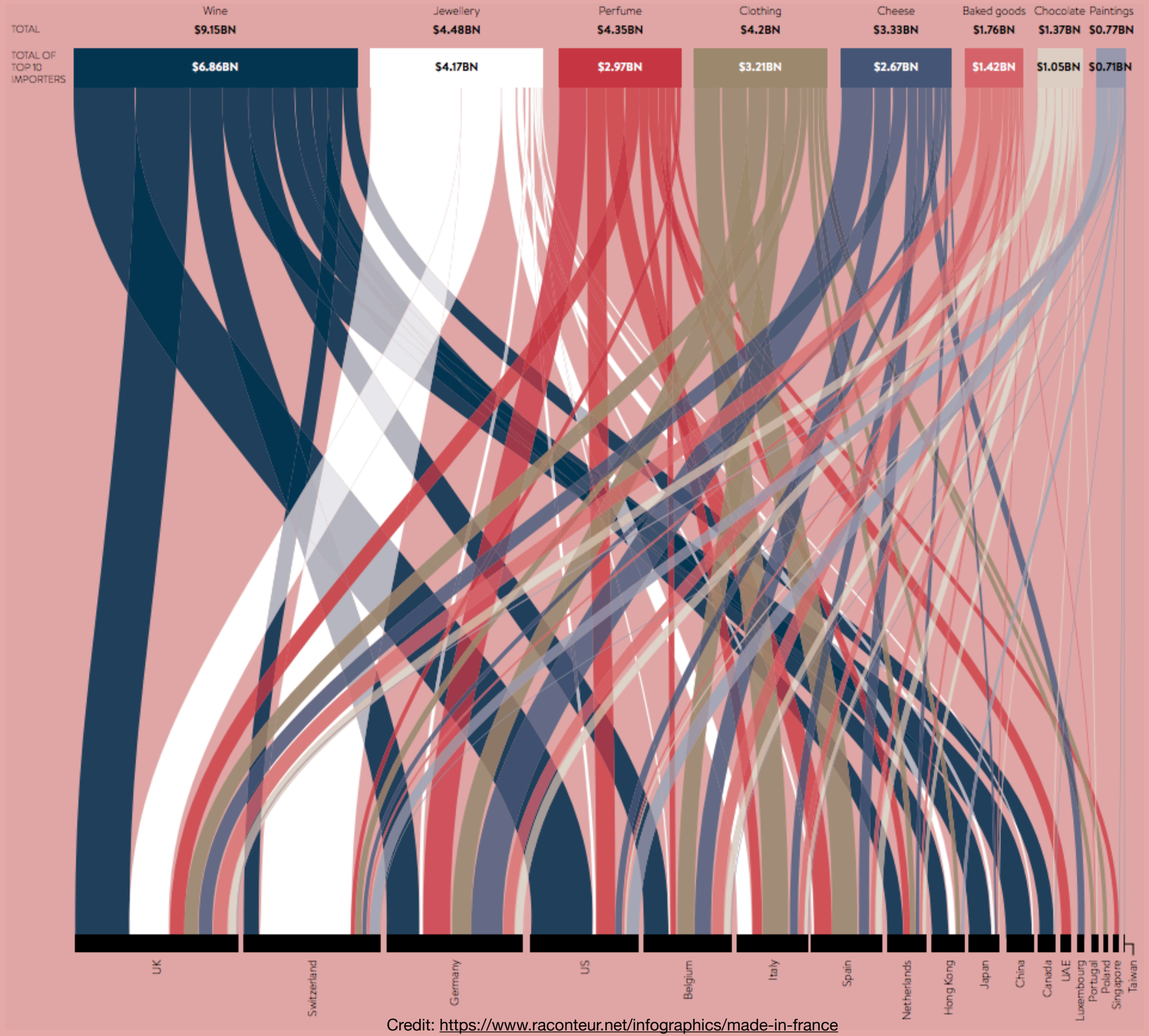
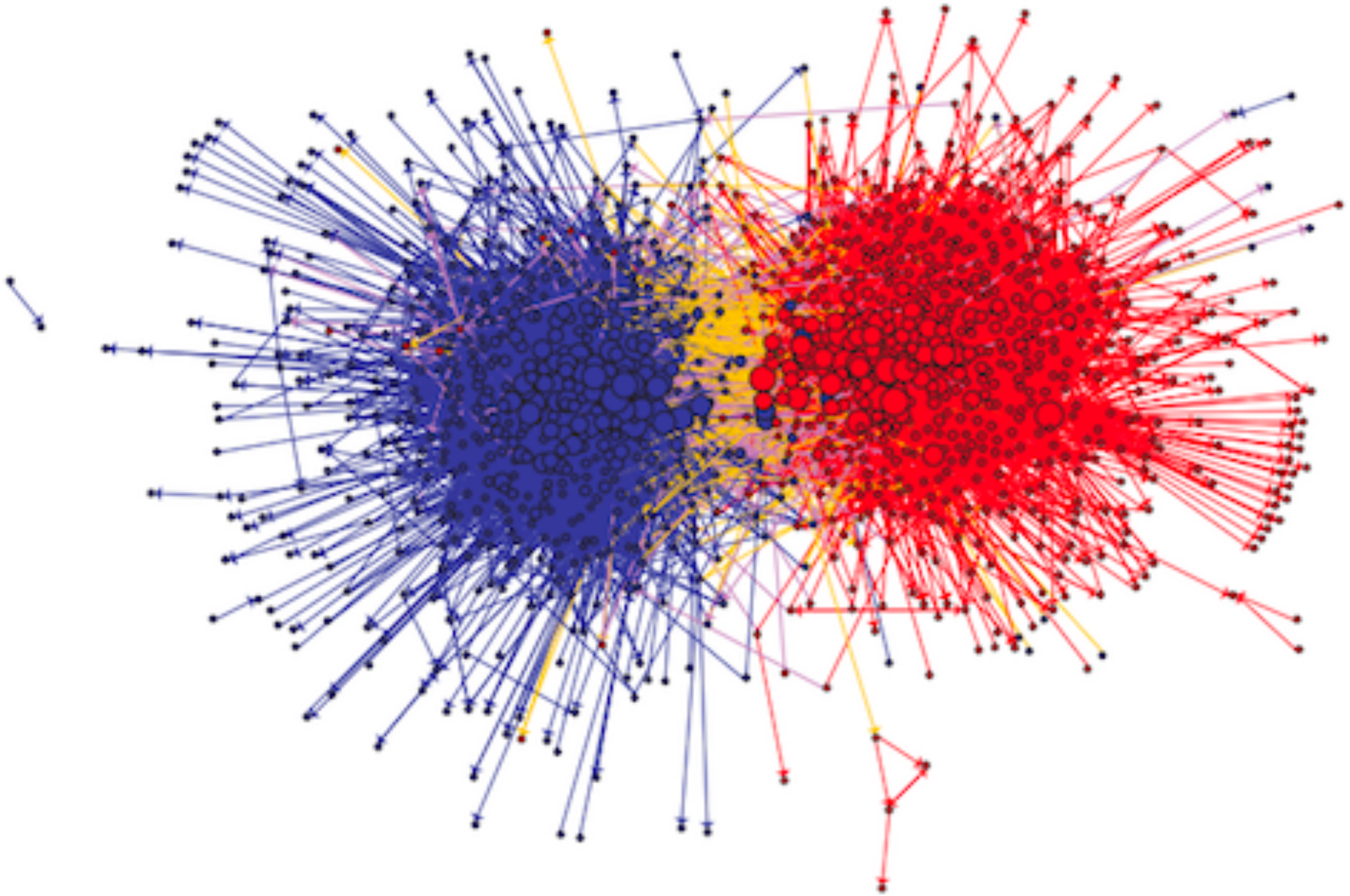



Credit: https://www.raconteur.net/infographics/made-in-france

# Graph / Network Visualizations

Jeff Rzeszotarski
Assistant Prof, InfoSci

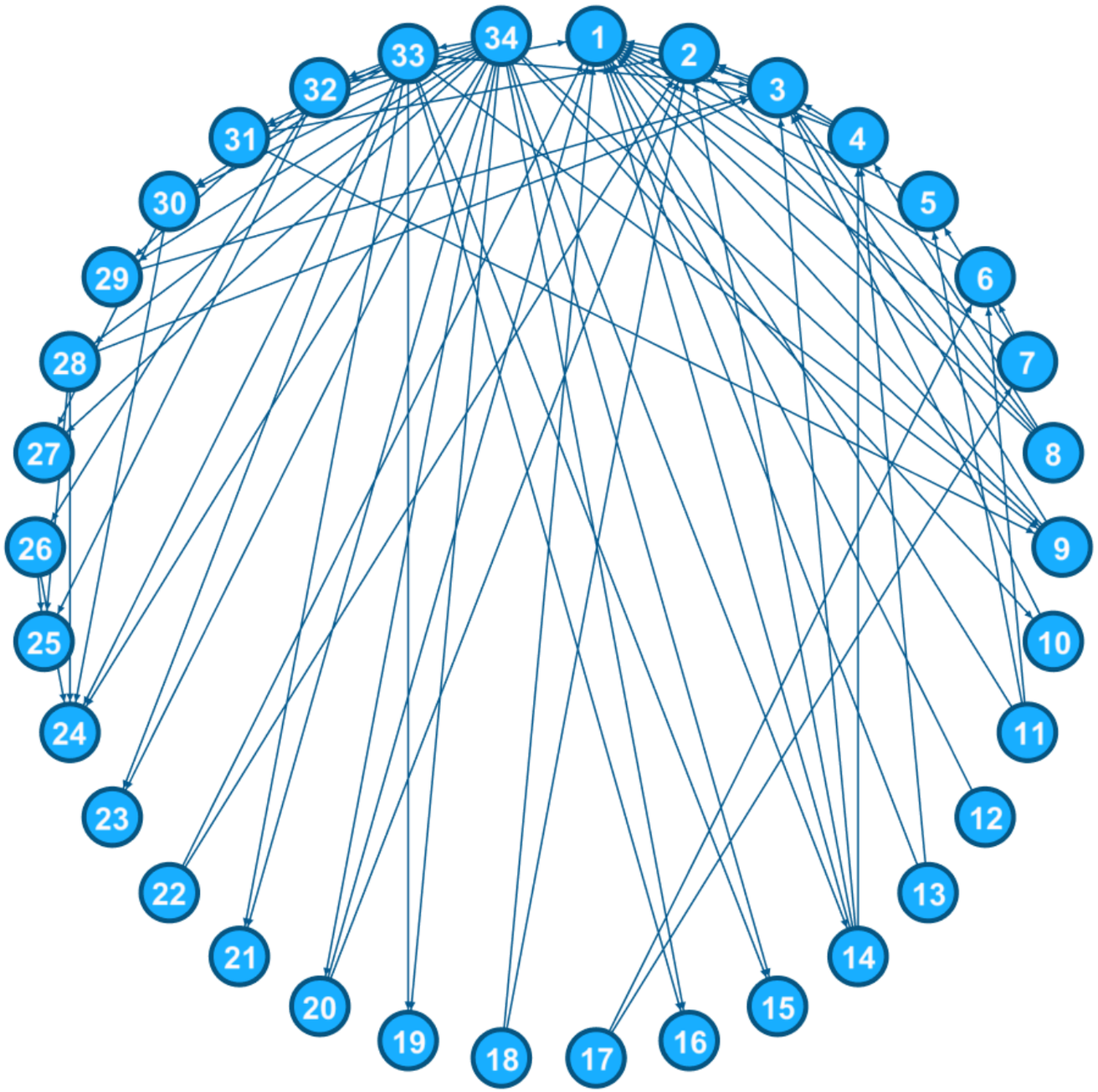


Adamic & Glance. 2005. The political blogosphere and the 2004 U.S. election: divided they blog

# Examples of graph data:

-

https://discord.gg/EREHnzkc




# “Zachary’s Karate Club”

2 yr longitudinal study

Nodes - club members

Edges - relationships outside of club

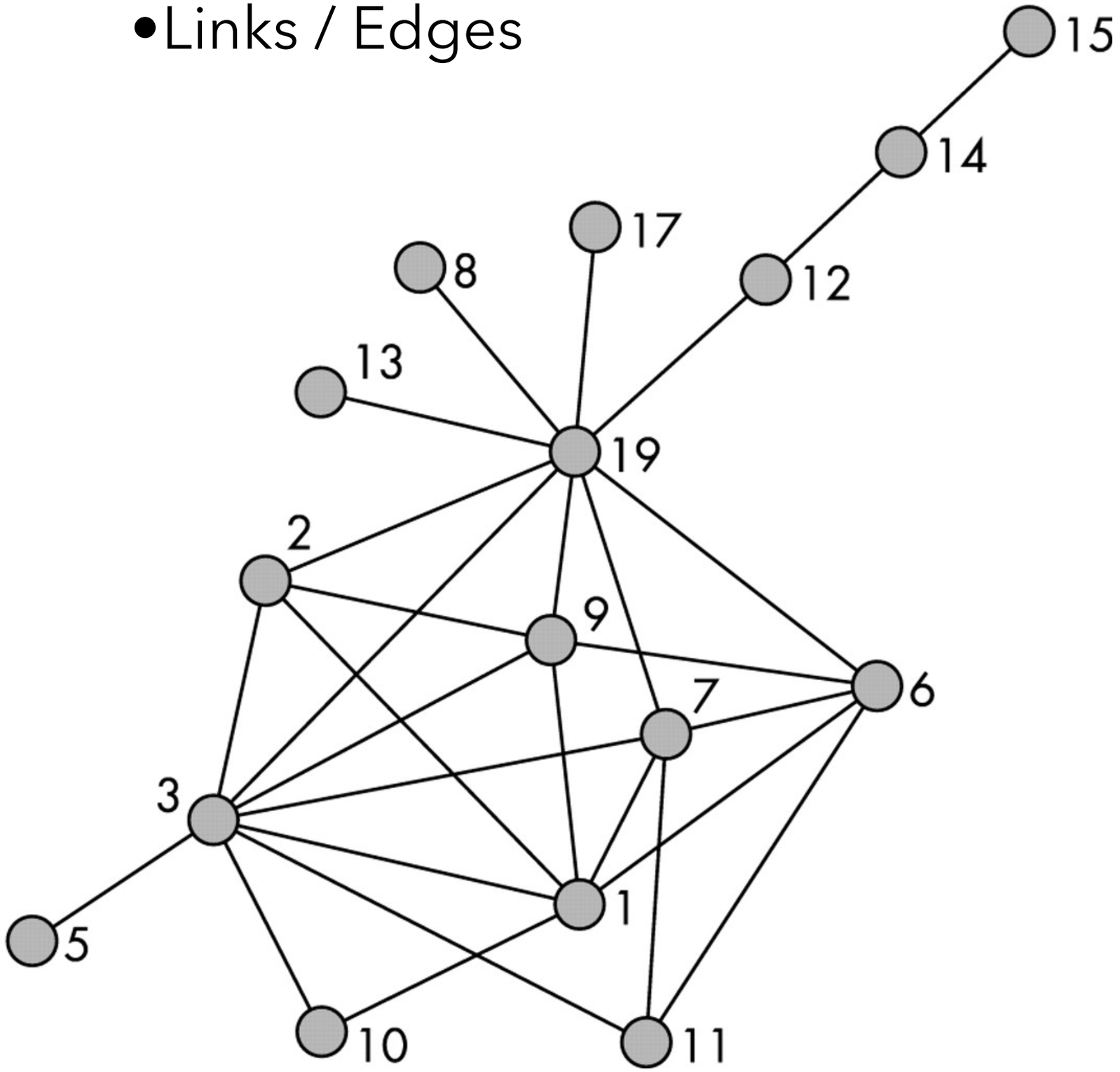
Split in group between “Mr. Hi” & “John”

