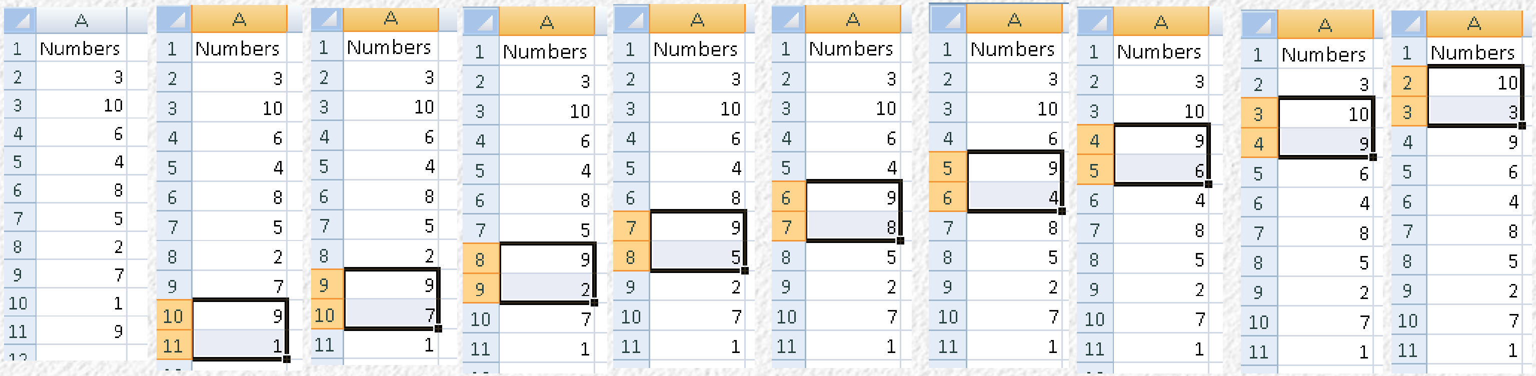
Finished!

Nothing changed in the last run, but needed to confirm that the list is in order

Better bubble sort

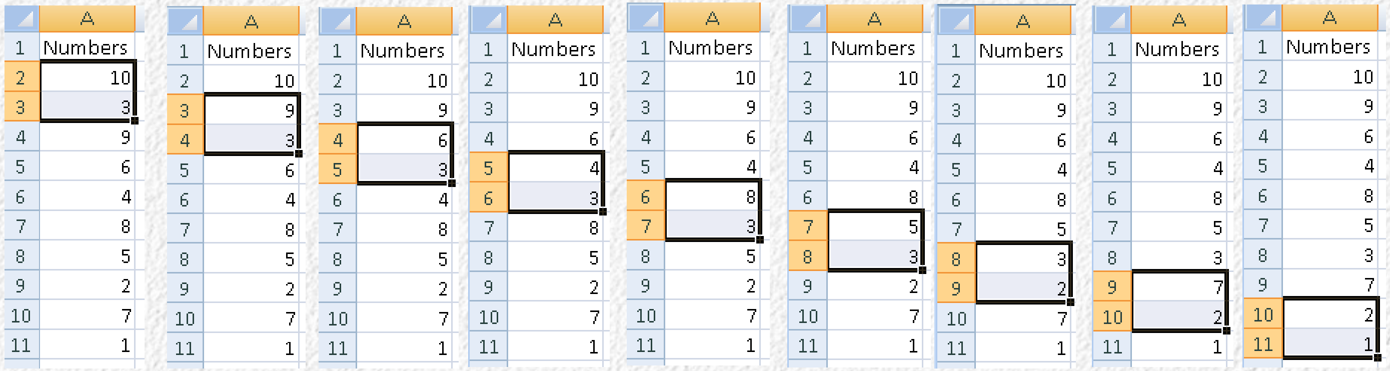
- A weakness of the algorithm: numbers move up rapidly, but down slowly
- An improved algorithm: alternate running up and down between runs

First run



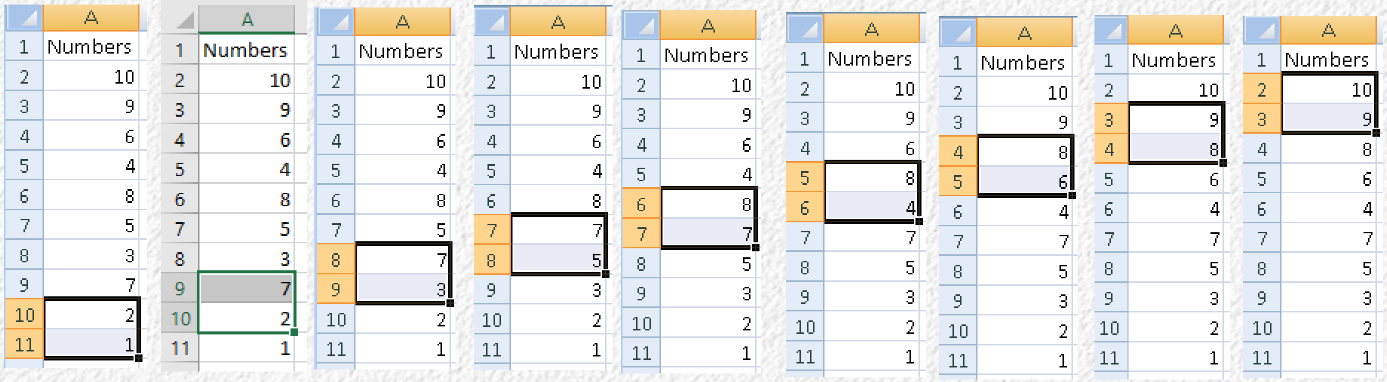
	A	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	3	3	3	3	3	3	3	3	3	10
3	10	10	10	10	10	10	10	10	10	3
4	6	6	6	6	6	6	6	9	9	9
5	4	4	4	4	4	4	9	6	6	6
6	8	8	8	8	8	9	4	4	4	4
7	5	5	5	5	9	8	8	8	8	8
8	2	2	2	9	5	5	5	5	5	5
9	7	7	9	2	2	2	2	2	2	2
10	1	9	7	7	7	7	7	7	7	7
11	9	1	1	1	1	1	1	1	1	1