4

16

18

- Nodes
- Links / Edges




http://jech.bmj.com/content/58/12/971

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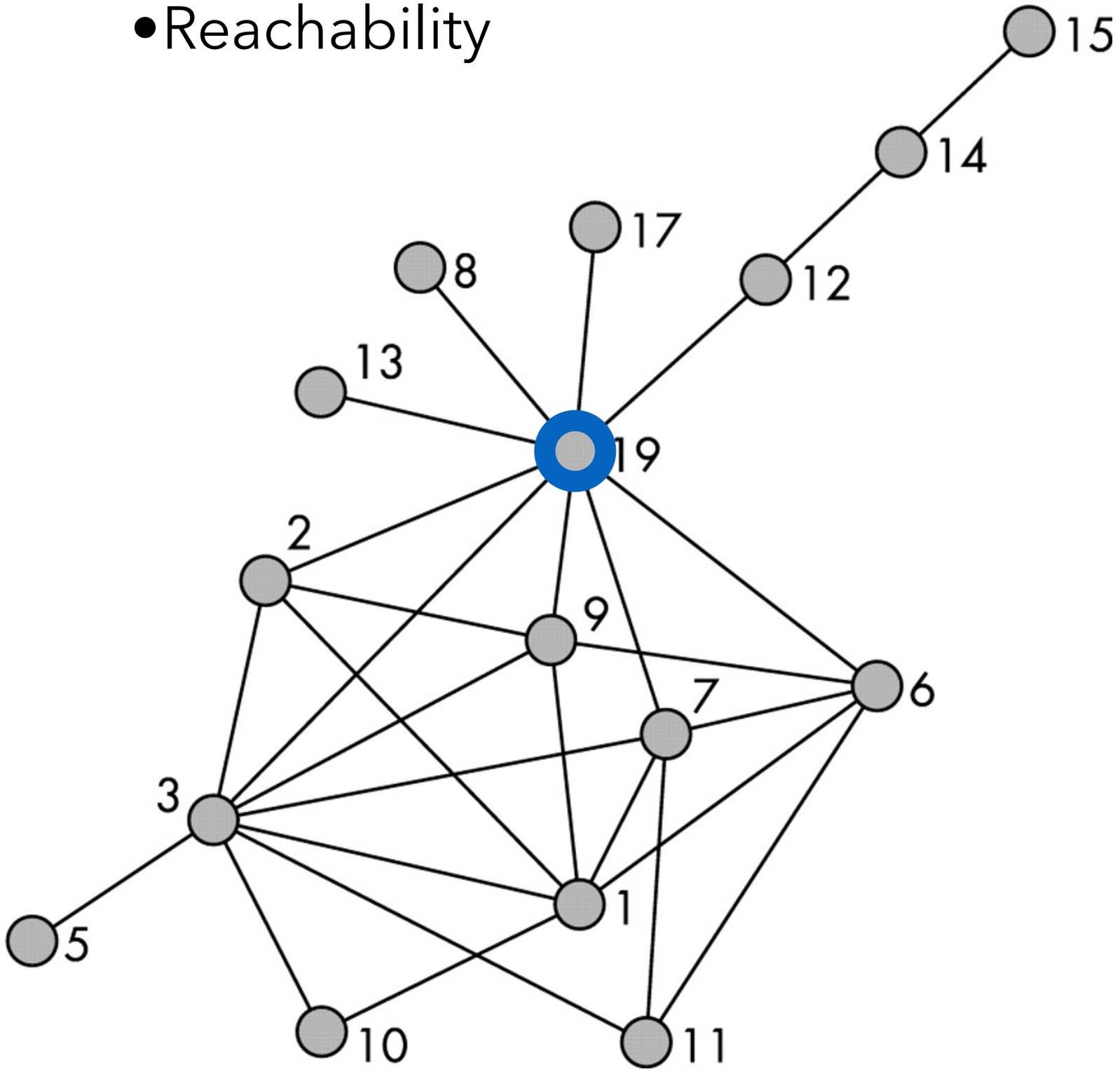
- Degree
- Reachability




http://jech.bmj.com/content/58/12/971

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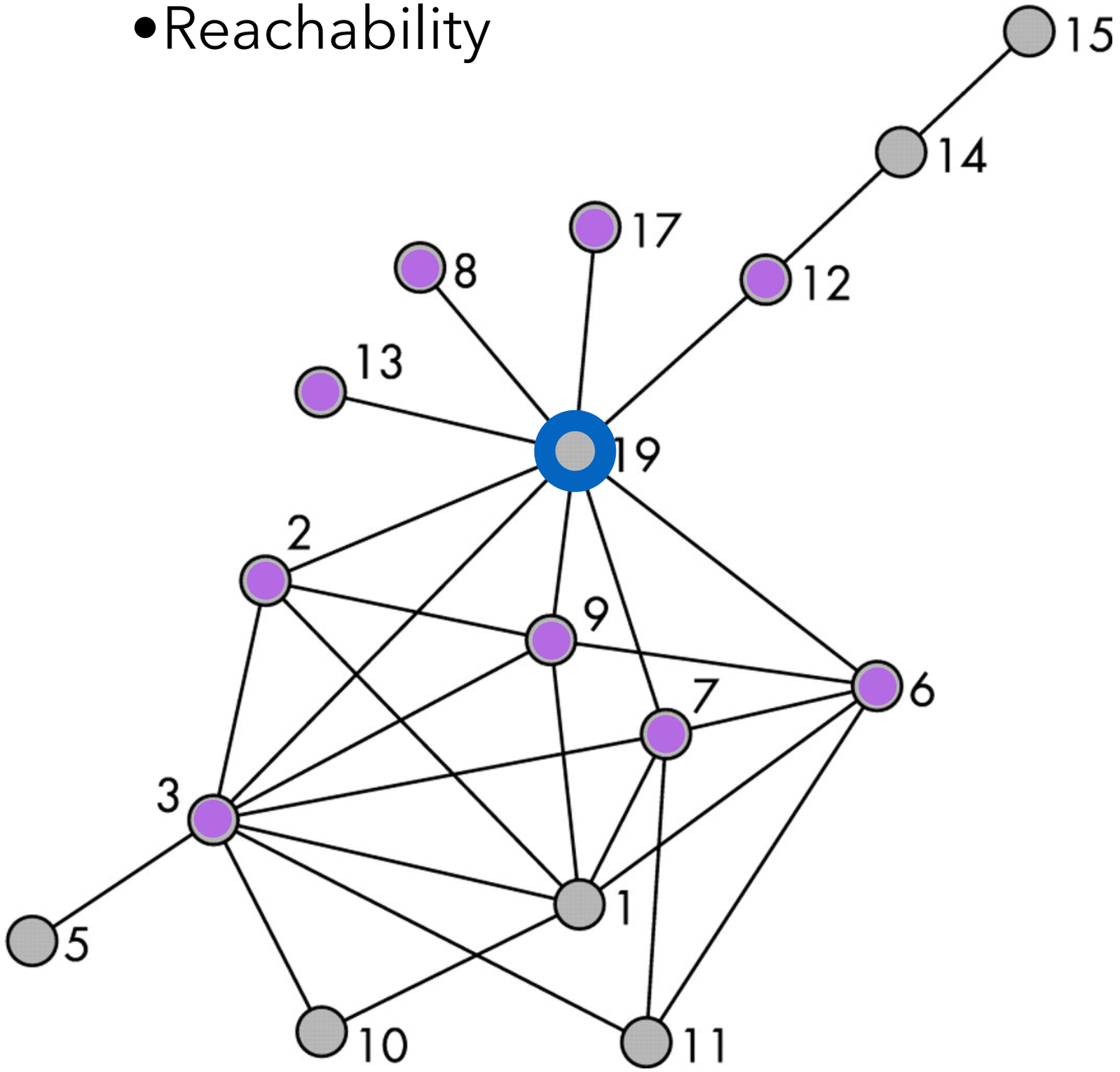
- Degree
- Reachability




http://jech.bmj.com/content/58/12/971

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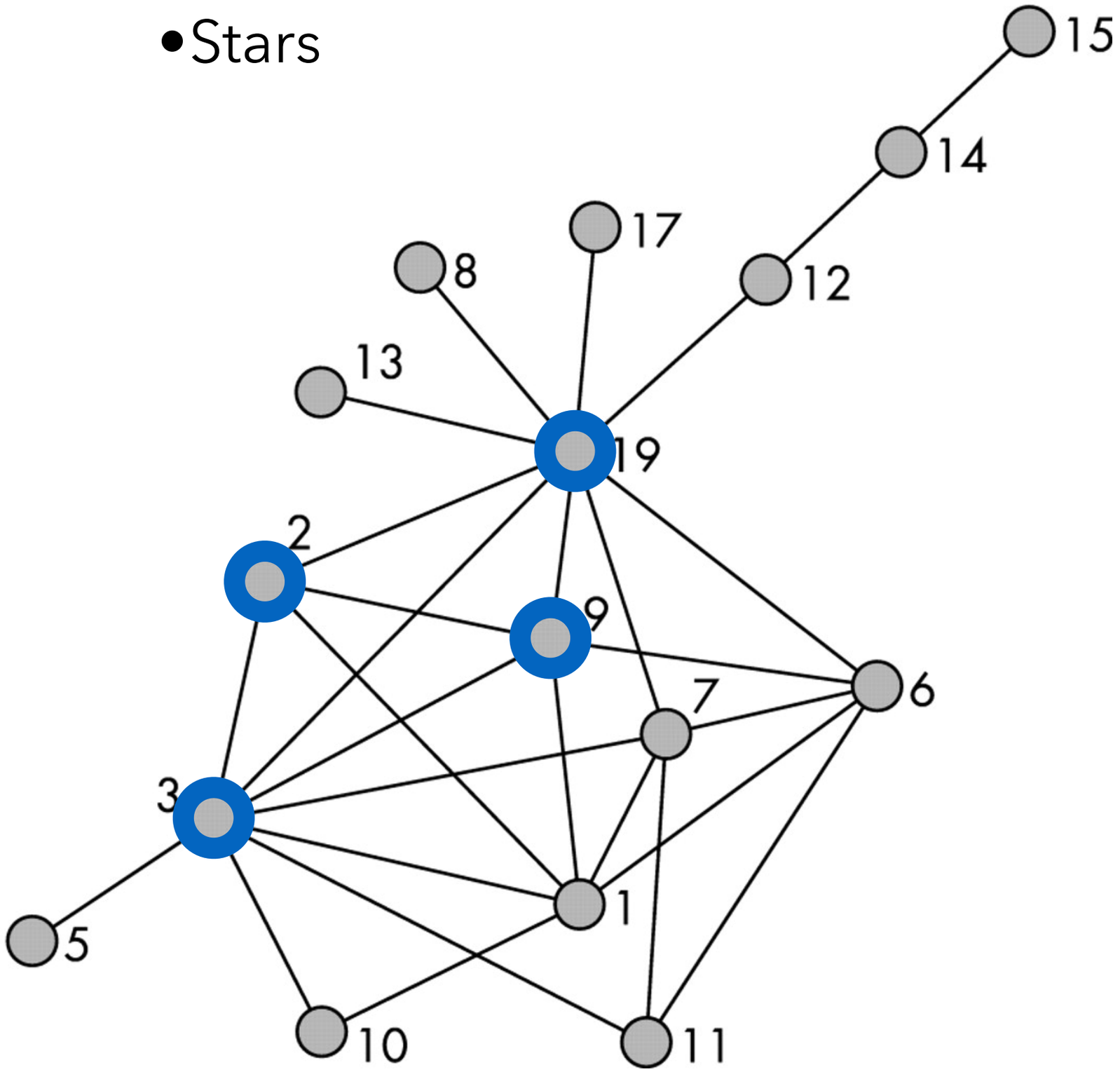
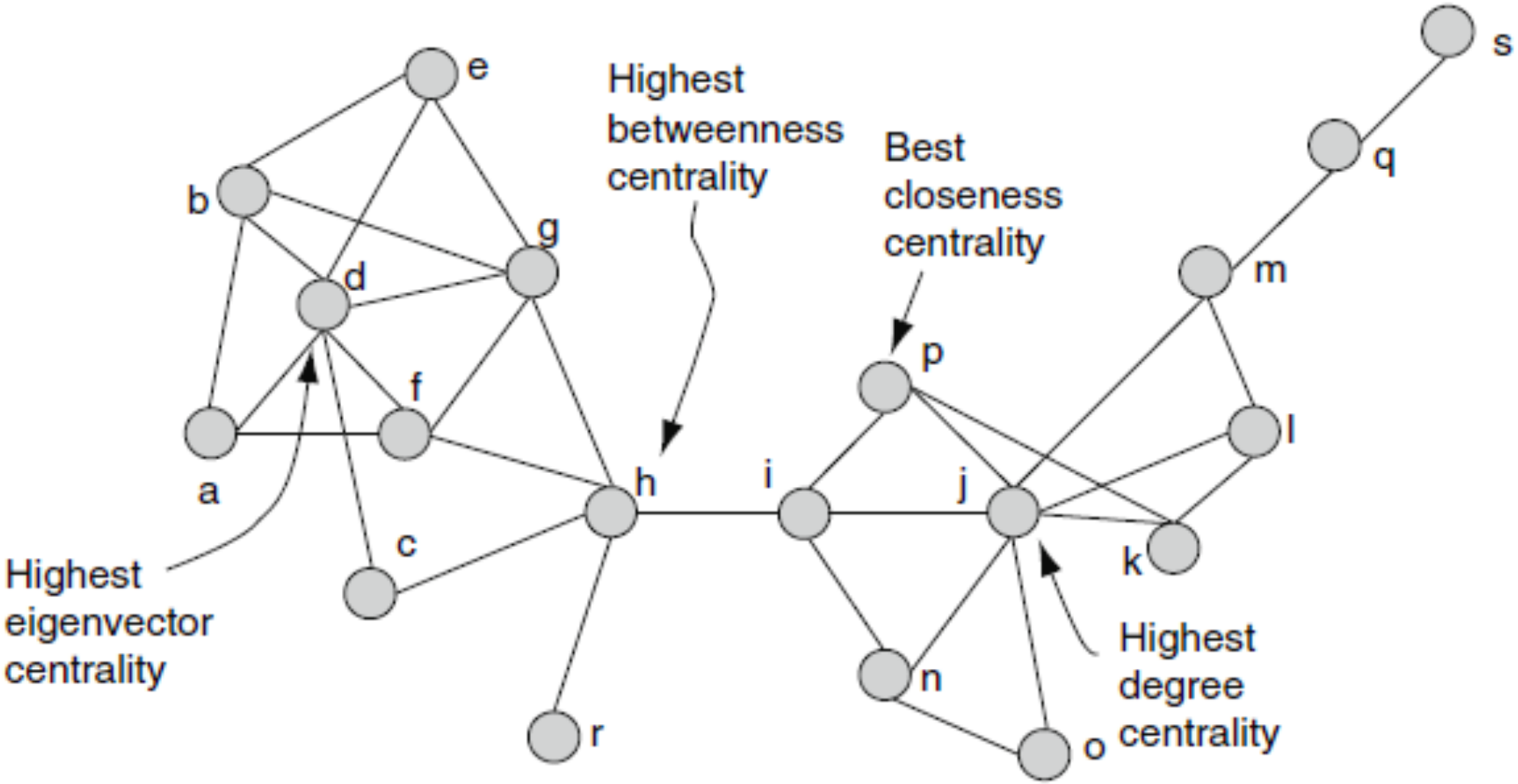
- Cliques
- Stars



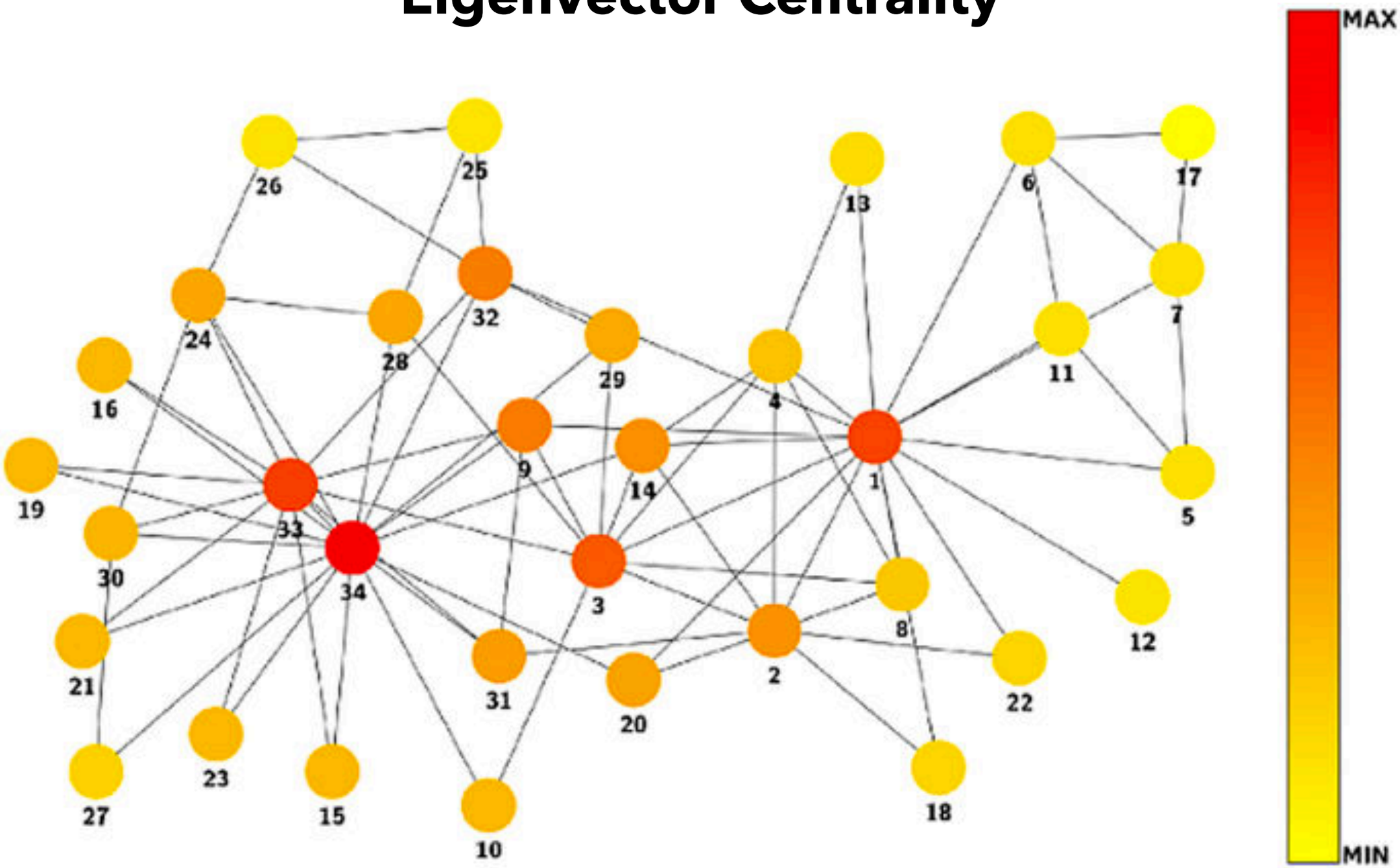

http://jech.bmj.com/content/58/12/971




(not the same dataset)

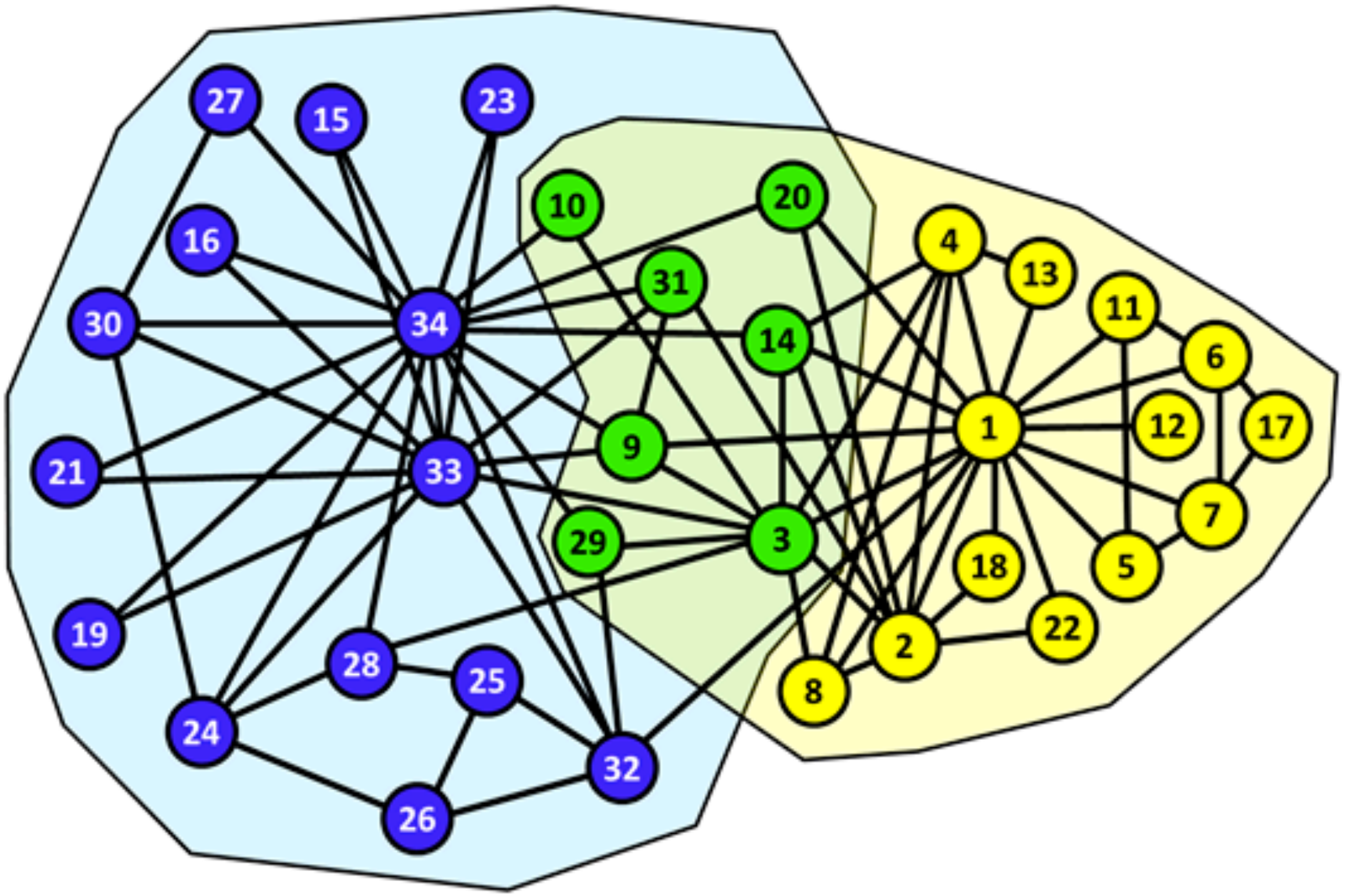
https://link.springer.com/chapter/10.1007/978-1-84882-229-0_2

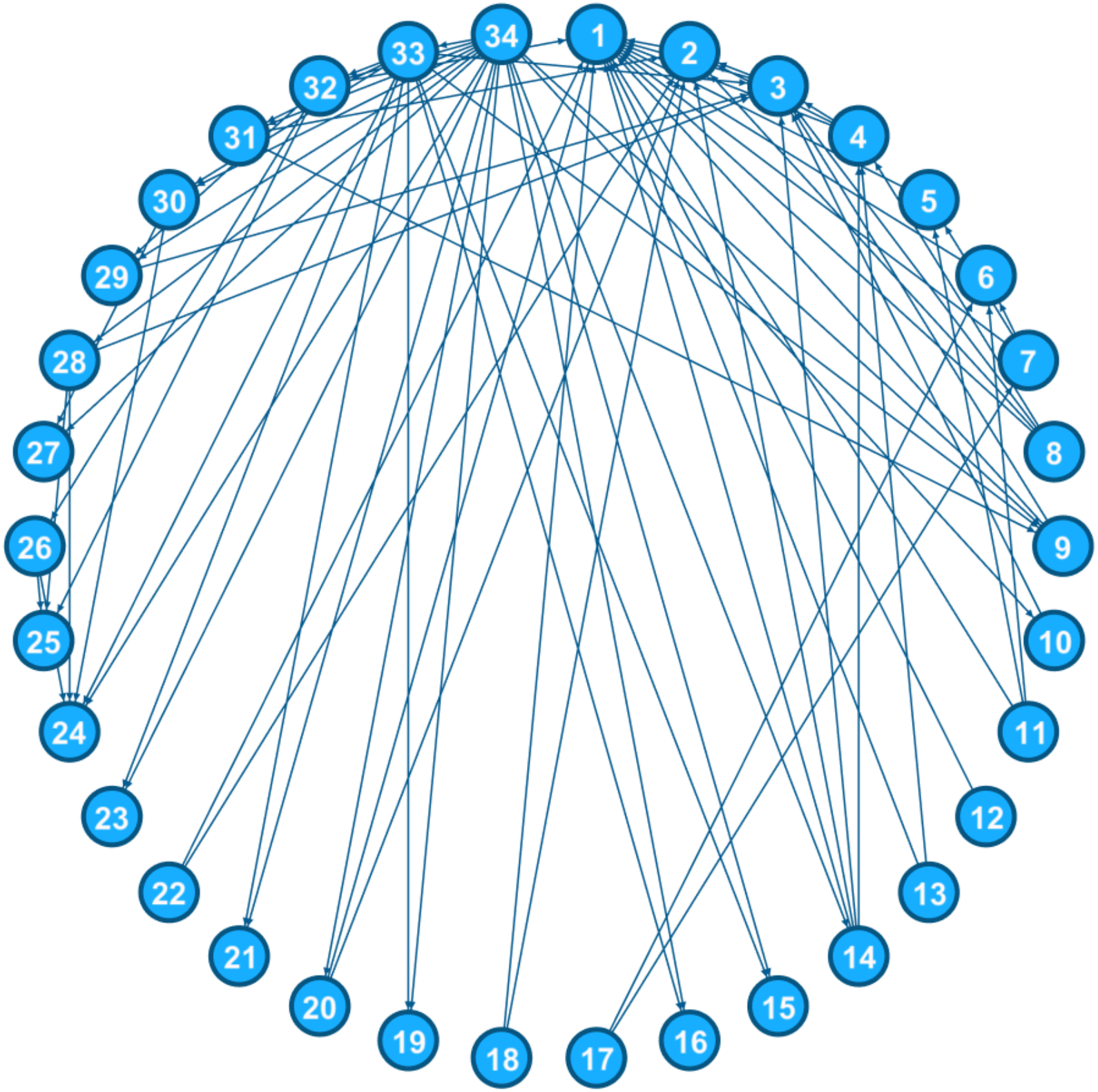
# Eigenvector Centrality




Which nodes are “John” and “Mr. Hi”?

# K-Means Clustering

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# Example structures / insights:

Leaders in a social group

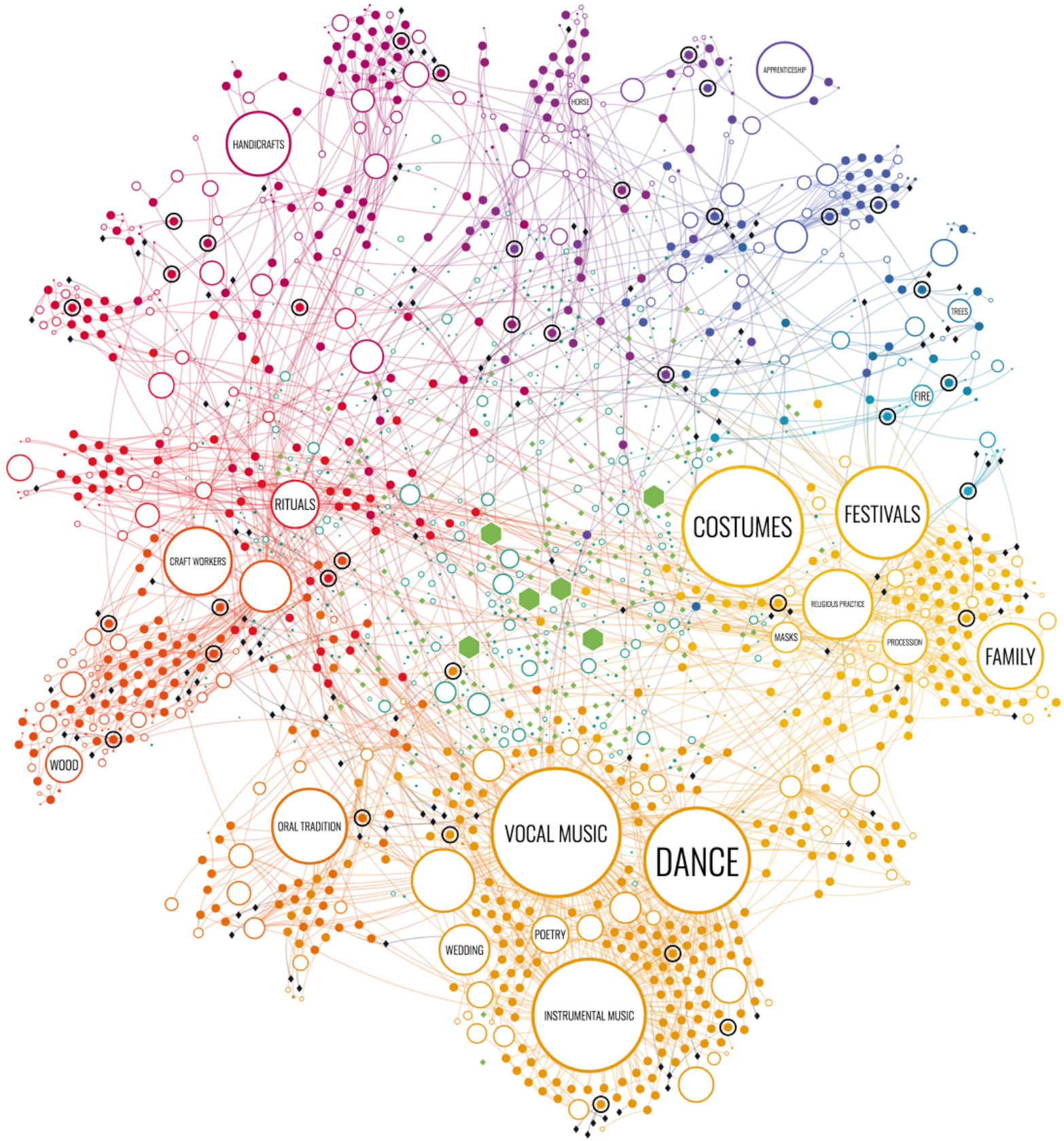
Partisan use of hashtags in Twitter discussion

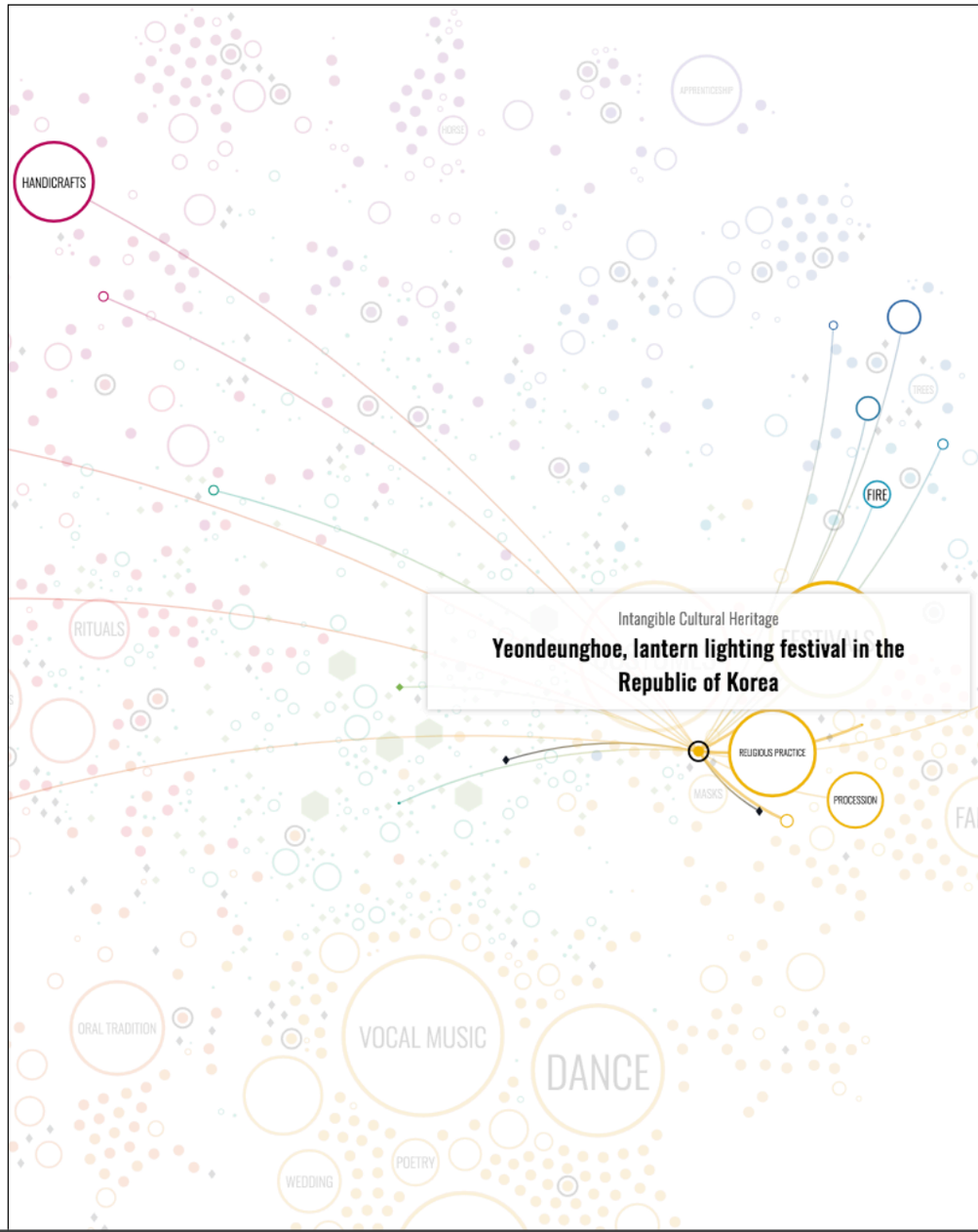
Relationship between Wikipedia articles by hyperlink

Lack of communication between business divisions

Most important road in a city for traffic management

Comparing friends with distant connections

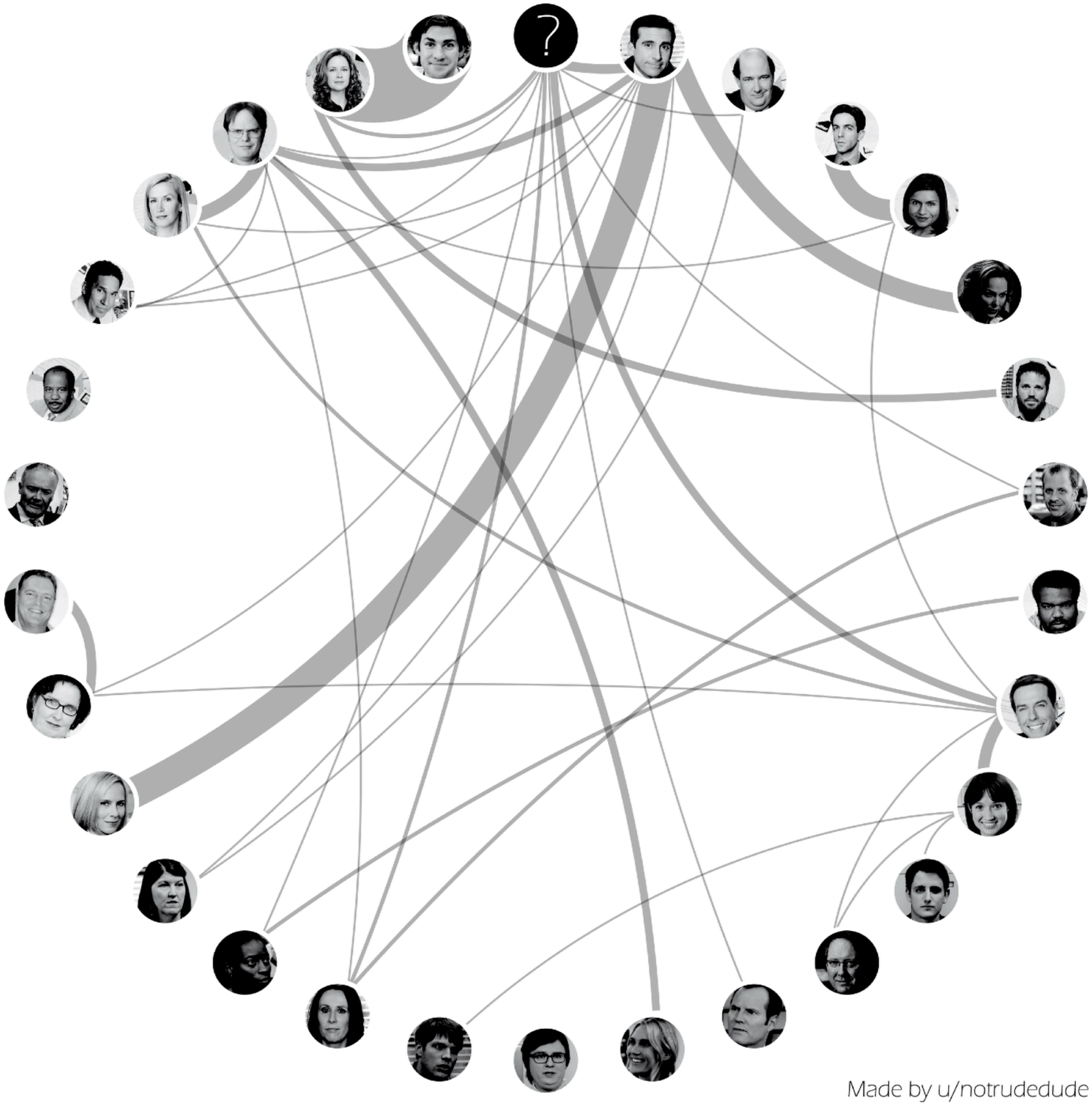



Credit: Nadieh Bremer https://www.visualcinnamon.com/portfolio/intangible-cultural-heritage/