Second run



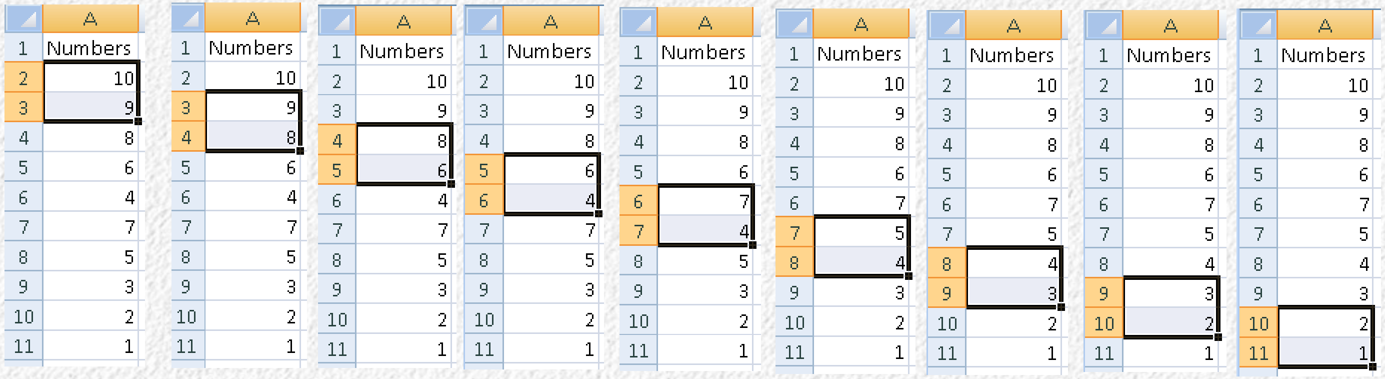
	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	3	9	9	9	9	9	9	9	9
4	9	3	6	6	6	6	6	6	6
5	6	6	3	4	4	4	4	4	4
6	4	4	4	3	8	8	8	8	8
7	8	8	8	8	3	5	5	5	5
8	5	5	5	5	5	3	3	3	3
9	2	2	2	2	2	2	2	7	7
10	7	7	7	7	7	7	7	2	2
11	1	1	1	1	1	1	1	1	1

Third run



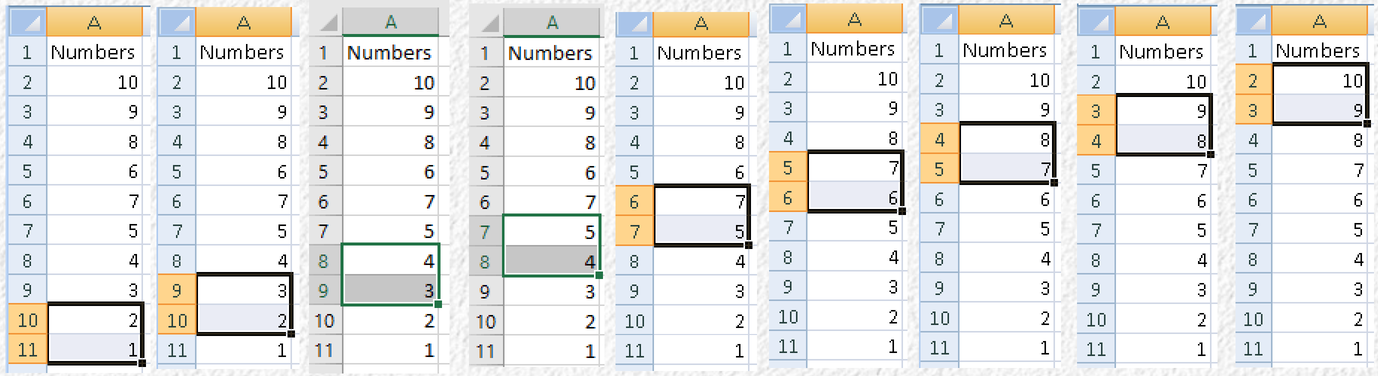
	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	6	6	6	6	6	6	8	8	8
5	4	4	4	4	4	8	6	6	6
6	8	8	8	8	8	4	4	4	4
7	5	5	5	7	7	7	7	7	7
8	3	3	7	5	5	5	5	5	5
9	7	7	3	3	3	3	3	3	3
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Fourth run



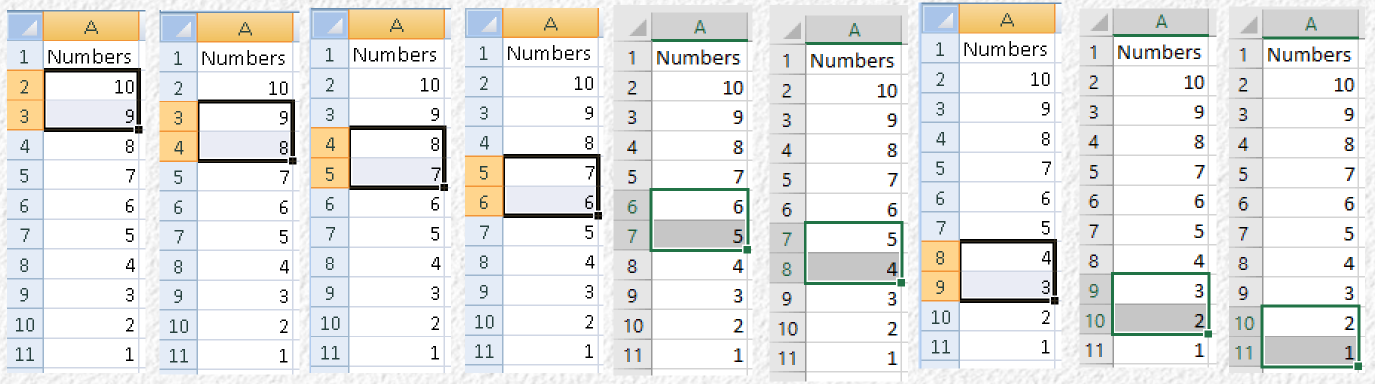
	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	8	8	8	8	8	8	8	8	8
5	6	6	6	6	6	6	6	6	6
6	4	4	4	4	7	7	7	7	7
7	7	7	7	7	4	5	5	5	5
8	5	5	5	5	5	4	4	4	4
9	3	3	3	3	3	3	3	3	3
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Fifth run



	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	8	8	8	8	8	8	8	8	8
5	6	6	6	6	6	7	7	7	7
6	7	7	7	7	7	6	6	6	6
7	5	5	5	5	5	5	5	5	5
8	4	4	4	4	4	4	4	4	4
9	3	3	3	3	3	3	3	3	3
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Sixth run



	A	A	A	A	A	A	A	A	A
1	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers	Numbers
2	10	10	10	10	10	10	10	10	10
3	9	9	9	9	9	9	9	9	9
4	8	8	8	8	8	8	8	8	8
5	7	7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6	6	6
7	5	5	5	5	5	5	5	5	5
8	4	4	4	4	4	4	4	4	4
9	3	3	3	3	3	3	3	3	3
10	2	2	2	2	2	2	2	2	2
11	1	1	1	1	1	1	1	1	1

Algorithms – the point

- Randomly sorting takes a really long, unpredictable amount of time
- Bubble sort takes 8 passes to complete
- Improved bubble sort takes 6 passes to complete – 25% improvement over bubble sort
- The amount of time that it takes to complete a task depends on the algorithm used

Programming a computer

- A program is a series of instructions executed by the computer
- They are written in a programming language
- They are executed in order, first to last