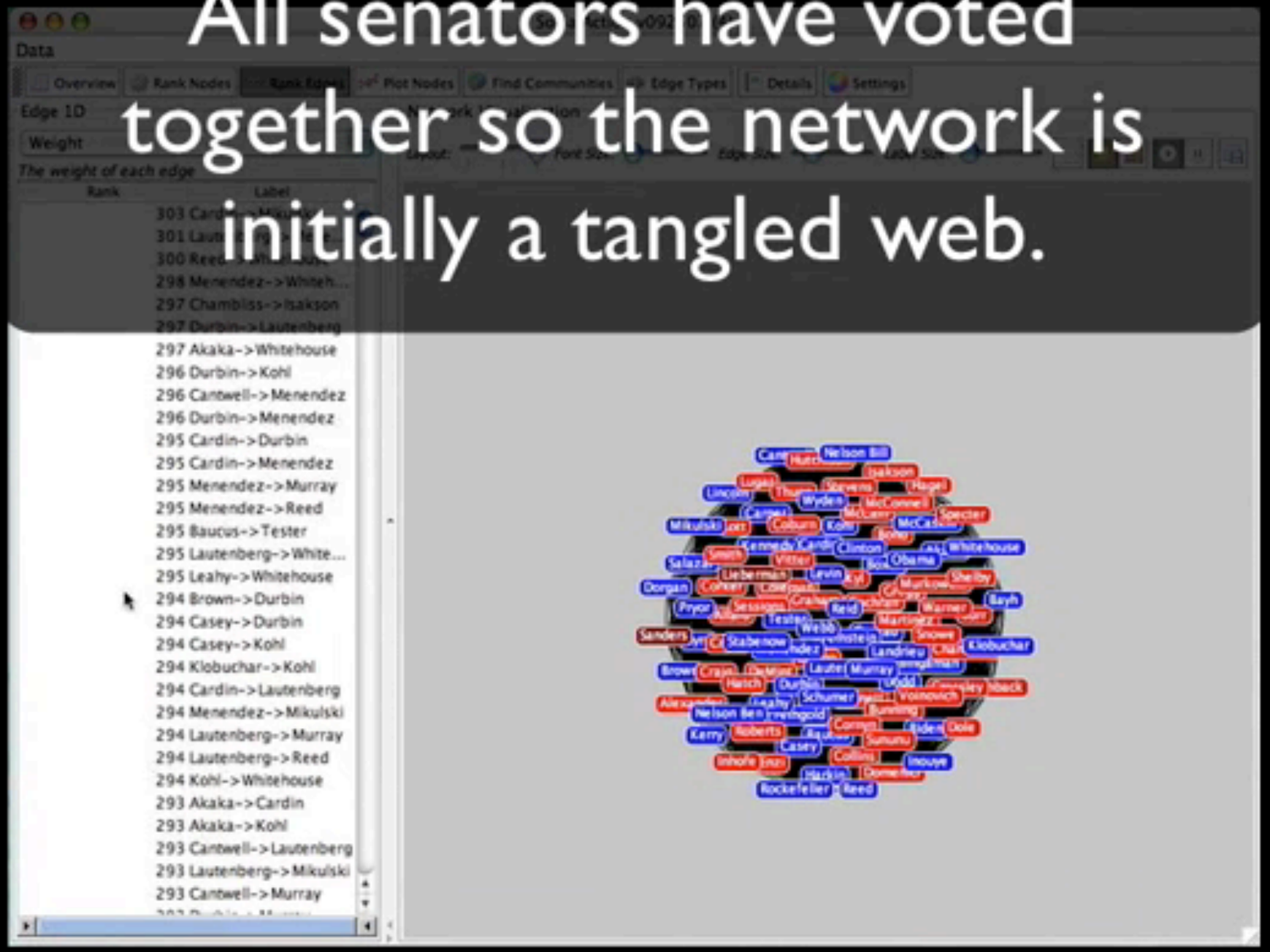
# Who kissed whom in the office






Made by u/notrudedude

# All senators have voted together so the network is initially a tangled web.




http://www.cs.umd.edu/hcil/socialaction/

# Graph visualizations depend on effective layouts (and interactions)

# Network Layout Algorithms

**Force-Directed** Optimization, unpredictable

**Spanning tree** Quick, good for SNS

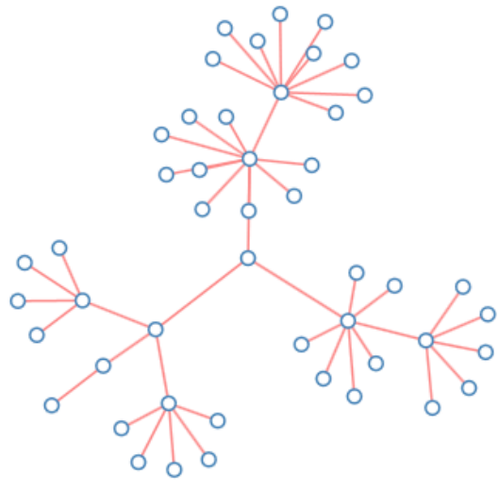
**Sugiyama** UML charts, pseudo-hierarchical

**Matrices** 2-d, quick, may be hard to interpret

**Radial** Circular, aggregated

**Pivot Graph & Edge Bundling**

research-based, reduce visual complexity



# Force-Directed Layout

**Optimization** - layout is an *energy model* with *constraints*

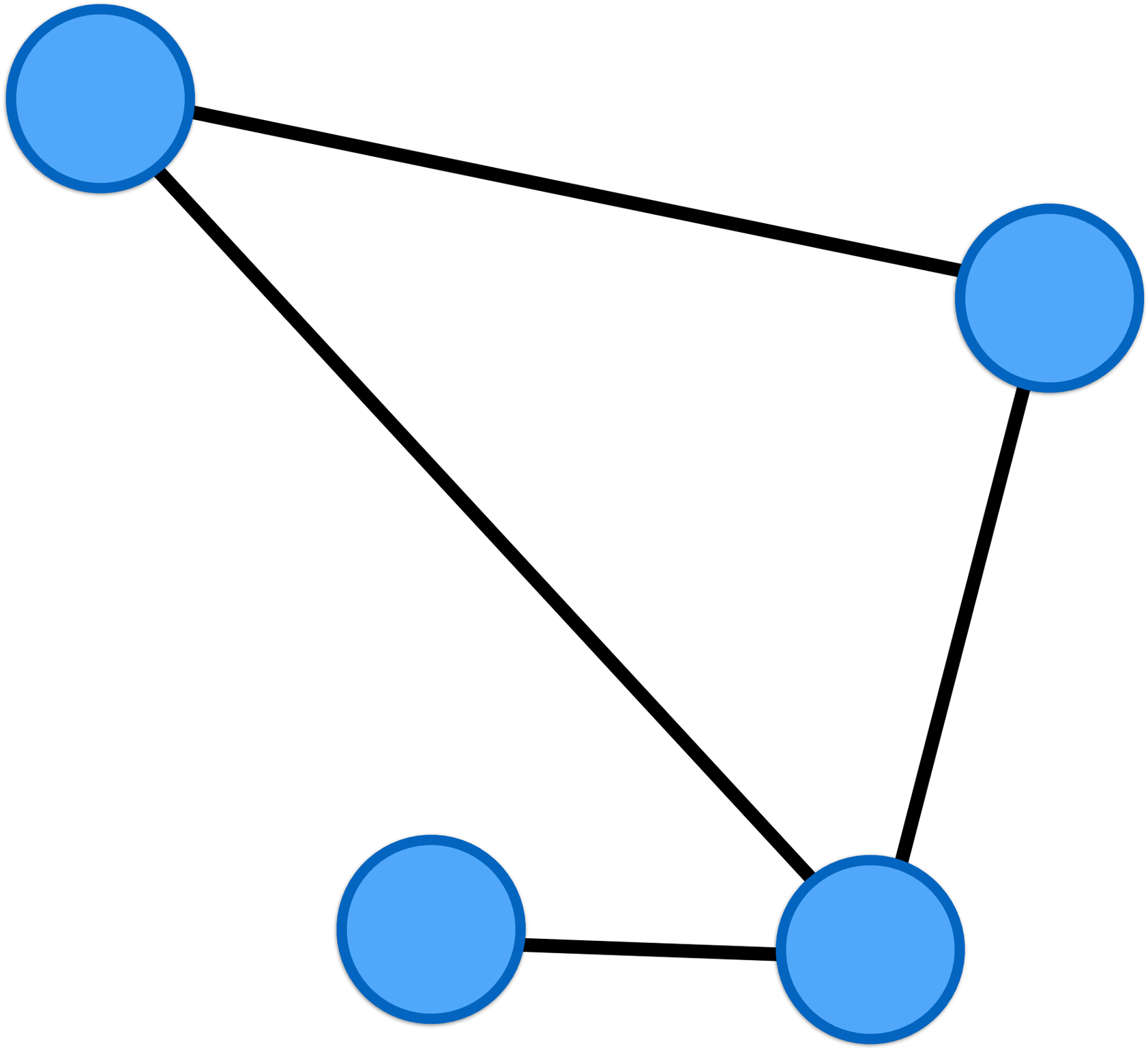
*low energy* - good layout, *constraints*

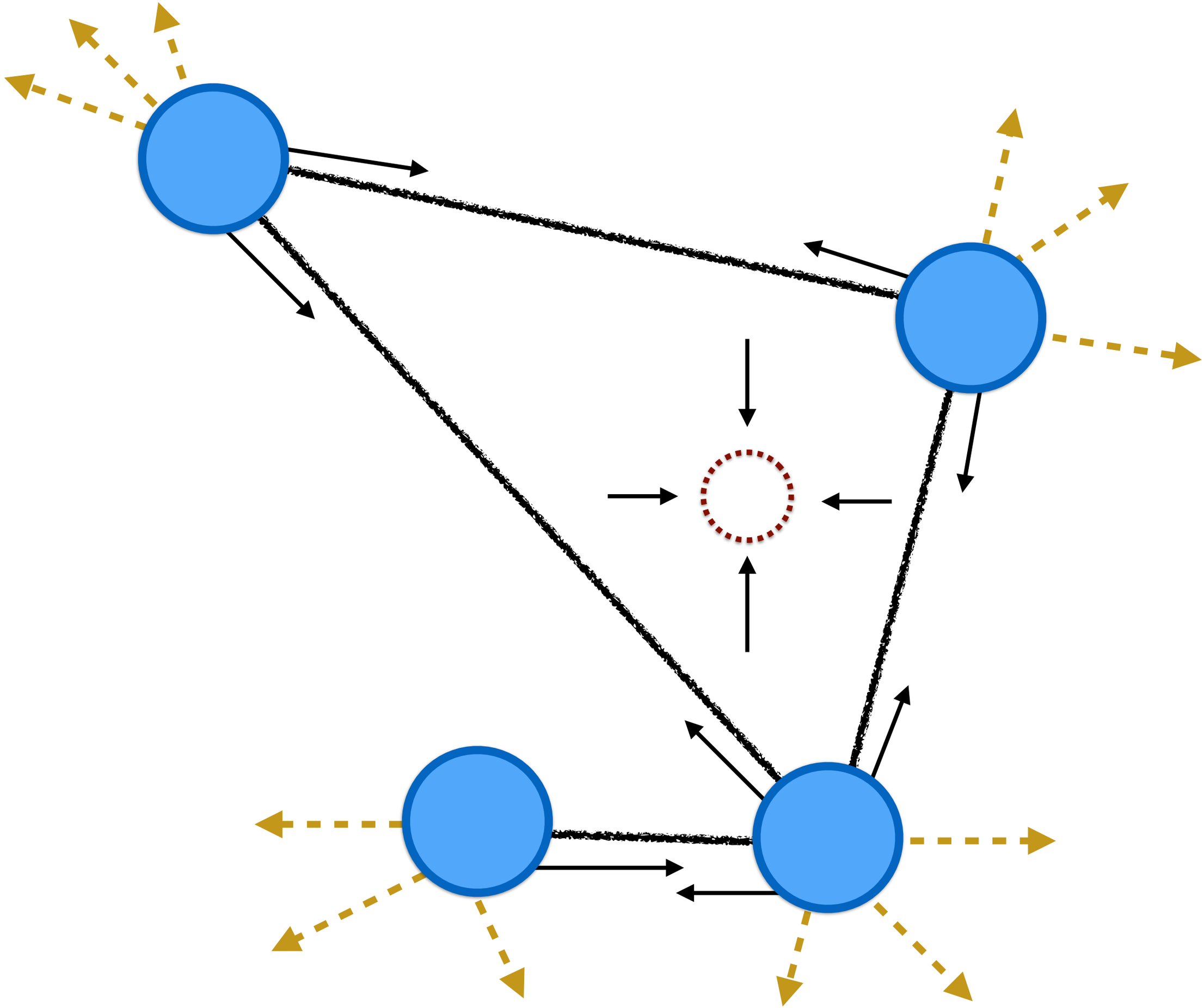
Treat layout like a physics system – gravity, springs, magnets

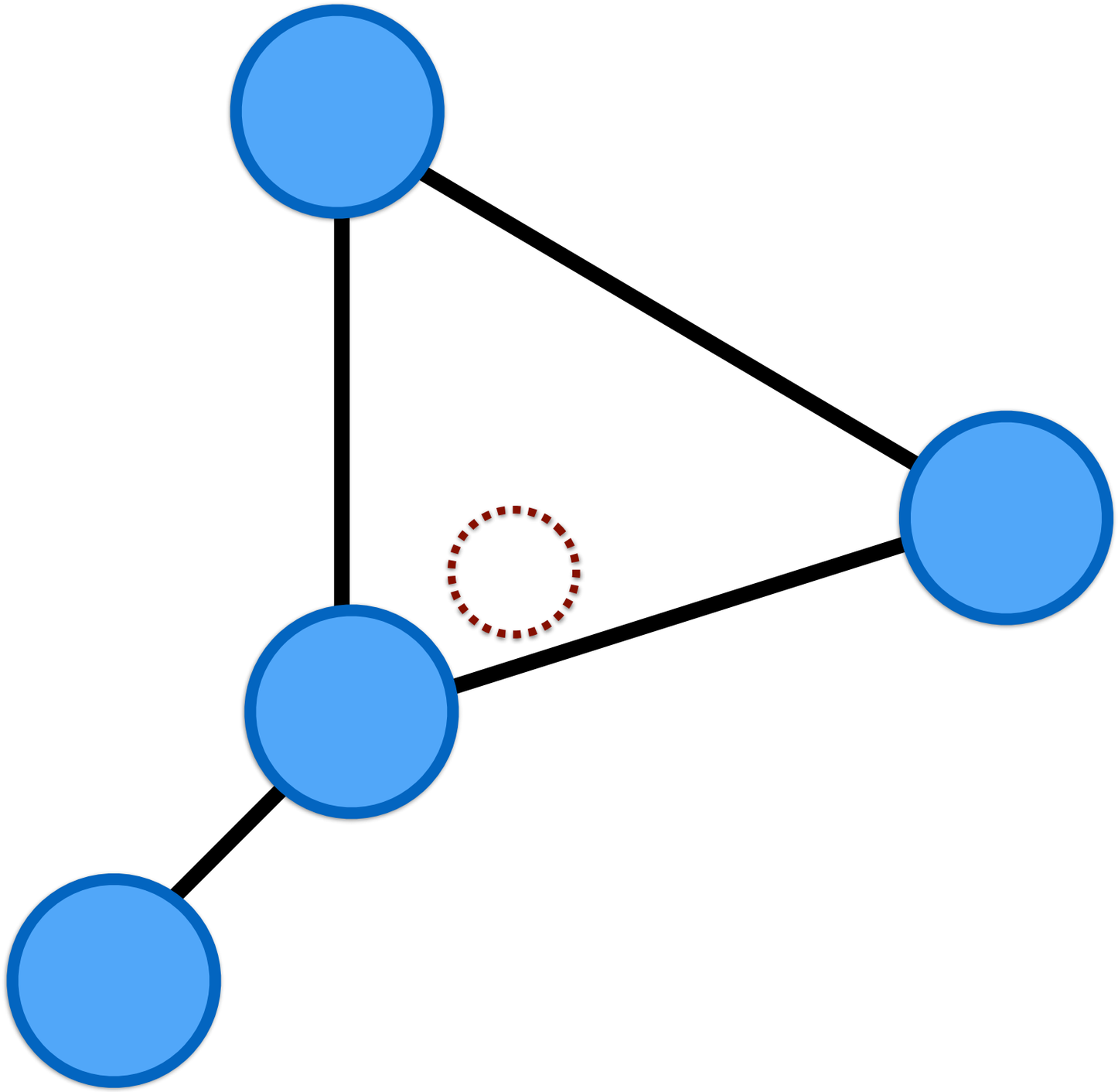
Additional complexity to make it more human-friendly