Programming languages

- Many out there, some more English like in their syntax than others
- Written as **code** = a series of instructions, with a syntax specific to the language
- Some languages use an **interpreter** = a program that translates the code into a binary form the computer understands and executes the commands
- Some **compile** the program = convert it into a binary code the computer understands and can be run without an interpreter

The language we will use

- The language used to program Excel is **Microsoft Visual Basic for Applications** (VBA)
    - Interpreted language
    - Only runs from within an MS Office application
    - Takes advantage of the capabilities of Excel
- Visual Basic is fairly simple to use, fairly English-like in its syntax
- Programs that run in Excel are called VBA **macros**

Macros in Excel

- Three major uses
  - Automating a complex task
  - Automating a repetitive task
  - Implementing functions/algorithms not already available in Excel
- Using Excel macros simplifies programming
  - Take advantage of Excel for storing data, file input/output, summary, graphing, worksheet formulas and functions
- Constrained by the way Excel works
  - Need to learn to move around the worksheet, select cells, from within the program
  - Slow

Example: Mantel tests

- Mantel tests are tests of association between two square matrices
- Often these are “distance matrices”
  - Geographic distance between sampled populations, genetic distance between sampled populations
- A measure of association between the matrices is calculated for the observed data
- Then the elements of the matrices are randomly shuffled
- The association is re-calculated with each random shuffle
- The observed association is compared with the randomly generated differences to obtain a p-value

Association between geographic distance and genetic distance

- Organisms tend to find mates in their vicinities
- This leads to “isolation by distance”
- Gene pools tend to become more different with increasing distance
- Is this true for humans?
- Let's look at the association between gene frequencies and location from the DNA fingerprint data

The analysis

- Data from 7 states
- Calculate a genetic distance among all possible pairs of states
- Treat the location of the capitol city as the location, calculate distances among them
- Test for association using a Mantel test

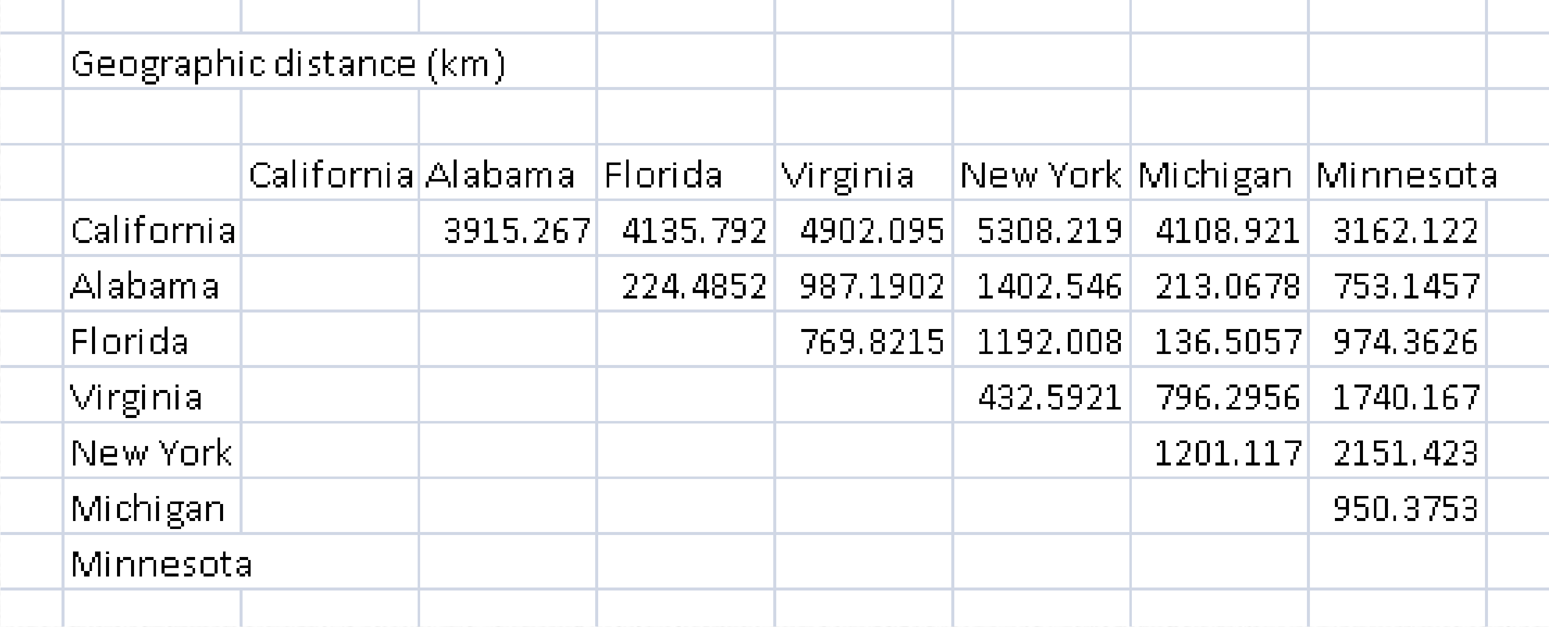
Euclidean distance

- As you no doubt recall, the distance between two points with coordinates (x_1,y_1) and (x_2, y_2) is:

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

- If we have more than two coordinates we just continue to add squared differences:

Distance between capitols



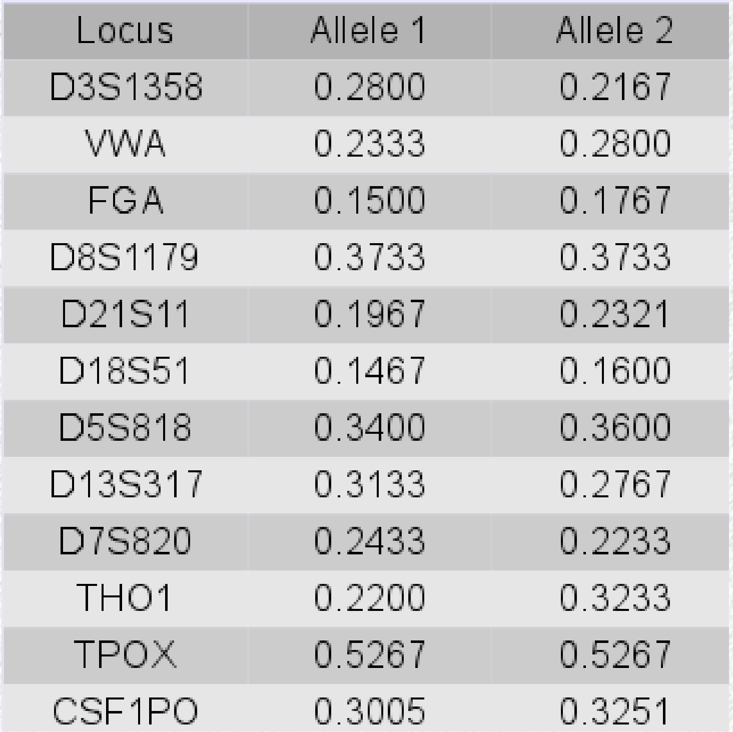
Geographic distance (km)