Iteratively solved w/finite approximation…

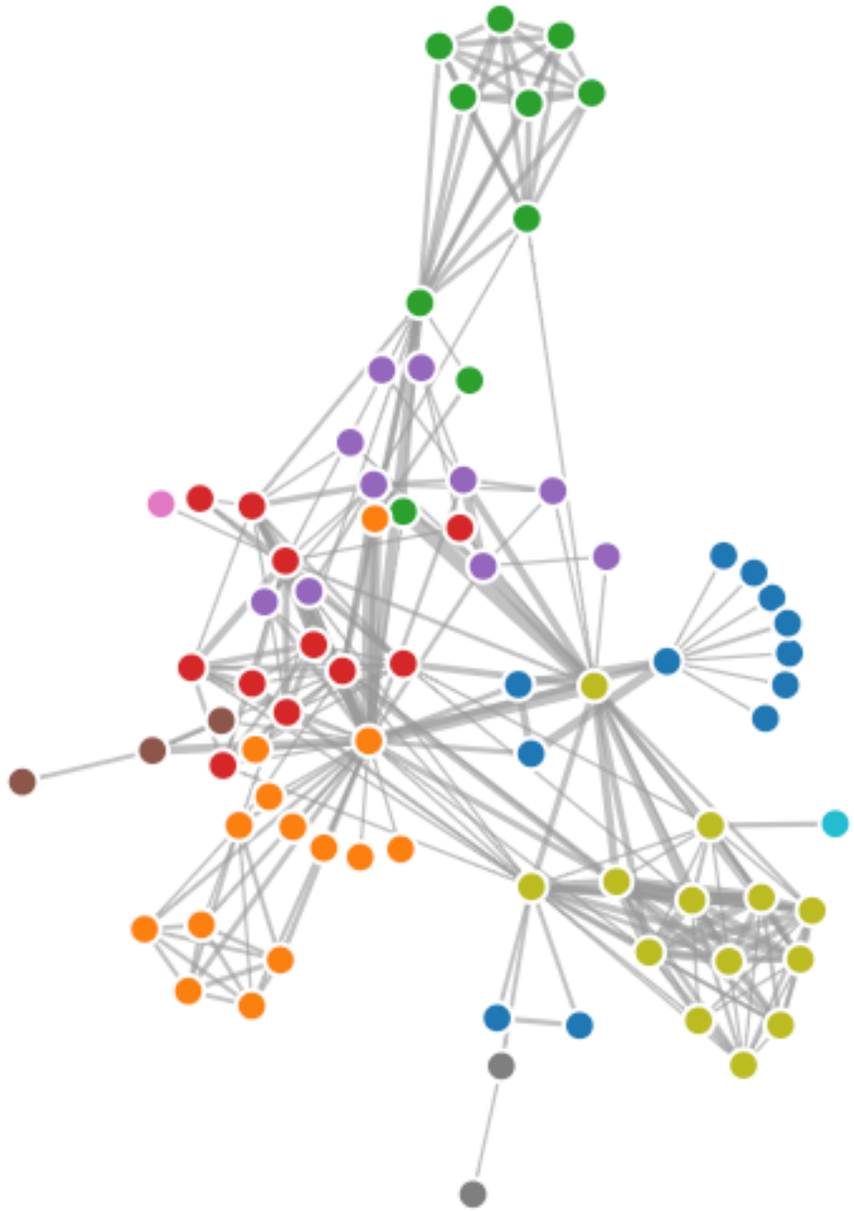
*which leads to many local minima!*







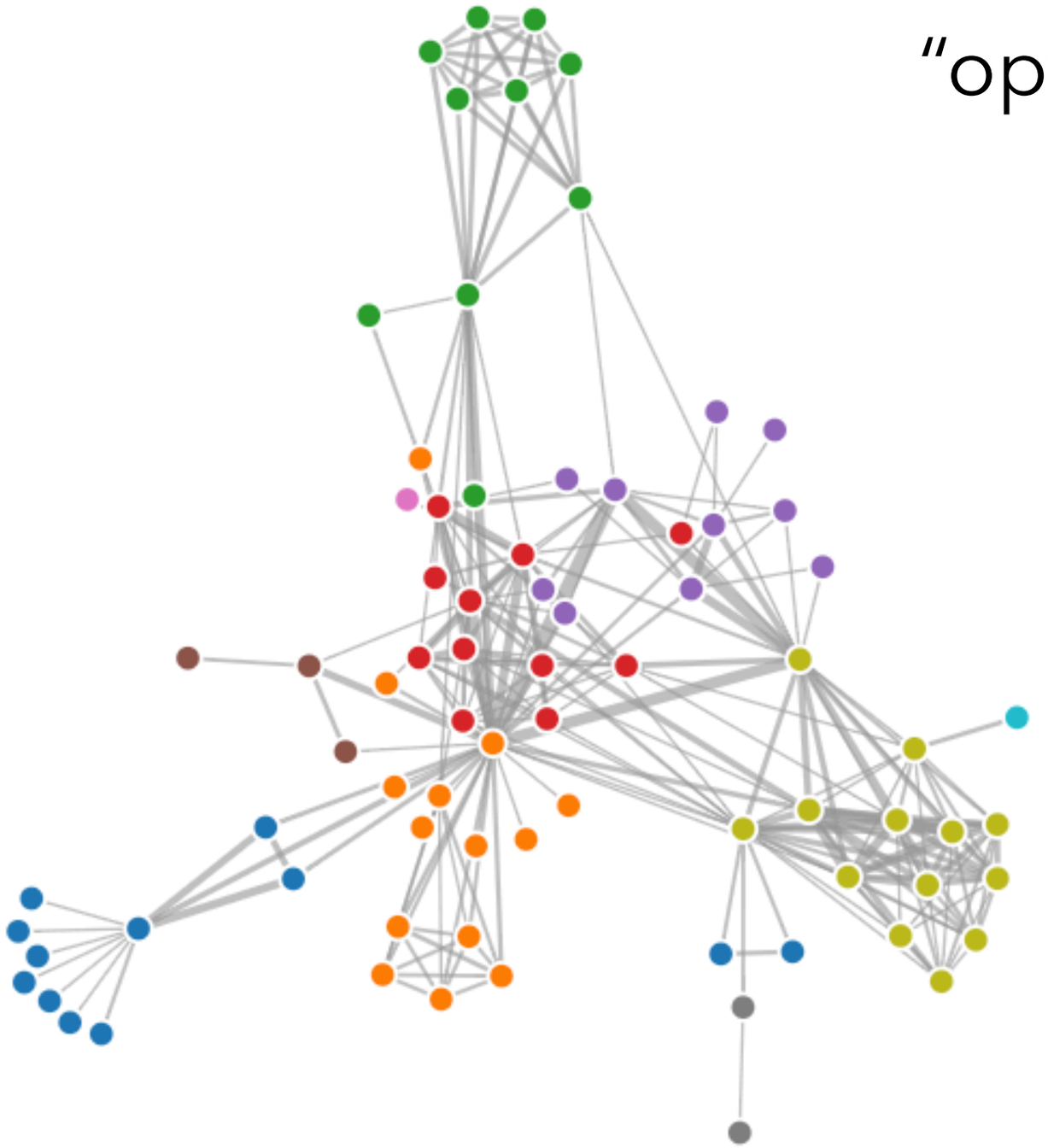
There is no single "optimal" layout



Les Misérables;  d3 defaults

Credit: Mike Bostock https://observablehq.com/@d3/force-directed-graph

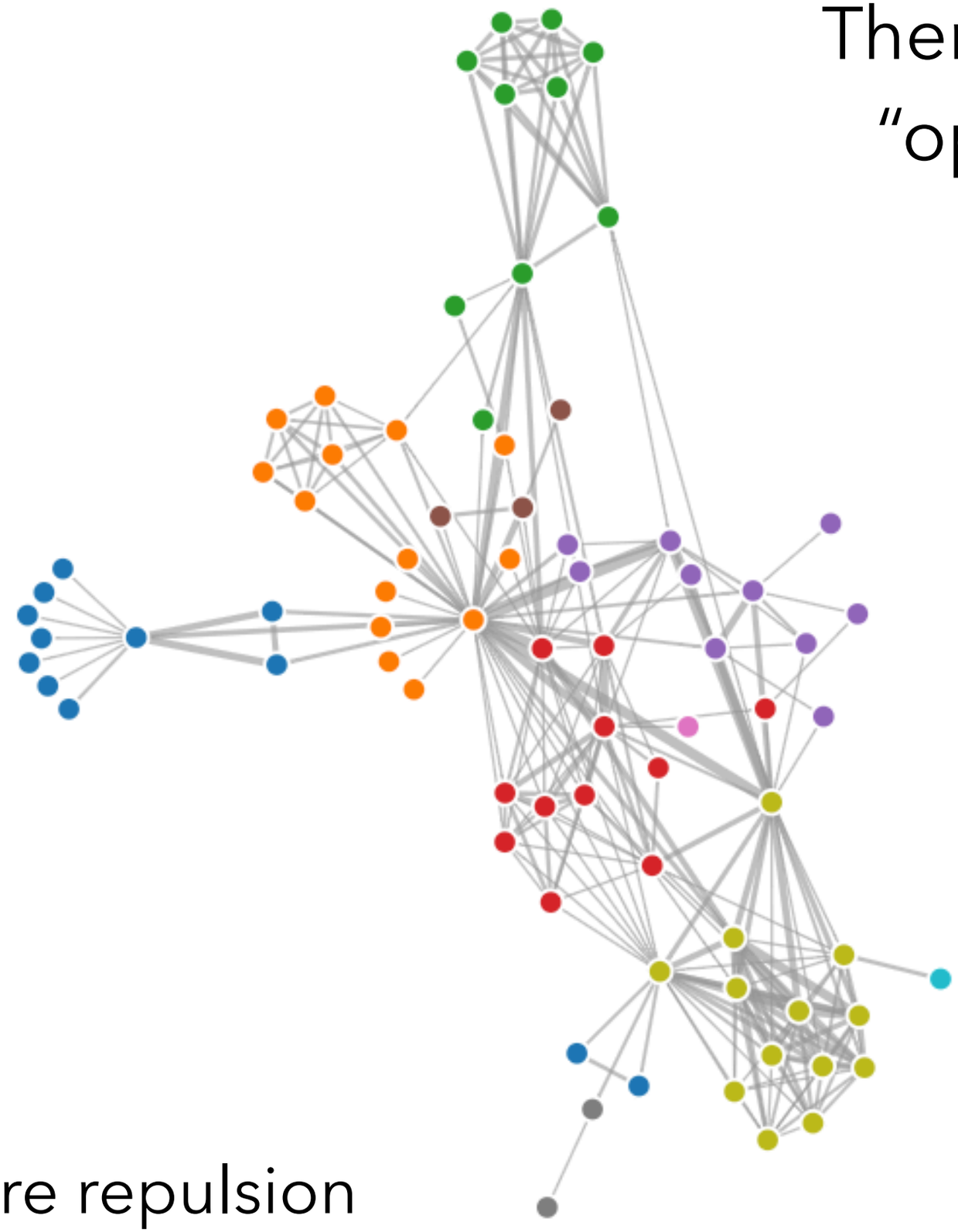
There is no single
“optimal” layout



Just moving some nodes around!