	California	Alabama	Florida	Virginia	New York	Michigan	Minnesota
California		3915.267	4135.792	4902.095	5308.219	4108.921	3162.122
Alabama			224.4852	987.1902	1402.546	213.0678	753.1457
Florida				769.8215	1192.008	136.5057	974.3626
Virginia					432.5921	796.2956	1740.167
New York						1201.117	2151.423
Michigan							950.3753
Minnesota							

Done in another program – earth is curved, longitude lines are not parallel, need software that knows this

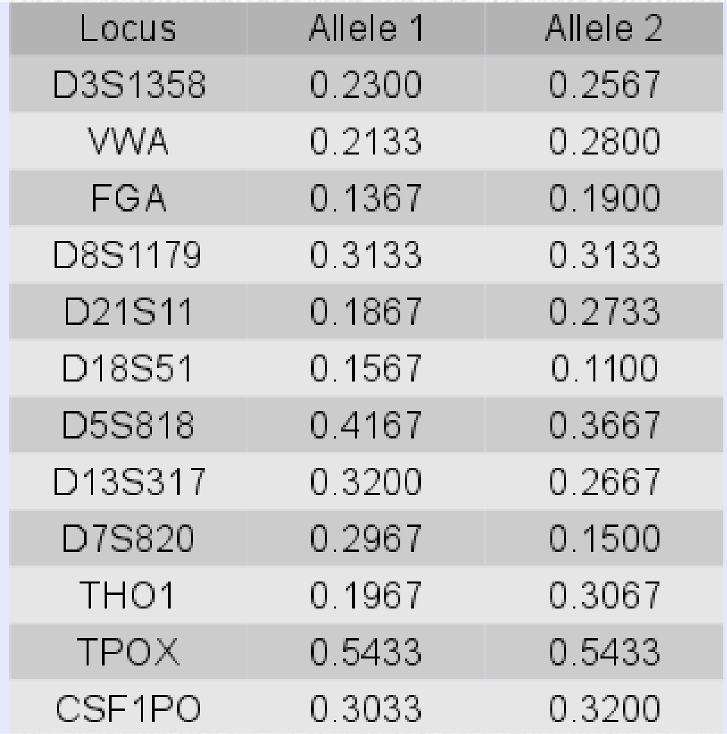
Distances between sets of gene frequencies

California

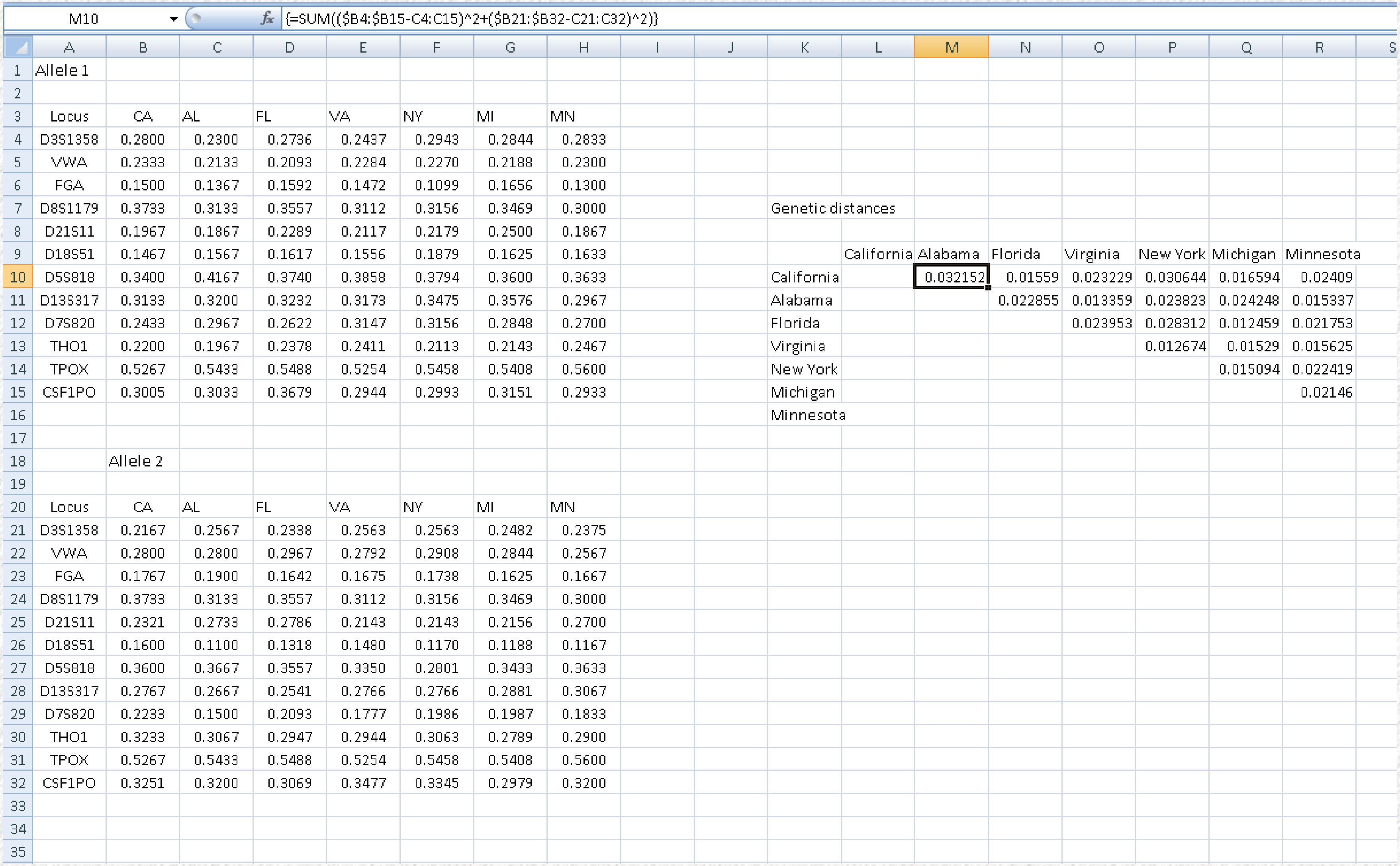


Locus	Allele 1	Allele 2
D3S1358	0.2800	0.2167
VWA	0.2333	0.2800
FGA	0.1500	0.1767
D8S1179	0.3733	0.3733
D21S11	0.1967	0.2321
D18S51	0.1467	0.1600
D5S818	0.3400	0.3600
D13S317	0.3133	0.2767
D7S820	0.2433	0.2233
THO1	0.2200	0.3233
TPOX	0.5267	0.5267
CSF1PO	0.3005	0.3251