Credit: Mike Bostock https://observablehq.com/@d3/force-directed-graph

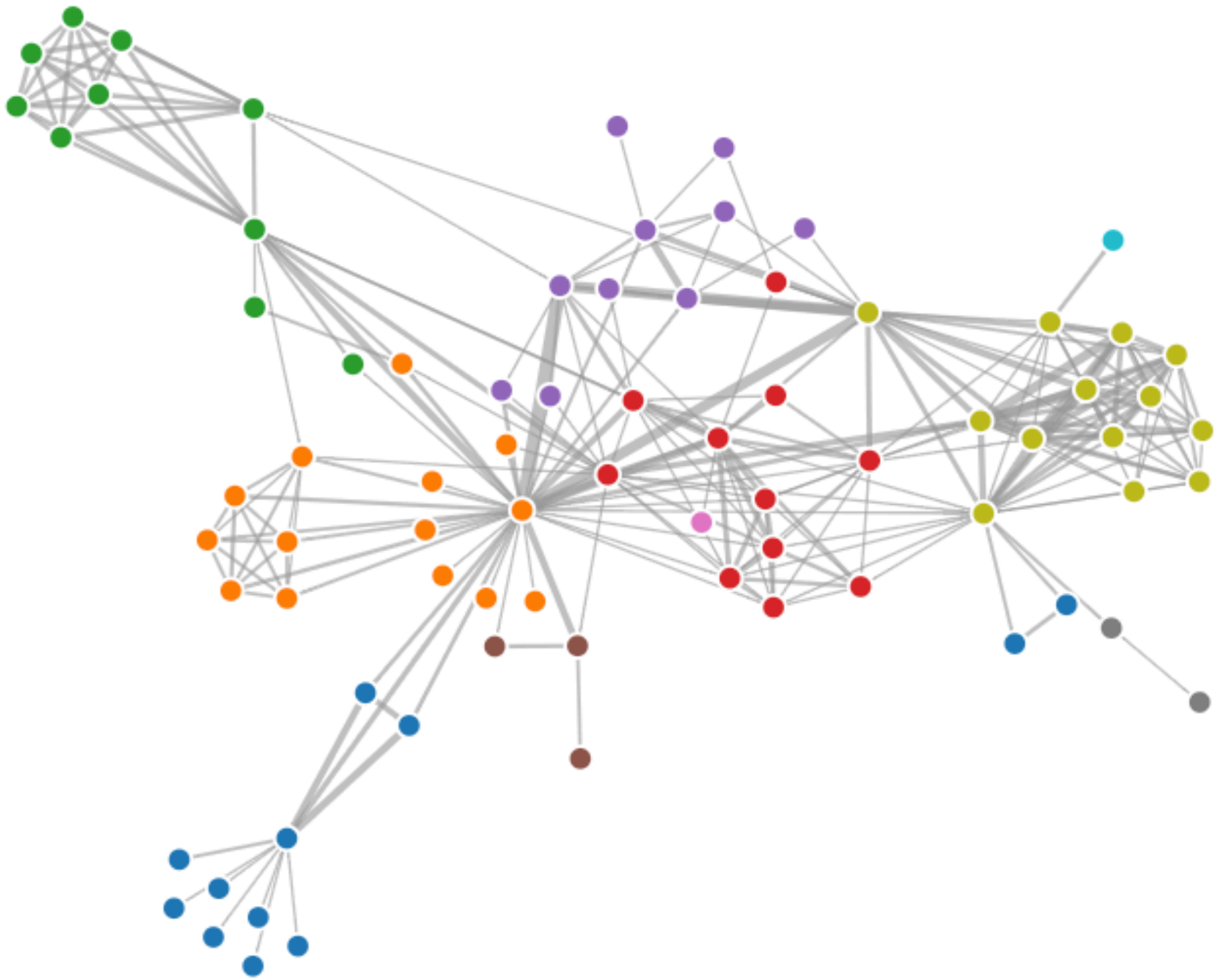
There is no single "optimal" layout



More repulsion

Credit: Mike Bostock https://observablehq.com/@d3/force-directed-graph

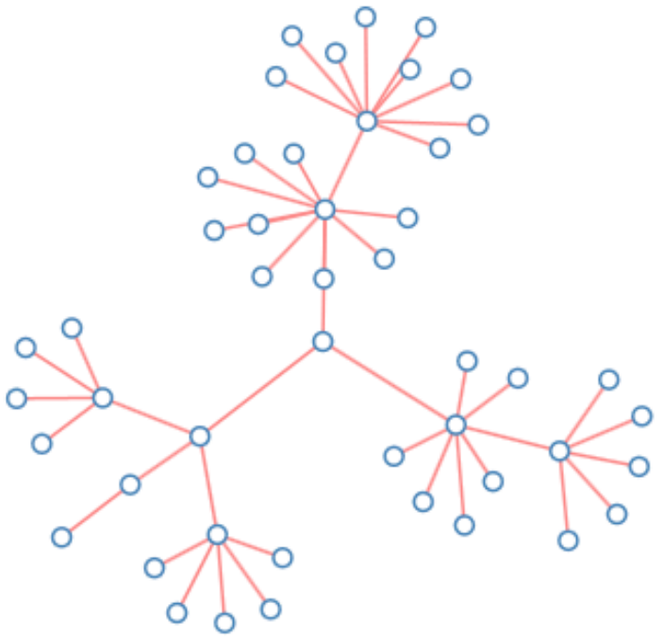
There is no single
“optimal” layout

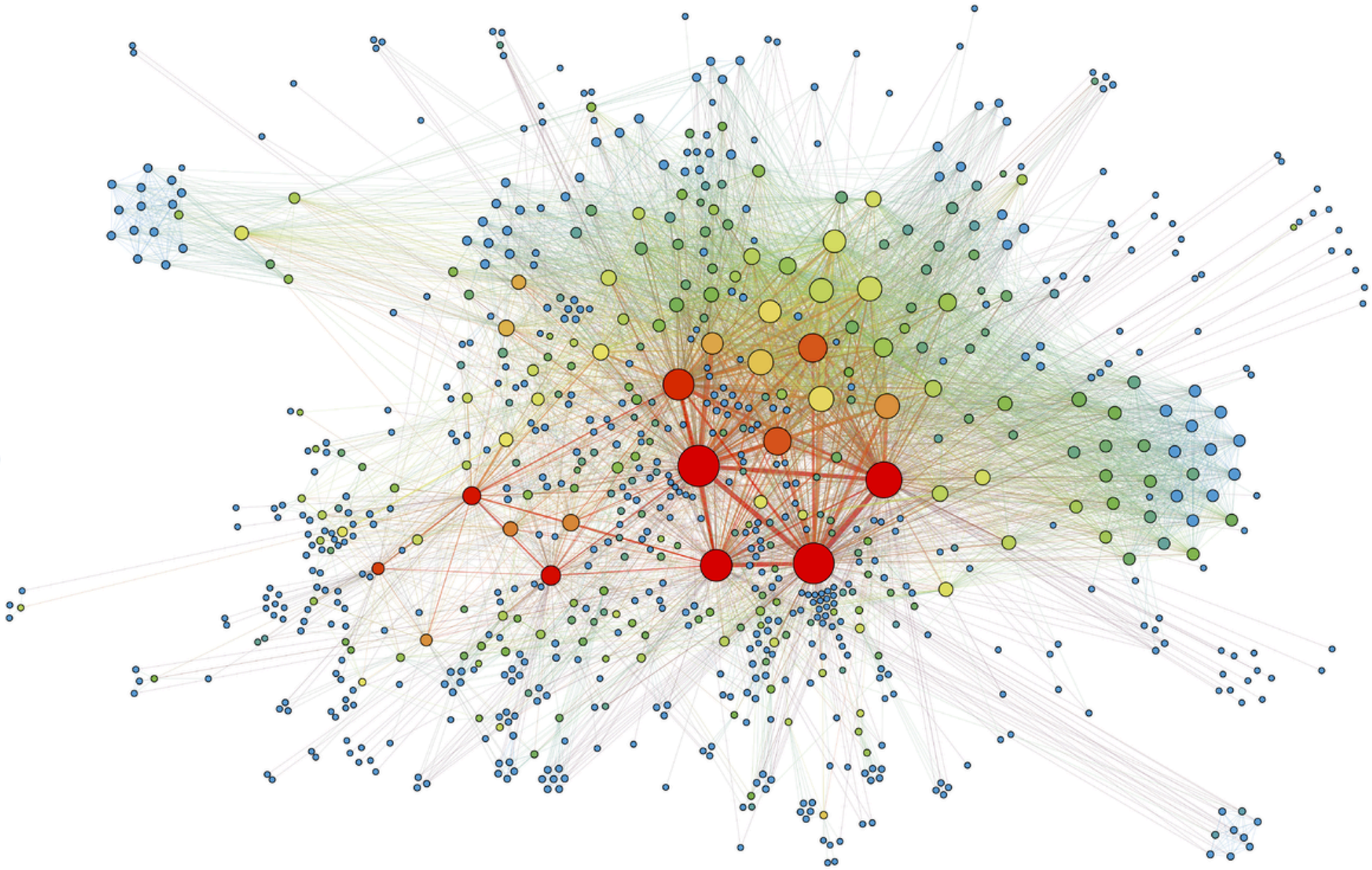


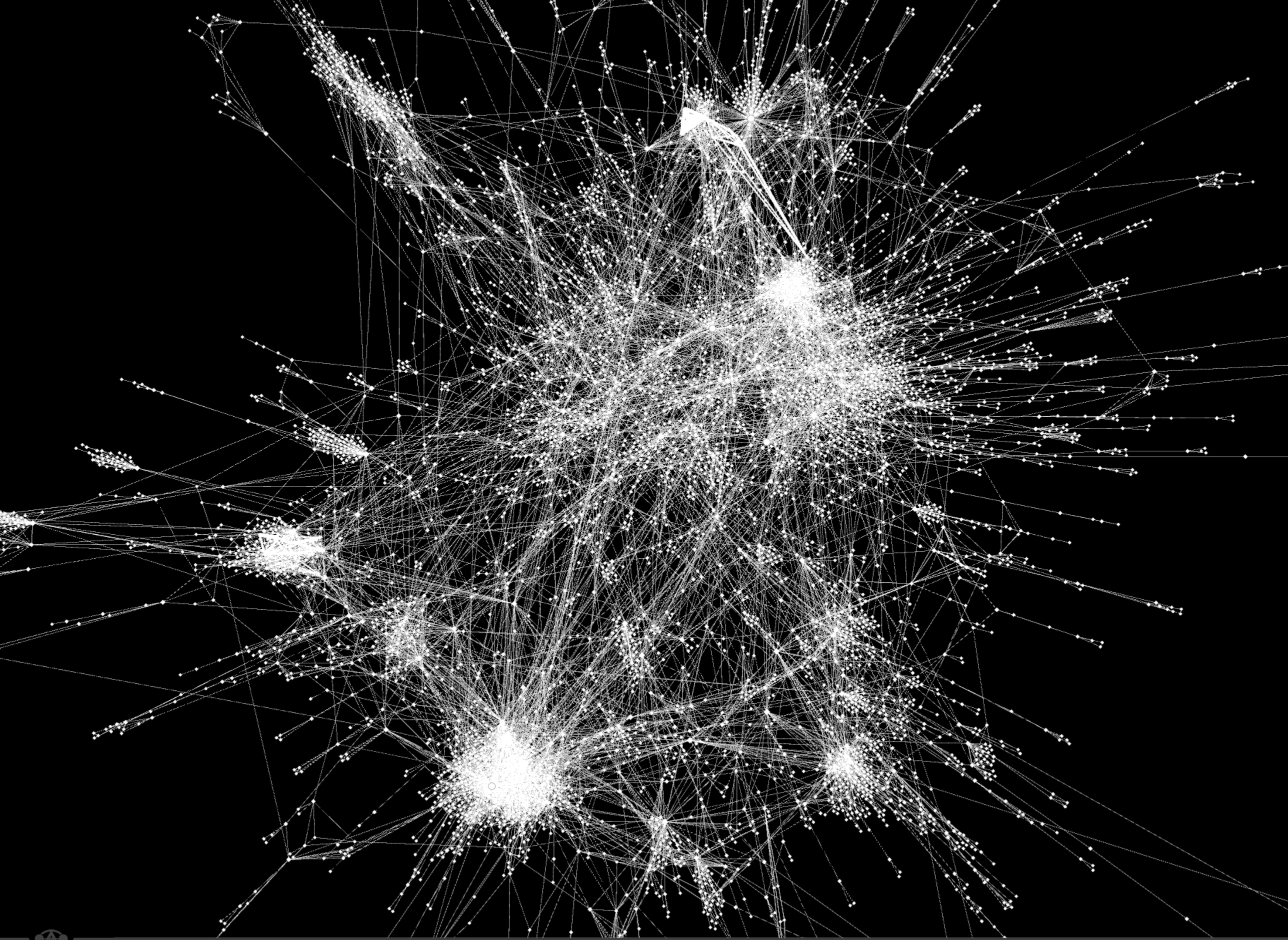
Collision radius increase

Credit: Mike Bostock https://observablehq.com/@d3/force-directed-graph

# Results aren’t always predictable







Cetus.

Taurus.

ERIDANUS.

PHŒNIX.

TOUCAN.

Hydrus.

Dorado.

Lepus.

Orion.

Columba.

Fig. PP.

Ware, C., 2000. Information visualization: design for perception. *Morgan Kauffman, San Mateo, CA*.

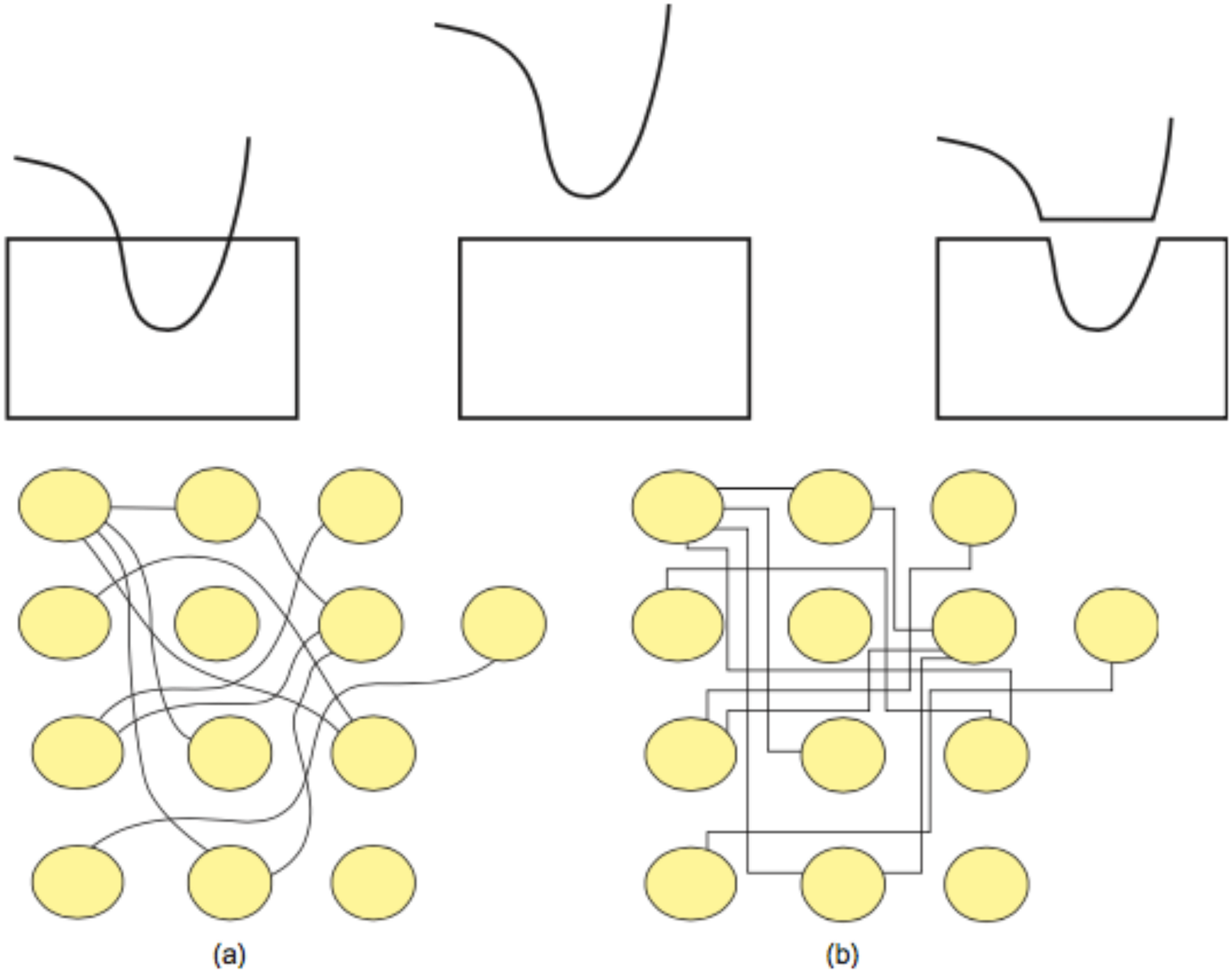
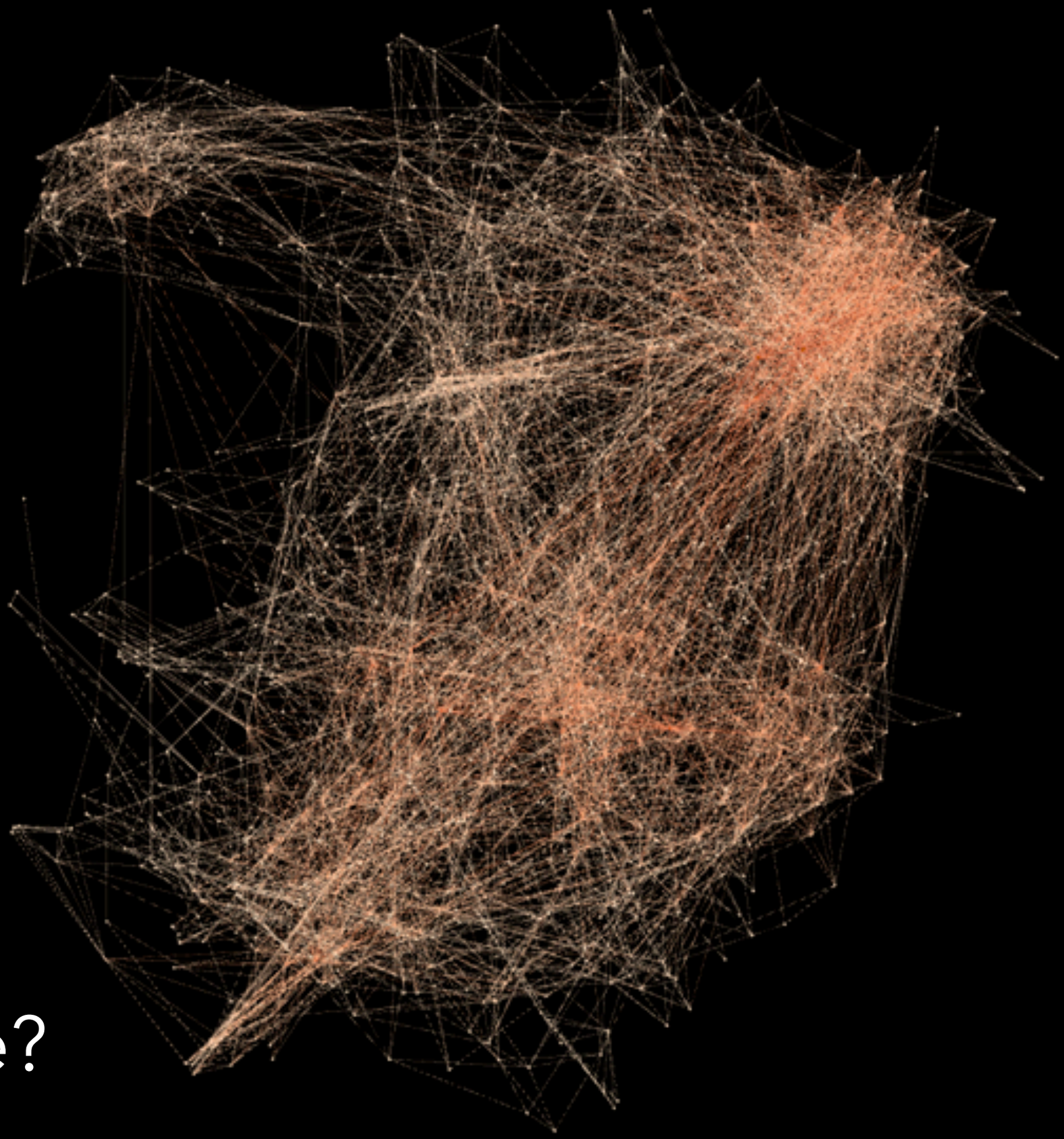



**Figure 6.7** In (a), smooth continuous contours are used to connect nodes in the diagram; in (b), lines with abrupt changes in direction are used. It is much easier to perceive connections with the smooth contours.

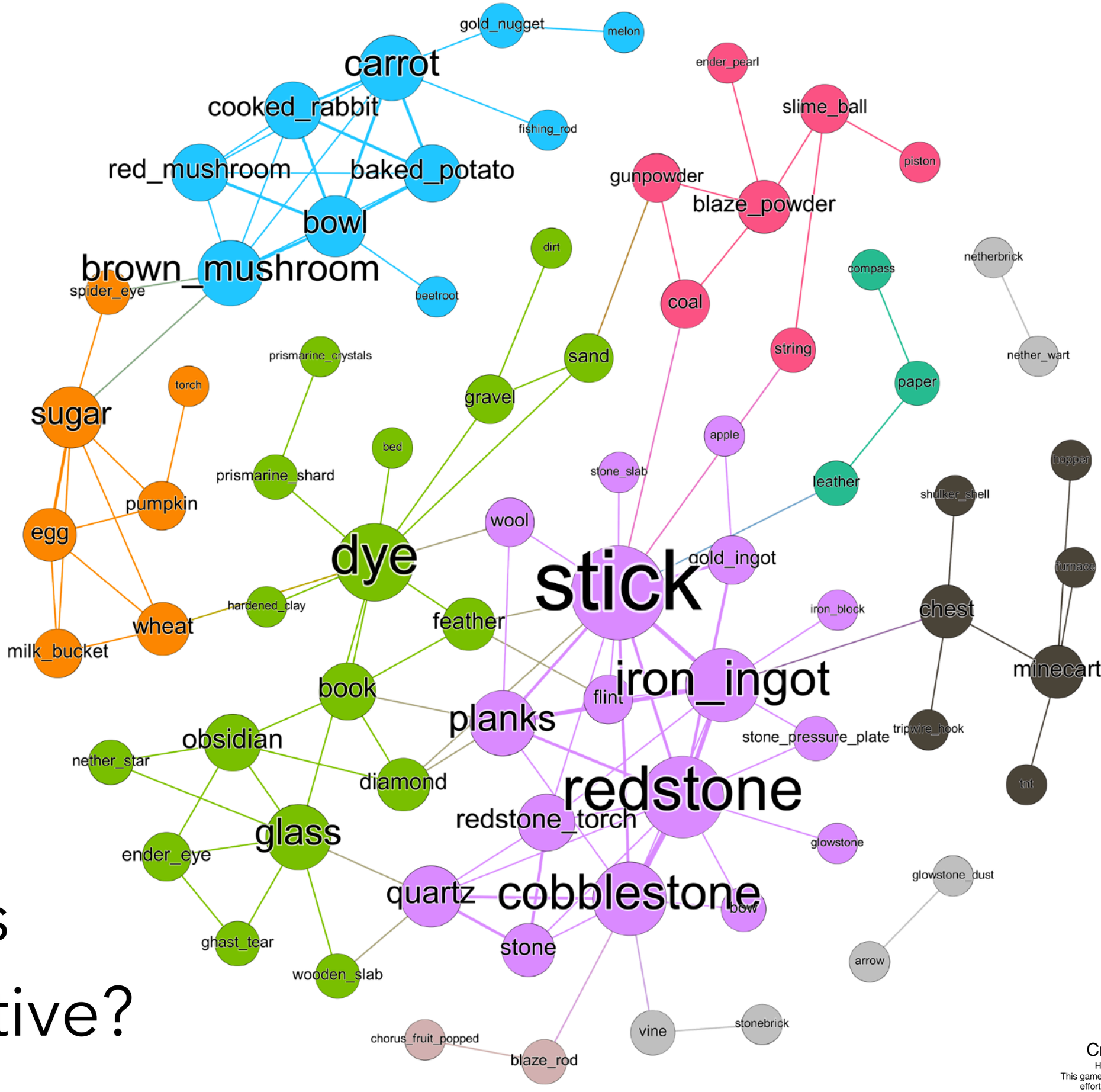
Ware, C., 2000. Information visualization: design for perception. *Morgan Kauffman, San Mateo, CA*.

## Network of Breast Cancer Co-Authors in the 2000's



Is this effective?

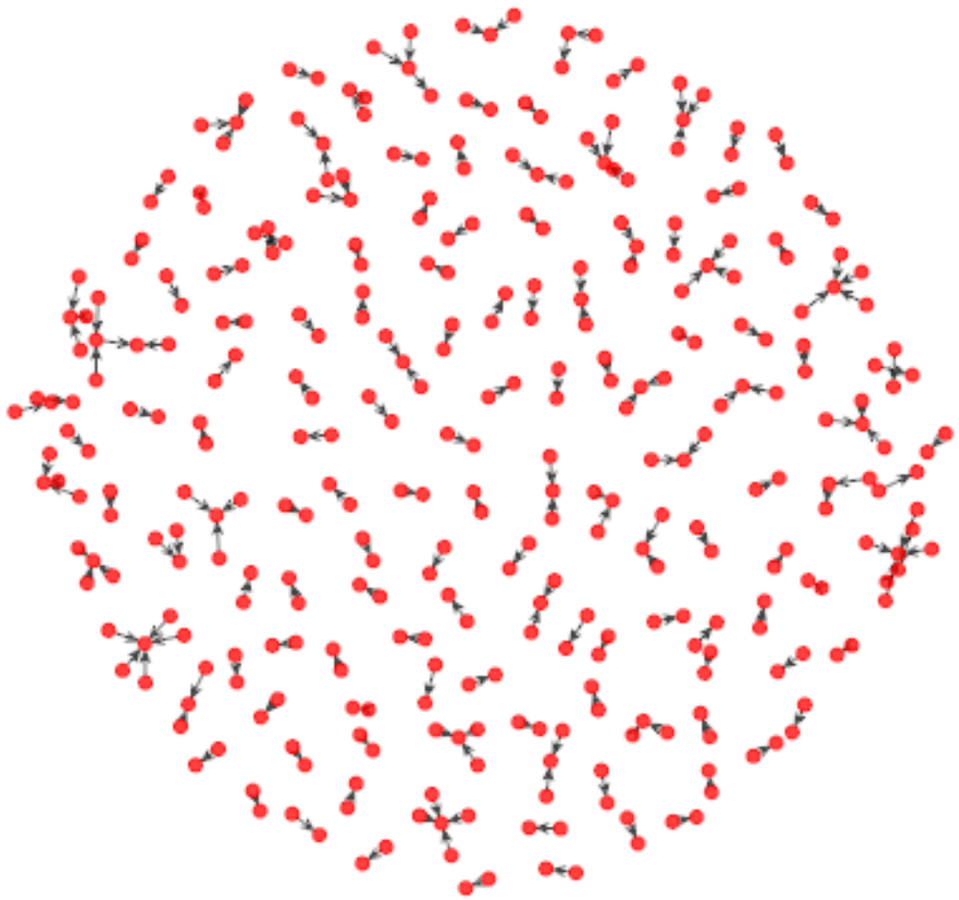
Credit: https://redd.it/k9ddbo



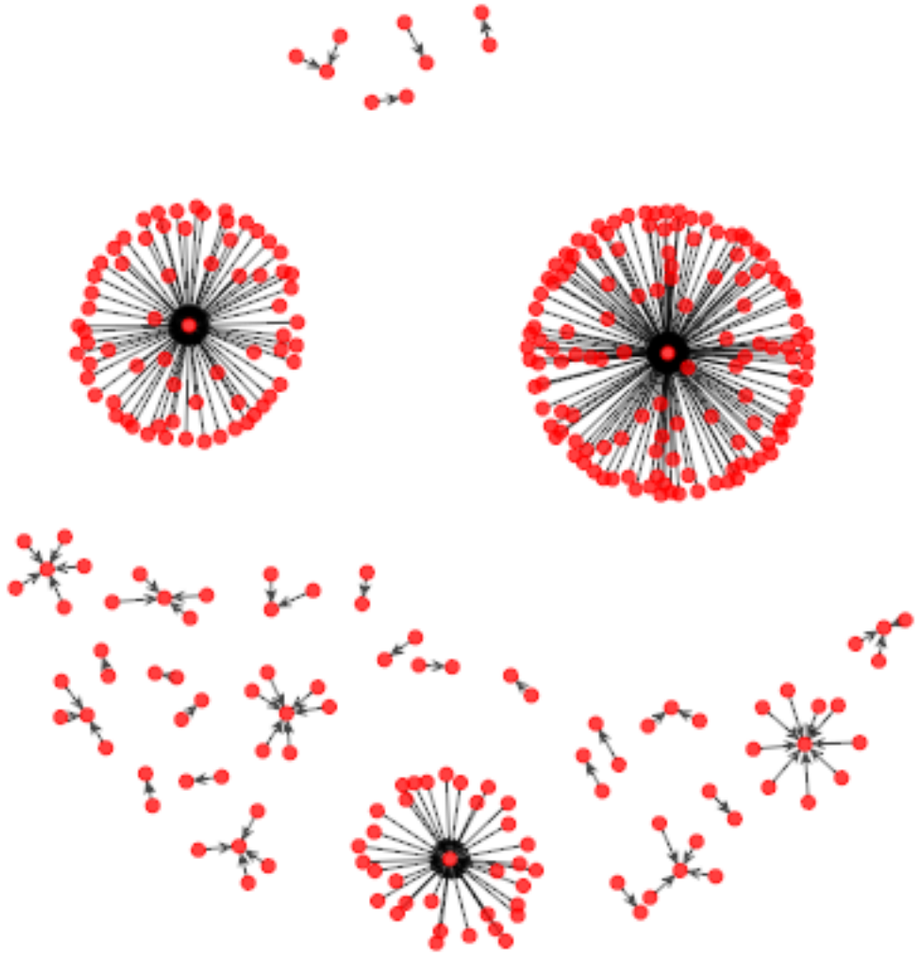

# Is this effective?

Credit: https://redd.it/au6saj

Hello, fellow kids who I assume still enjoy Minecraft™. This game reference emphasizes that I am making a concerted effort to "be hip" and connect with you on a familiar level!



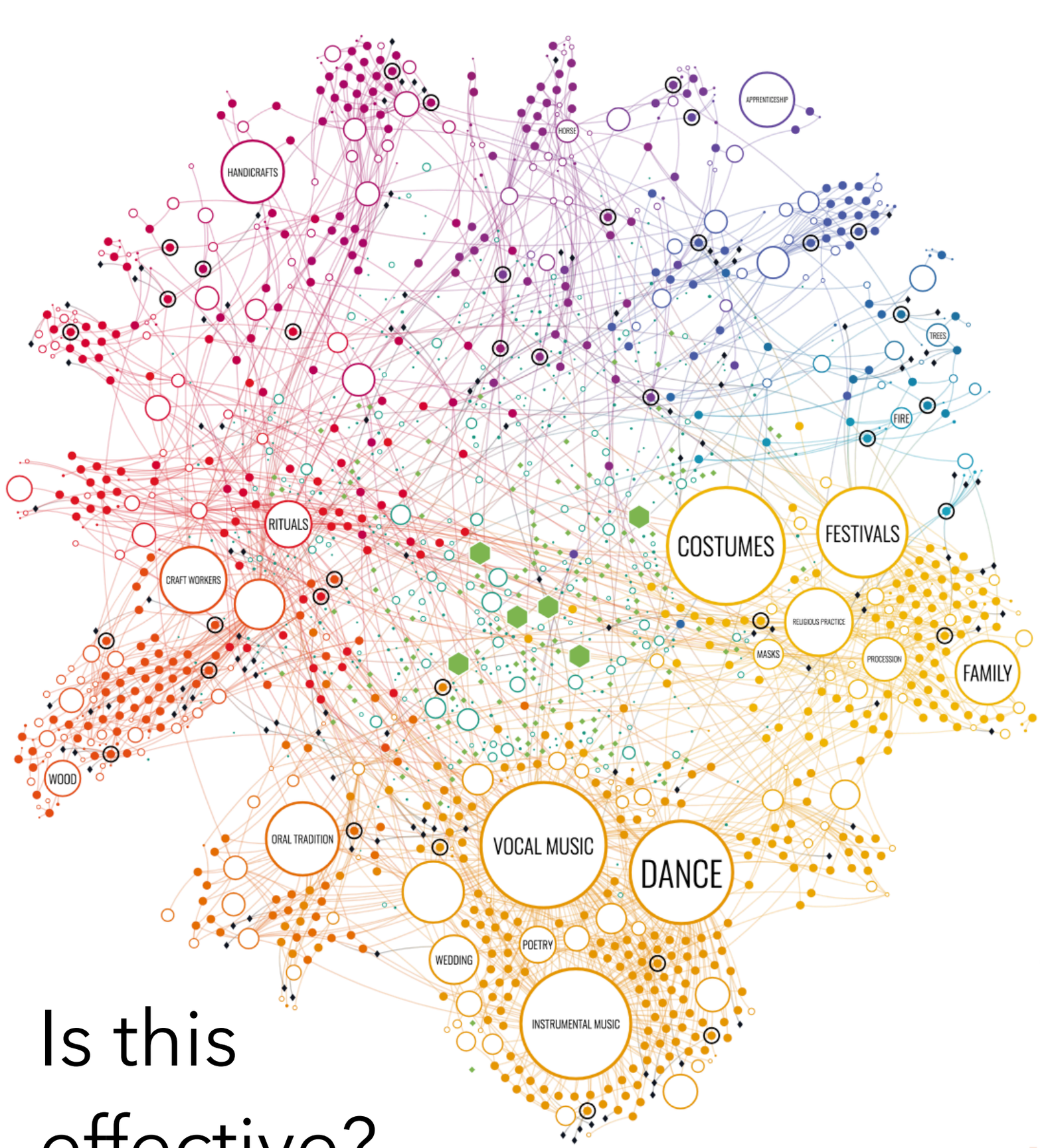
#qtna

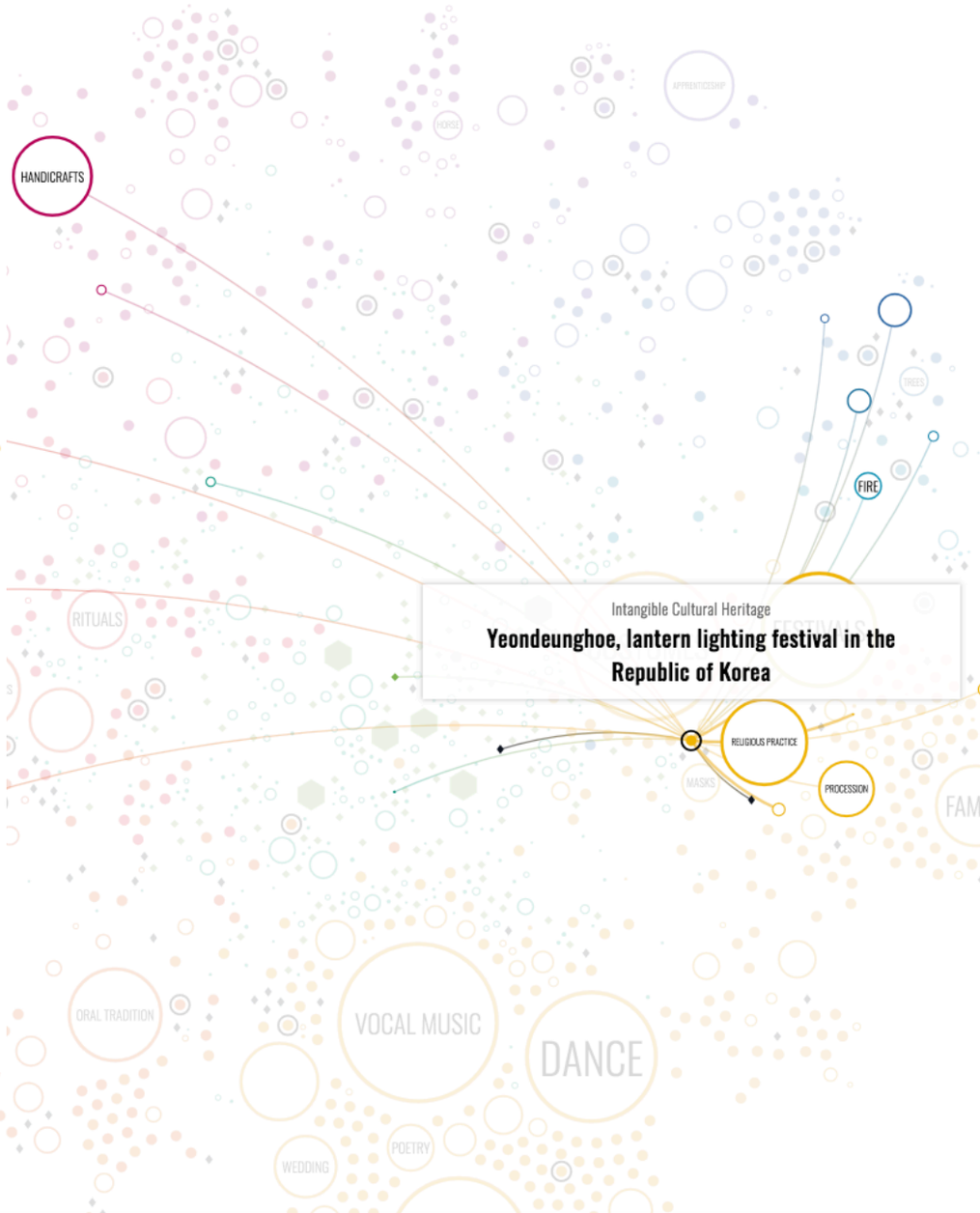


#randomquestion

# Is this effective?

Rzeszotarski, J.M., Spiro, E.S., Matias, J.N., Monroy-Hernández, A. and Morris, M.R., 2014. Is anyone out there?: unpacking Q&A hashtags on twitter. ACM SIGCHI

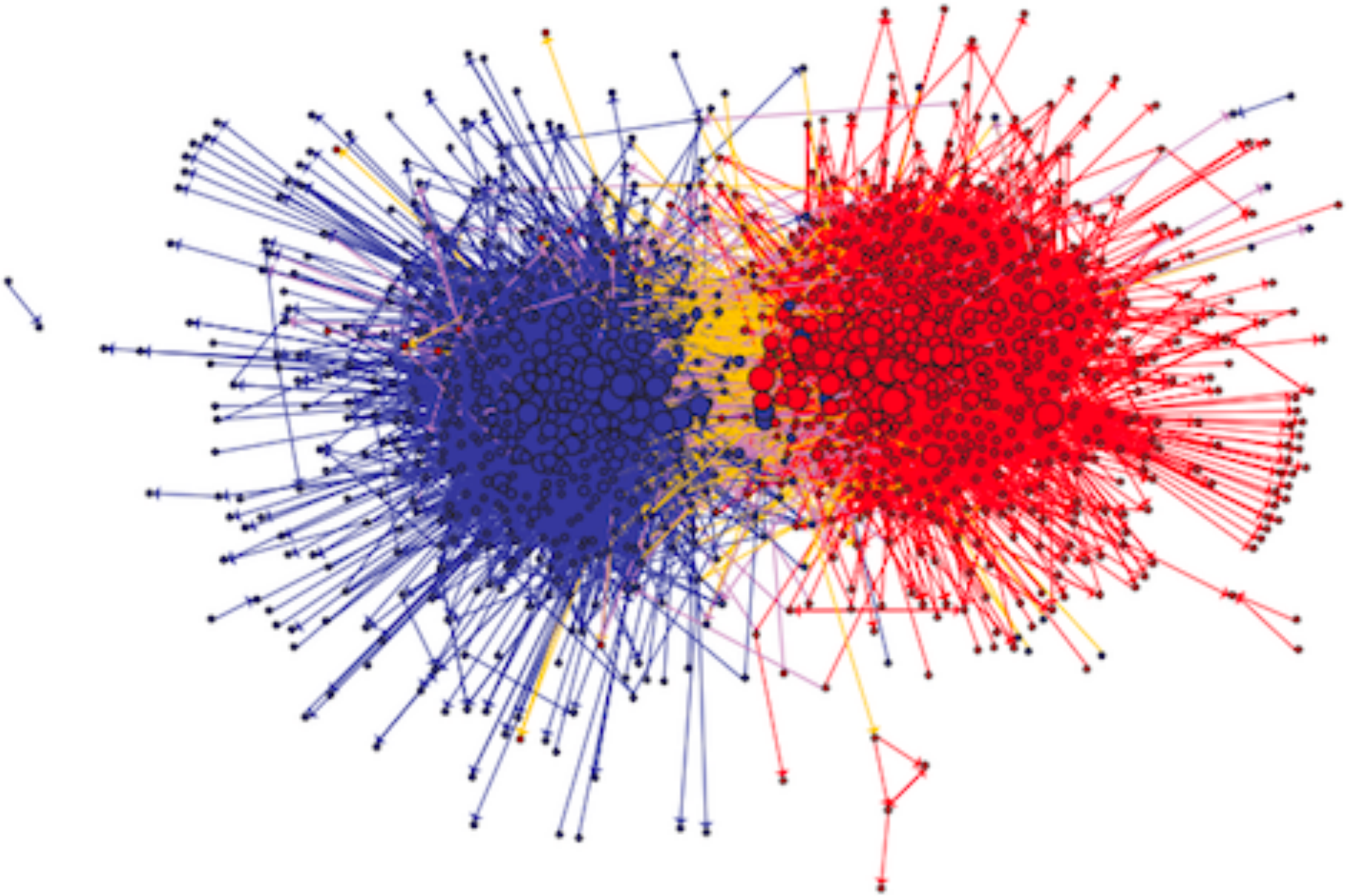


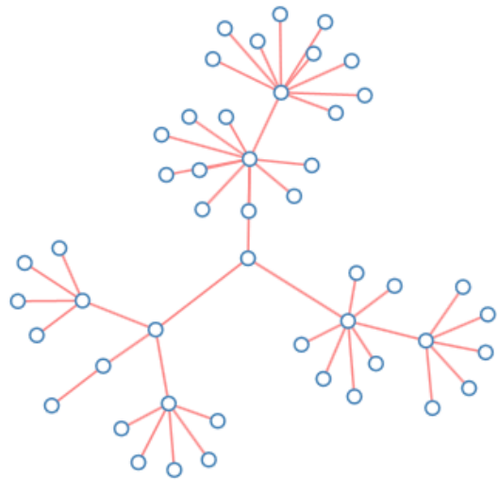

# Is this effective?

Credit: Nadieh Bremer https://www.visualcinnamon.com/portfolio/intangible-cultural-heritage/

# Verify layout with other data



Adamic & Glance. 2005. The political blogosphere and the 2004 U.S. election: divided they blog