Alabama



Locus	Allele 1	Allele 2
D3S1358	0.2300	0.2567
VWA	0.2133	0.2800
FGA	0.1367	0.1900
D8S1179	0.3133	0.3133
D21S11	0.1867	0.2733
D18S51	0.1567	0.1100
D5S818	0.4167	0.3667
D13S317	0.3200	0.2667
D7S820	0.2967	0.1500
THO1	0.1967	0.3067
TPOX	0.5433	0.5433
CSF1PO	0.3033	0.3200



```
{=SUM(($B4:$B15-C4:C15)^2+($B21:$B32-C21:C32)^2)}
```

Allele 1

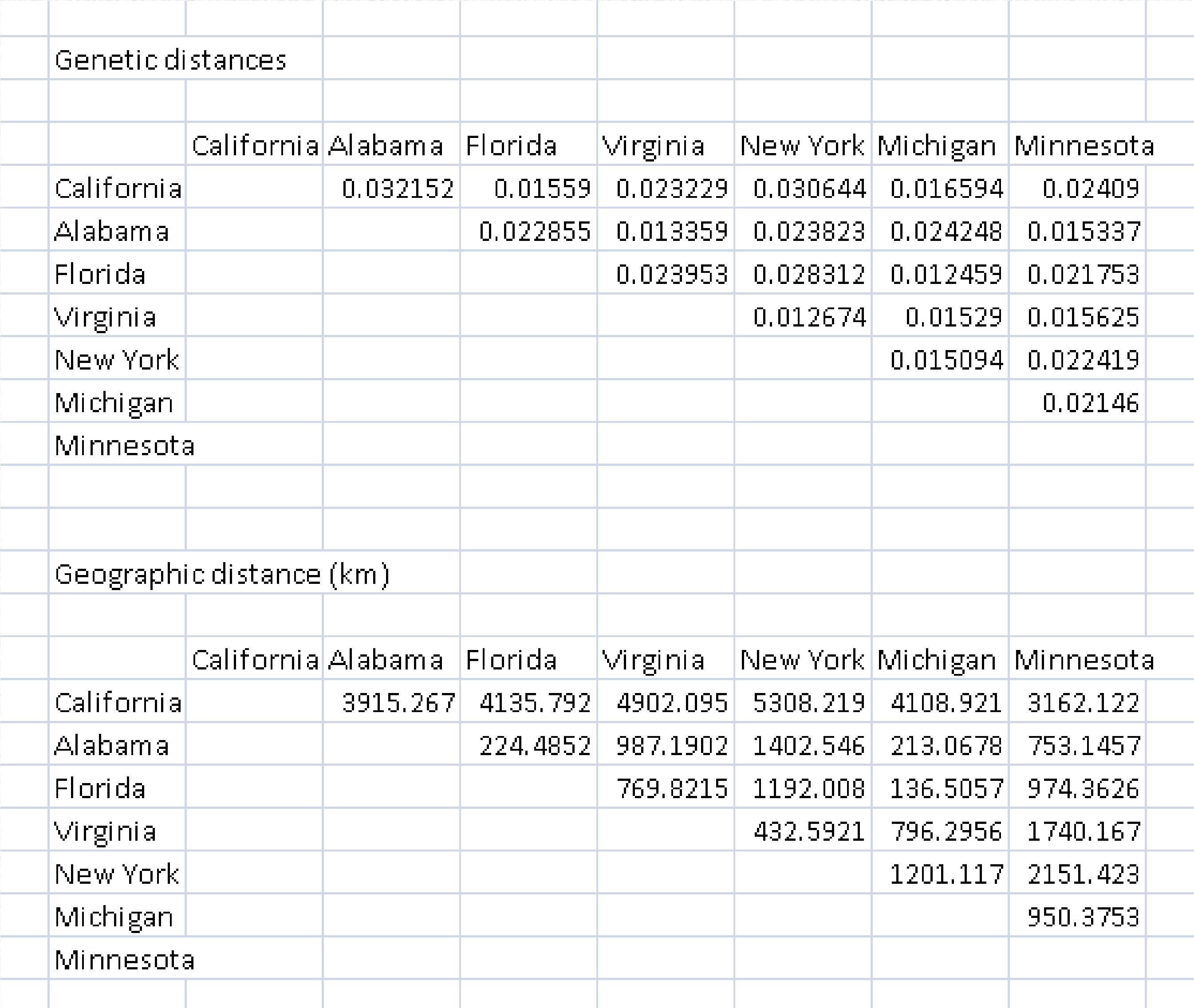
Locus	CA	AL	FL	VA	NY	MI	MN
D3S1358	0.2800	0.2300	0.2736	0.2437	0.2943	0.2844	0.2833
VWA	0.2333	0.2133	0.2093	0.2284	0.2270	0.2188	0.2300
FGA	0.1500	0.1367	0.1592	0.1472	0.1099	0.1656	0.1300
D8S1179	0.3733	0.3133	0.3557	0.3112	0.3156	0.3469	0.3000
D21S11	0.1967	0.1867	0.2289	0.2117	0.2179	0.2500	0.1867
D18S51	0.1467	0.1567	0.1617	0.1556	0.1879	0.1625	0.1633
D5S818	0.3400	0.4167	0.3740	0.3858	0.3794	0.3600	0.3633
D13S317	0.3133	0.3200	0.3232	0.3173	0.3475	0.3576	0.2967
D7S820	0.2433	0.2967	0.2622	0.3147	0.3156	0.2848	0.2700
THO1	0.2200	0.1967	0.2378	0.2411	0.2113	0.2143	0.2467
TPOX	0.5267	0.5433	0.5488	0.5254	0.5458	0.5408	0.5600
CSF1PO	0.3005	0.3033	0.3679	0.2944	0.2993	0.3151	0.2933

Allele 2

Locus	CA	AL	FL	VA	NY	MI	MN
D3S1358	0.2167	0.2567	0.2338	0.2563	0.2563	0.2482	0.2375
VWA	0.2800	0.2800	0.2967	0.2792	0.2908	0.2844	0.2567
FGA	0.1767	0.1900	0.1642	0.1675	0.1738	0.1625	0.1667
D8S1179	0.3733	0.3133	0.3557	0.3112	0.3156	0.3469	0.3000
D21S11	0.2321	0.2733	0.2786	0.2143	0.2143	0.2156	0.2700
D18S51	0.1600	0.1100	0.1318	0.1480	0.1170	0.1188	0.1167
D5S818	0.3600	0.3667	0.3557	0.3350	0.2801	0.3433	0.3633
D13S317	0.2767	0.2667	0.2541	0.2766	0.2766	0.2881	0.3067
D7S820	0.2233	0.1500	0.2093	0.1777	0.1986	0.1987	0.1833
THO1	0.3233	0.3067	0.2947	0.2944	0.3063	0.2789	0.2900
TPOX	0.5267	0.5433	0.5488	0.5254	0.5458	0.5408	0.5600
CSF1PO	0.3251	0.3200	0.3069	0.3477	0.3345	0.2979	0.3200

Genetic distances

	California	Alabama	Florida	Virginia	New York	Michigan	Minnesota
California		0.032152	0.01559	0.023229	0.030644	0.016594	0.02409
Alabama			0.022855	0.013359	0.023823	0.024248	0.015337
Florida				0.023953	0.028312	0.012459	0.021753
Virginia					0.012674	0.01529	0.015625
New York						0.015094	0.022419
Michigan							0.02146
Minnesota							



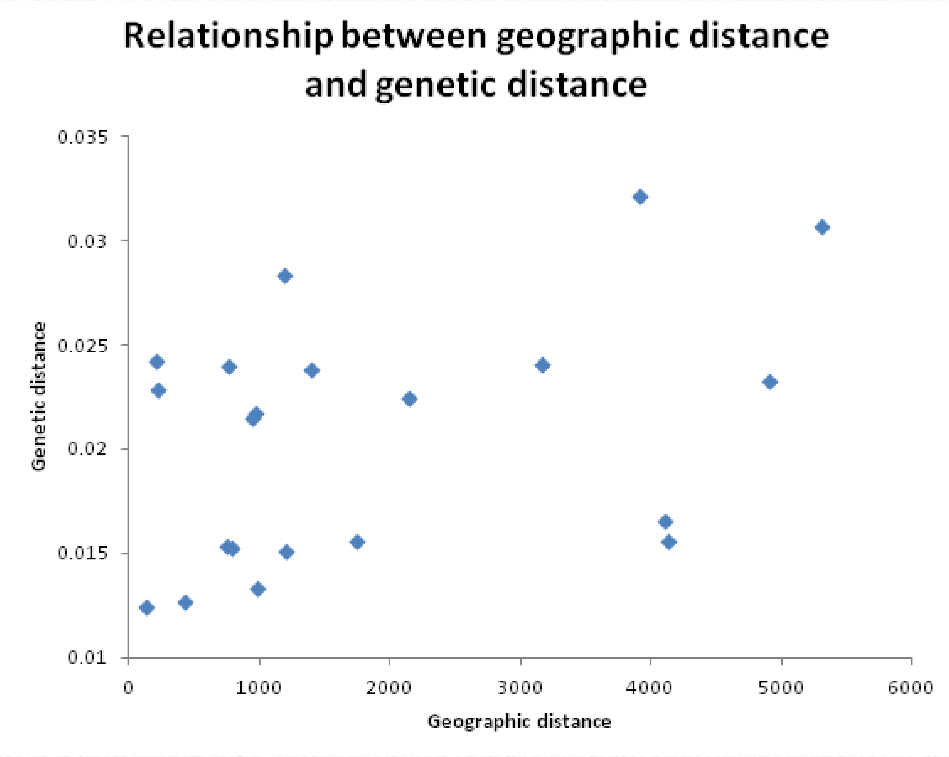
Genetic distances

	California	Alabama	Florida	Virginia	New York	Michigan	Minnesota
California		0.032152	0.01559	0.023229	0.030644	0.016594	0.02409
Alabama			0.022855	0.013359	0.023823	0.024248	0.015337
Florida				0.023953	0.028312	0.012459	0.021753
Virginia					0.012674	0.01529	0.015625
New York						0.015094	0.022419
Michigan							0.02146
Minnesota							

Geographic distance (km)

	California	Alabama	Florida	Virginia	New York	Michigan	Minnesota
California		3915.267	4135.792	4902.095	5308.219	4108.921	3162.122
Alabama			224.4852	987.1902	1402.546	213.0678	753.1457
Florida				769.8215	1192.008	136.5057	974.3626
Virginia					432.5921	796.2956	1740.167
New York						1201.117	2151.423
Michigan							950.3753
Minnesota							

The relationship we'll test



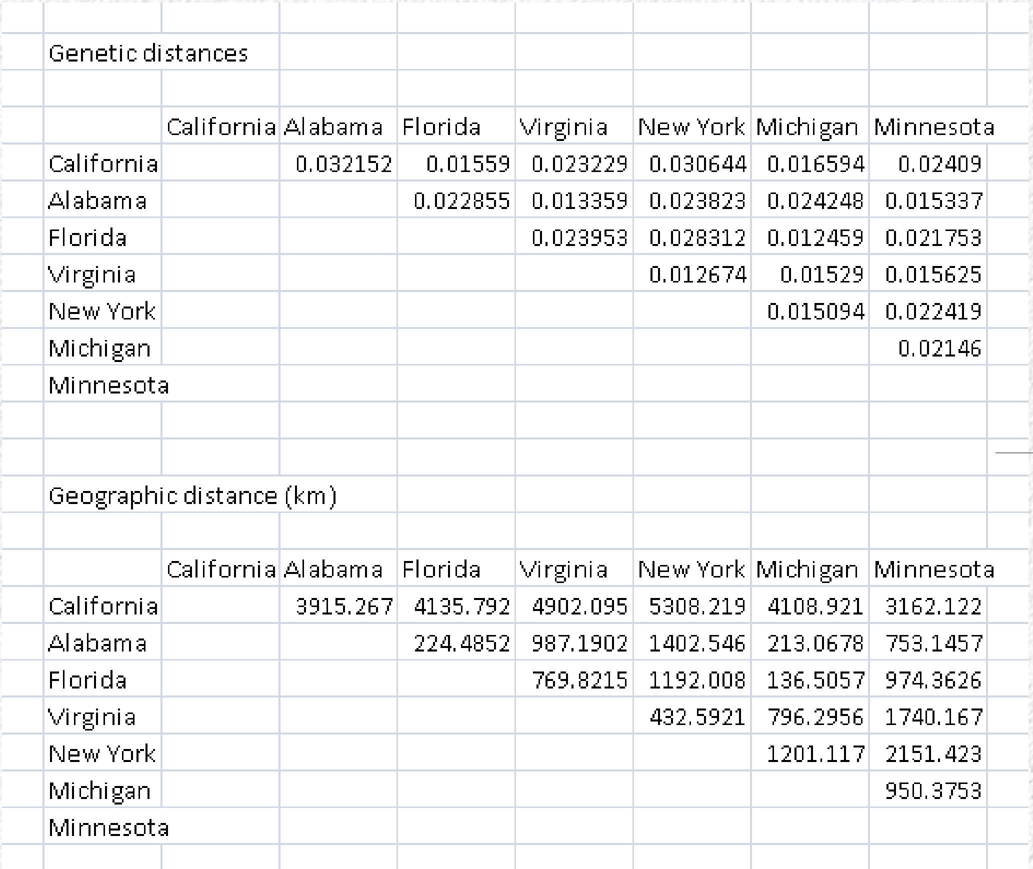
Correlation between these is 0.39

Does the genetic distance depend on geographic distance?

Why not just test the correlation?

- The measures aren't independent
- We have only 7 states, but we've generated 21 distances of each type
- Since parametric tests require independence, we can't use them
- But, a randomization test doesn't make this assumption, because any dependence will be accounted for when we randomly shuffle the data

Unfold the data



Genetic distances

	California	Alabama	Florida	Virginia	New York	Michigan	Minnesota
California		0.032152	0.01559	0.023229	0.030644	0.016594	0.02409
Alabama			0.022855	0.013359	0.023823	0.024248	0.015337
Florida				0.023953	0.028312	0.012459	0.021753
Virginia					0.012674	0.01529	0.015625
New York						0.015094	0.022419
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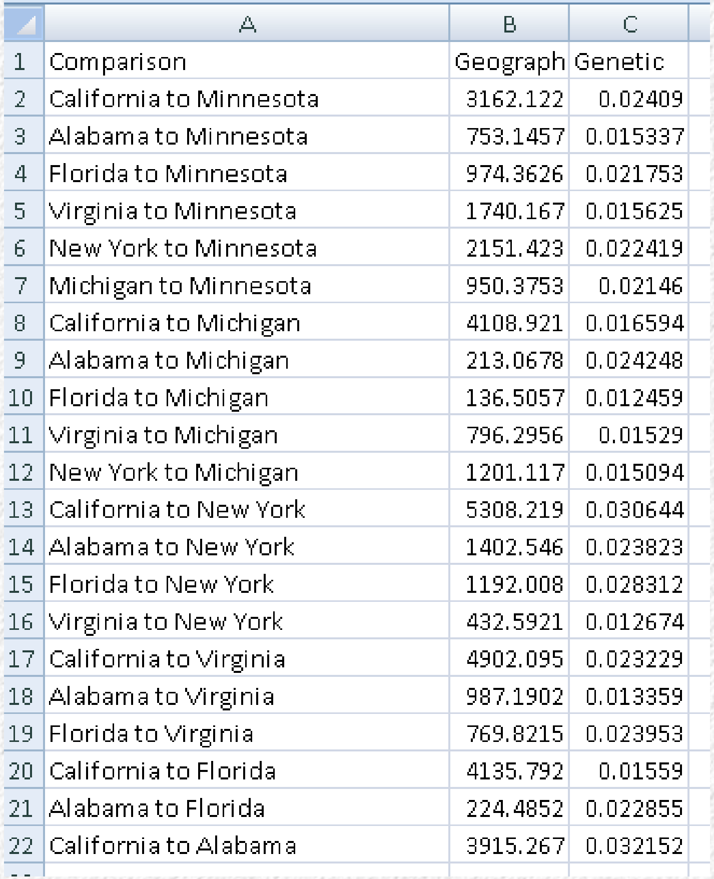
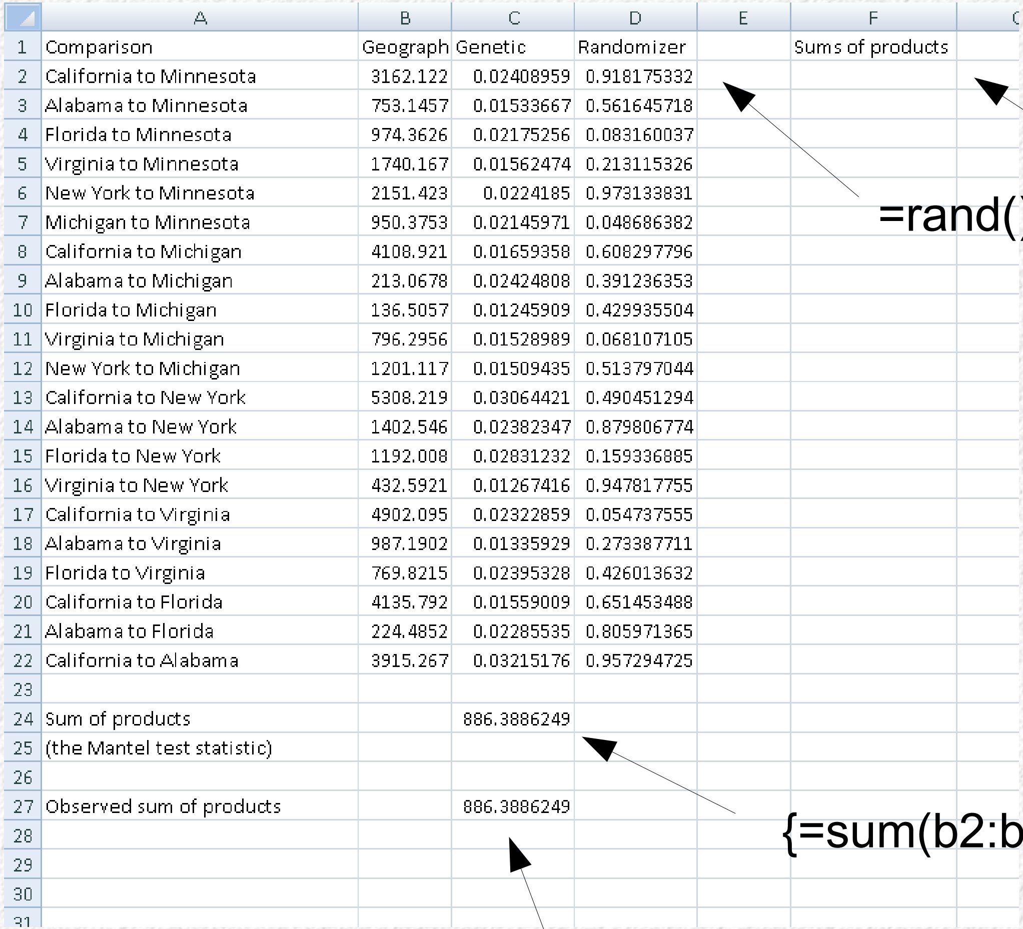


	A	B	C
1	Comparison	Geograph	Genetic
2	California to Minnesota	3162.122	0.02409
3	Alabama to Minnesota	753.1457	0.015337
4	Florida to Minnesota	974.3626	0.021753
5	Virginia to Minnesota	1740.167	0.015625
6	New York to Minnesota	2151.423	0.022419
7	Michigan to Minnesota	950.3753	0.02146
8	California to Michigan	4108.921	0.016594
9	Alabama to Michigan	213.0678	0.024248
10	Florida to Michigan	136.5057	0.012459
11	Virginia to Michigan	796.2956	0.01529
12	New York to Michigan	1201.117	0.015094
13	California to New York	5308.219	0.030644
14	Alabama to New York	1402.546	0.023823
15	Florida to New York	1192.008	0.028312
16	Virginia to New York	432.5921	0.012674
17	California to Virginia	4902.095	0.023229
18	Alabama to Virginia	987.1902	0.013359
19	Florida to Virginia	769.8215	0.023953
20	California to Florida	4135.792	0.01559
21	Alabama to Florida	224.4852	0.022855
22	California to Alabama	3915.267	0.032152

The logic of the test

- Assume no relationship
  - The correlation between them is just random sampling
  - If so, the amount of correlation should be typical of randomly generated data
- If true, randomly shuffled genetic and geographic distances will give correlations as big as observed
- Conversely, if the amount of association we see is big compared to what we see when we randomly shuffle the data, we can conclude the association is real

Set up the worksheet



	A	B	C	D	E	F
1	Comparison	Geograph	Genetic	Randomizer		Sums of products
2	California to Minnesota	3162.122	0.02408959	0.918175332		
3	Alabama to Minnesota	753.1457	0.01533667	0.561645718		
4	Florida to Minnesota	974.3626	0.02175256	0.083160037		
5	Virginia to Minnesota	1740.167	0.01562474	0.213115326		
6	New York to Minnesota	2151.423	0.0224185	0.973133831		
7	Michigan to Minnesota	950.3753	0.02145971	0.048686382		
8	California to Michigan	4108.921	0.01659358	0.608297796		
9	Alabama to Michigan	213.0678	0.02424808	0.391236353		
10	Florida to Michigan	136.5057	0.01245909	0.429935504		
11	Virginia to Michigan	796.2956	0.01528989	0.068107105		
12	New York to Michigan	1201.117	0.01509435	0.513797044		
13	California to New York	5308.219	0.03064421	0.490451294		
14	Alabama to New York	1402.546	0.02382347	0.879806774		
15	Florida to New York	1192.008	0.02831232	0.159336885		
16	Virginia to New York	432.5921	0.01267416	0.947817755		
17	California to Virginia	4902.095	0.02322859	0.054737555		
18	Alabama to Virginia	987.1902	0.01335929	0.273387711		
19	Florida to Virginia	769.8215	0.02395328	0.426013632		
20	California to Florida	4135.792	0.01559009	0.651453488		
21	Alabama to Florida	224.4852	0.02285535	0.805971365		
22	California to Alabama	3915.267	0.03215176	0.957294725		
23						
24	Sum of products		886.3886249			
25	(the Mantel test statistic)					
26						
27	Observed sum of products		886.3886249			
28						
29						
30						
31						

=rand()

Column for test statistic for random shuffles

{=sum(b2:b22,c2:c22)}

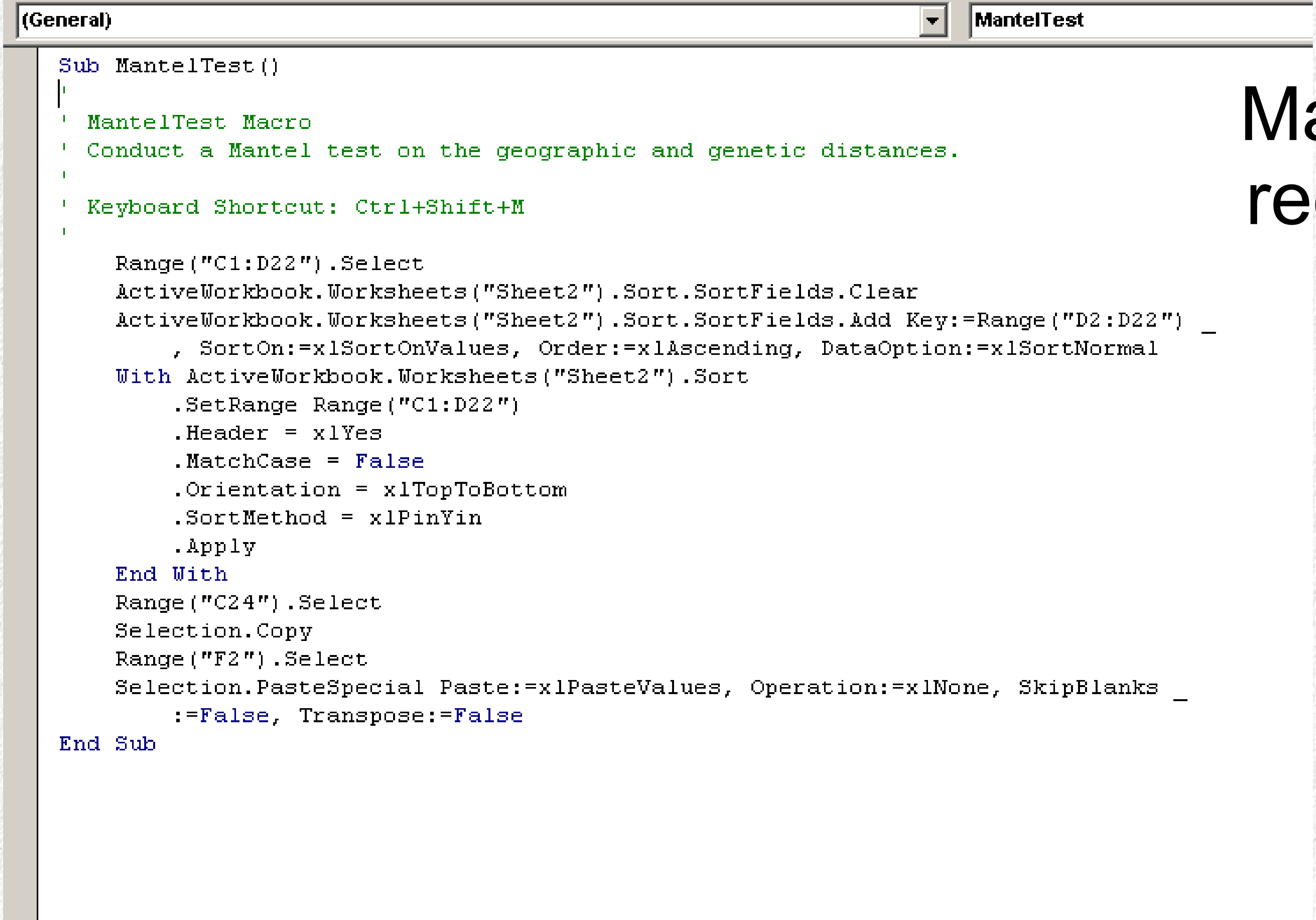
A copy of the observed test statistic

Use the macro recorder to:

Sort ***only the genetic distances*** by the Randomizer column

Copy the new test statistic and paste-special to column F

Macro as recorded



```
Sub MantelTest()
'
' MantelTest Macro
' Conduct a Mantel test on the geographic and genetic distances.
'
' Keyboard Shortcut: Ctrl+Shift+M
'
    Range("C1:D22").Select
    ActiveWorkbook.Worksheets("Sheet2").Sort.SortFields.Clear
    ActiveWorkbook.Worksheets("Sheet2").Sort.SortFields.Add Key:=Range("D2:D22") _
        , SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:=xlSortNormal
    With ActiveWorkbook.Worksheets("Sheet2").Sort
        .SetRange Range("C1:D22")
        .Header = xlYes
        .MatchCase = False
        .Orientation = xlTopToBottom
        .SortMethod = xlPinYin
        .Apply
    End With
    Range("C24").Select
    Selection.Copy
    Range("F2").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
End Sub
```

Today

- We will set up Excel to perform a randomization test
  - Set up the worksheet
  - Record the macro
- Automating the randomization will come next time...