# Aesthetic Constraints

Edge crossings

Overall area

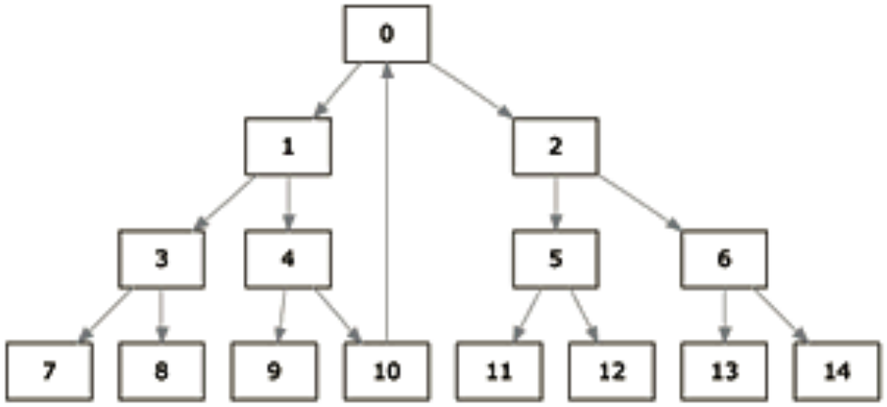
Edge intersection angle

Overall slope

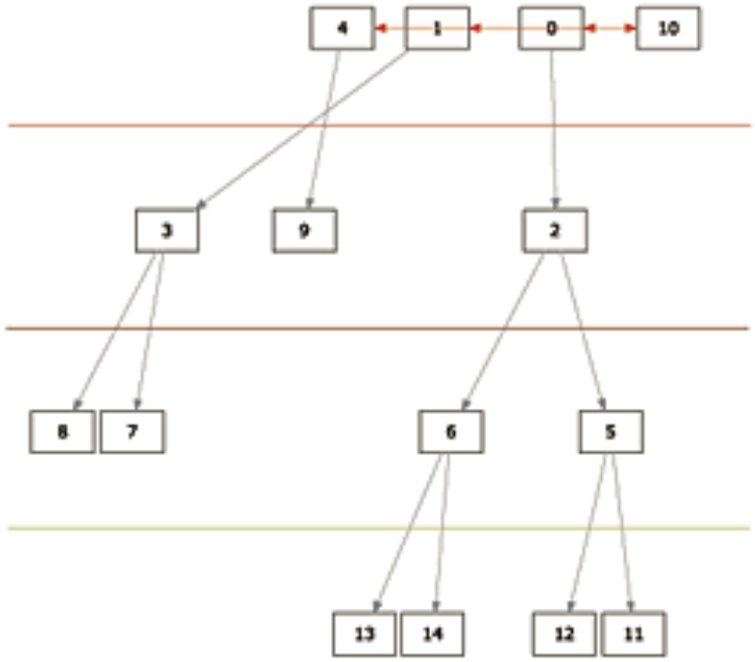
Symmetry

Node positioning

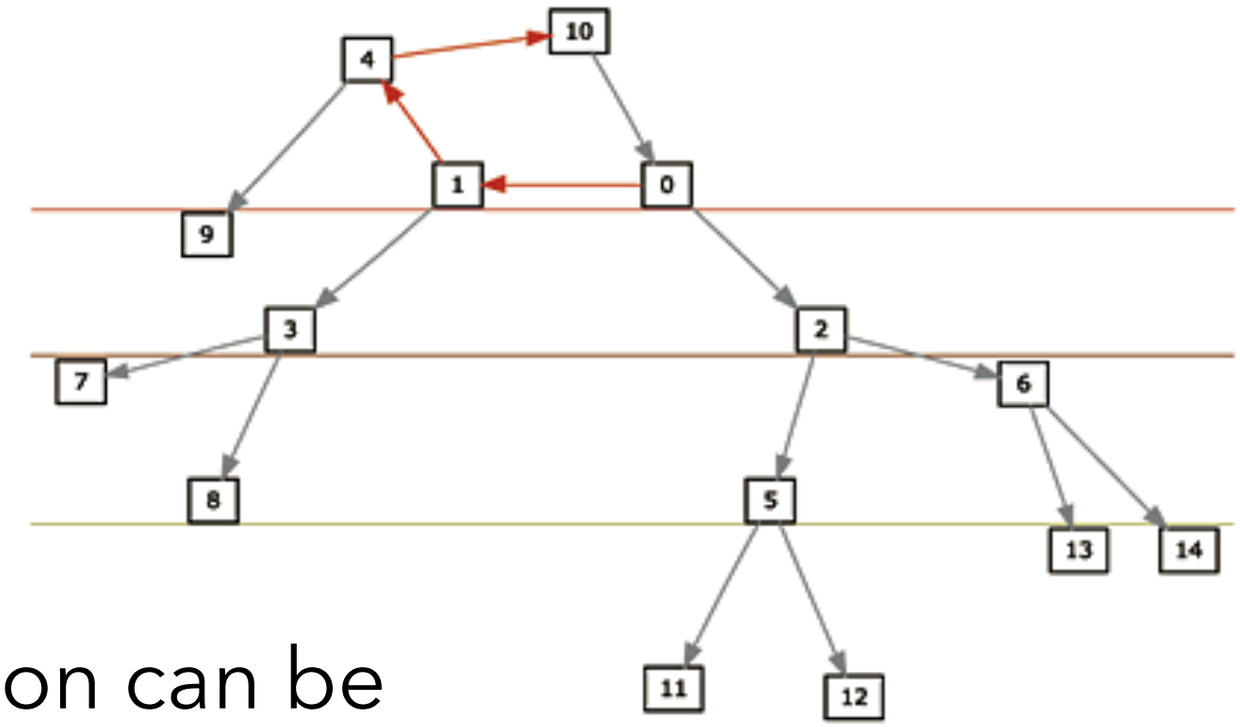
**Every constraint adds significant processing time**




(a)



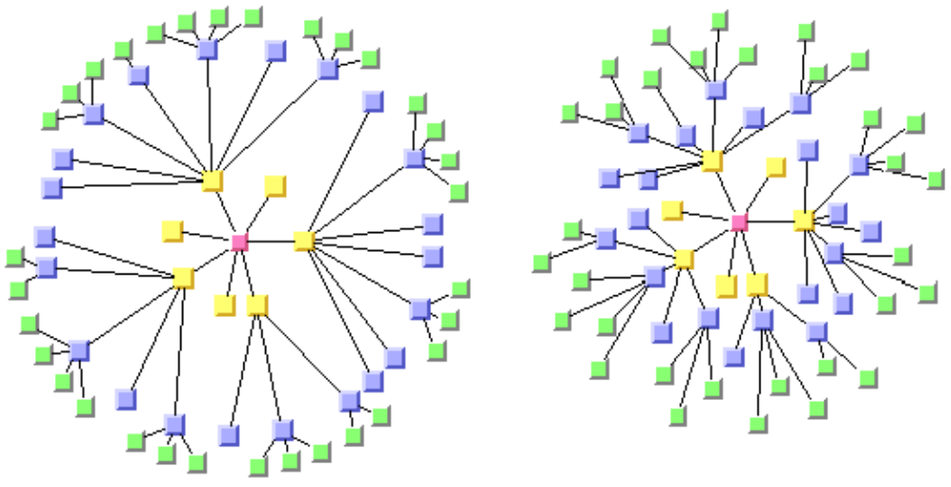

(b)




(c)

Force-direction can be applied to other layouts

Dwyer, T., Koren, Y. and Marriott, K., 2006. Drawing directed graphs using quadratic programming.



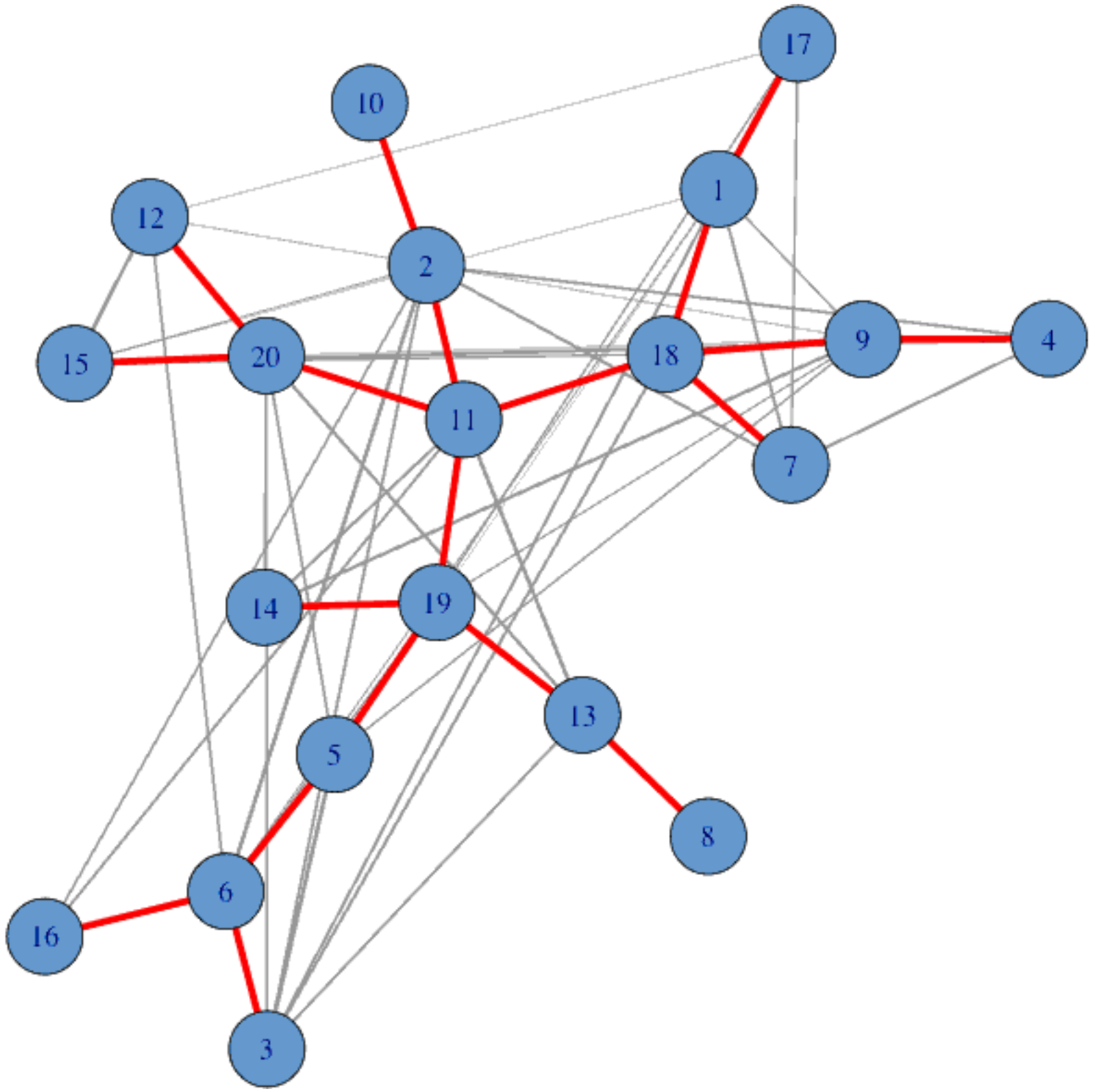
# Spanning Trees

**Minimum spanning tree** - make tree out of graph which connects all nodes and has the smallest total edge weight

Can build if graph is connected, but not always useful

Lots of data are conducive to minimum spanning trees

Once you have a tree, apply tree layouts but show all edges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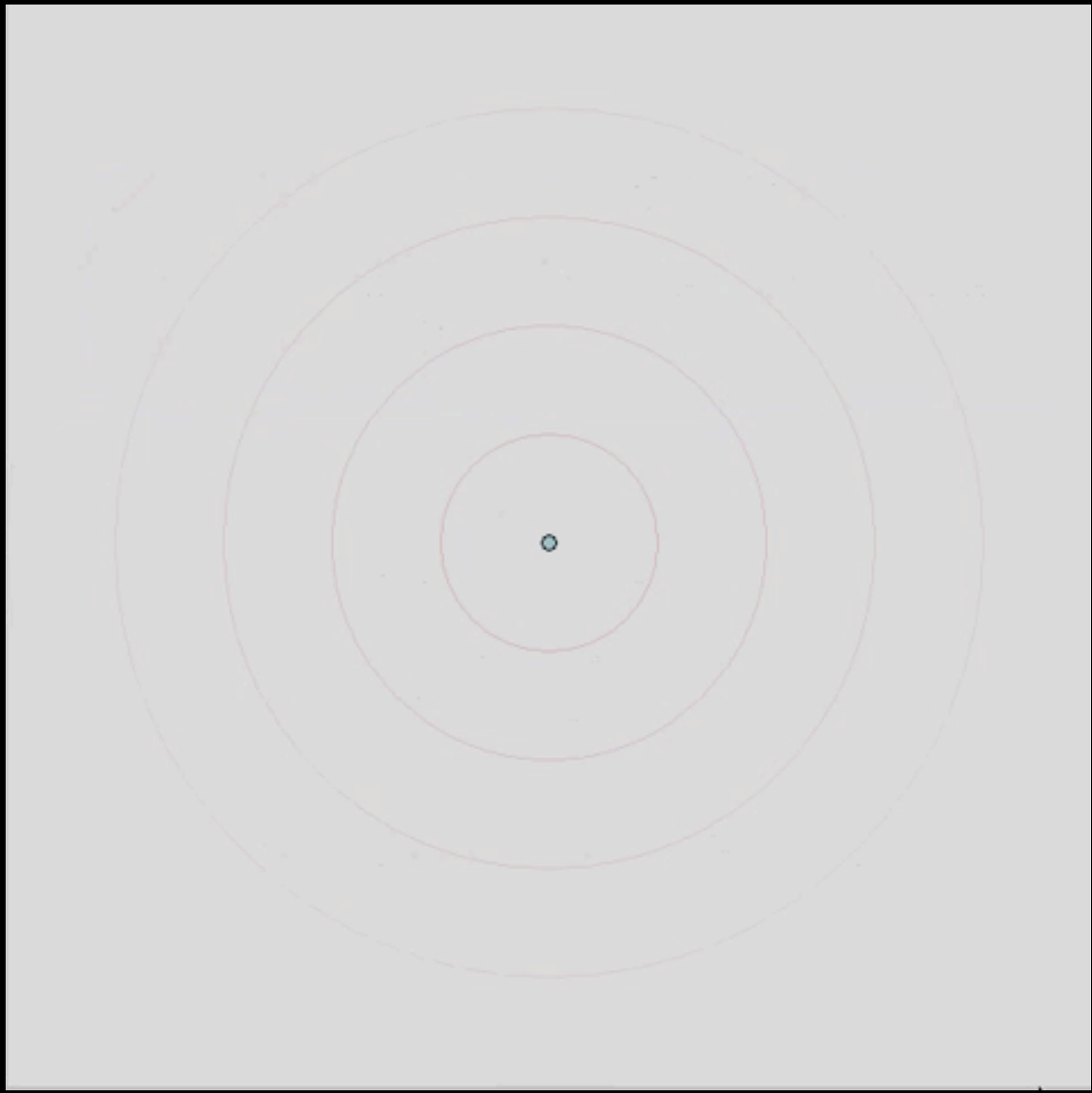
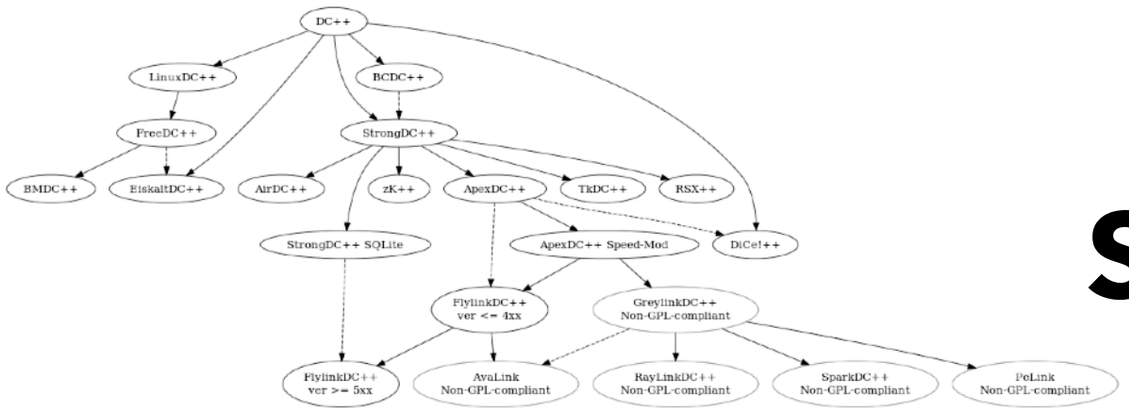


Yee, K.P., Fisher, D., Dhamija, R. and Hearst, M., 2001. Animated exploration of dynamic graphs with radial layout. In Information Visualization, 2001.



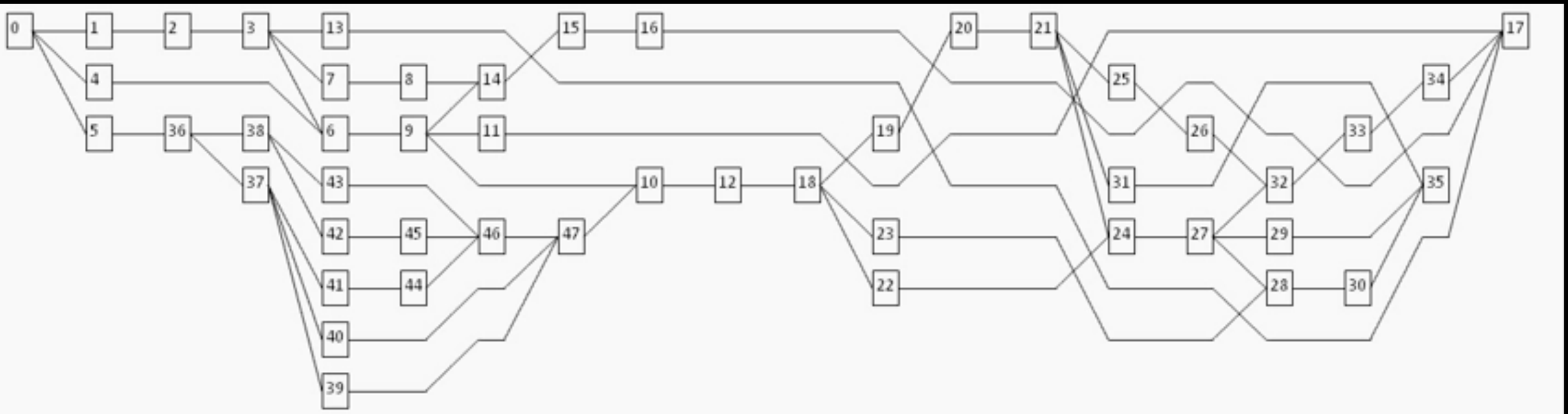

# Sugiyama Layout

**Kozo Sugiyama** - created lots of graph layout algorithms

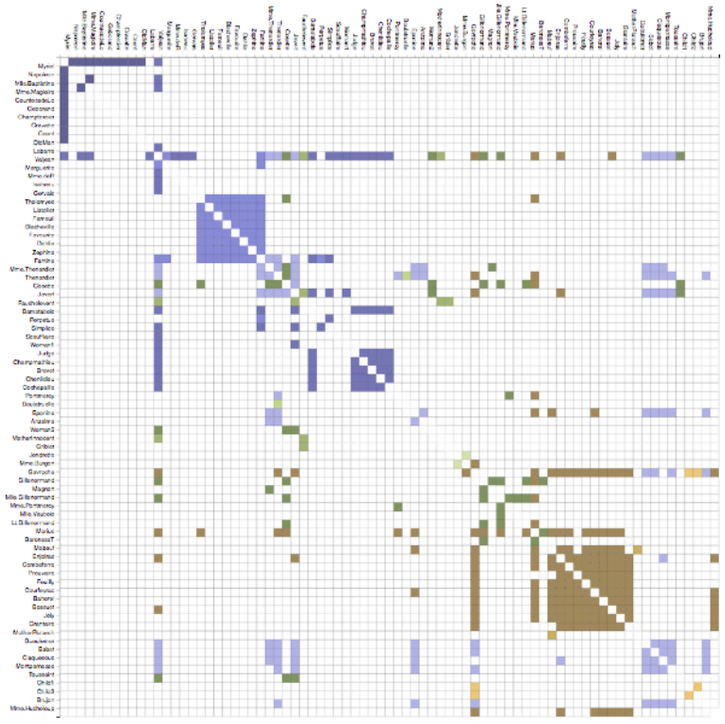
Make “layers” out of nodes from chosen center

Gets messy if you have lots of cycles

“Hill-climbing” algorithms




https://www.youtube.com/watch?v=n3tG0AKwiRE



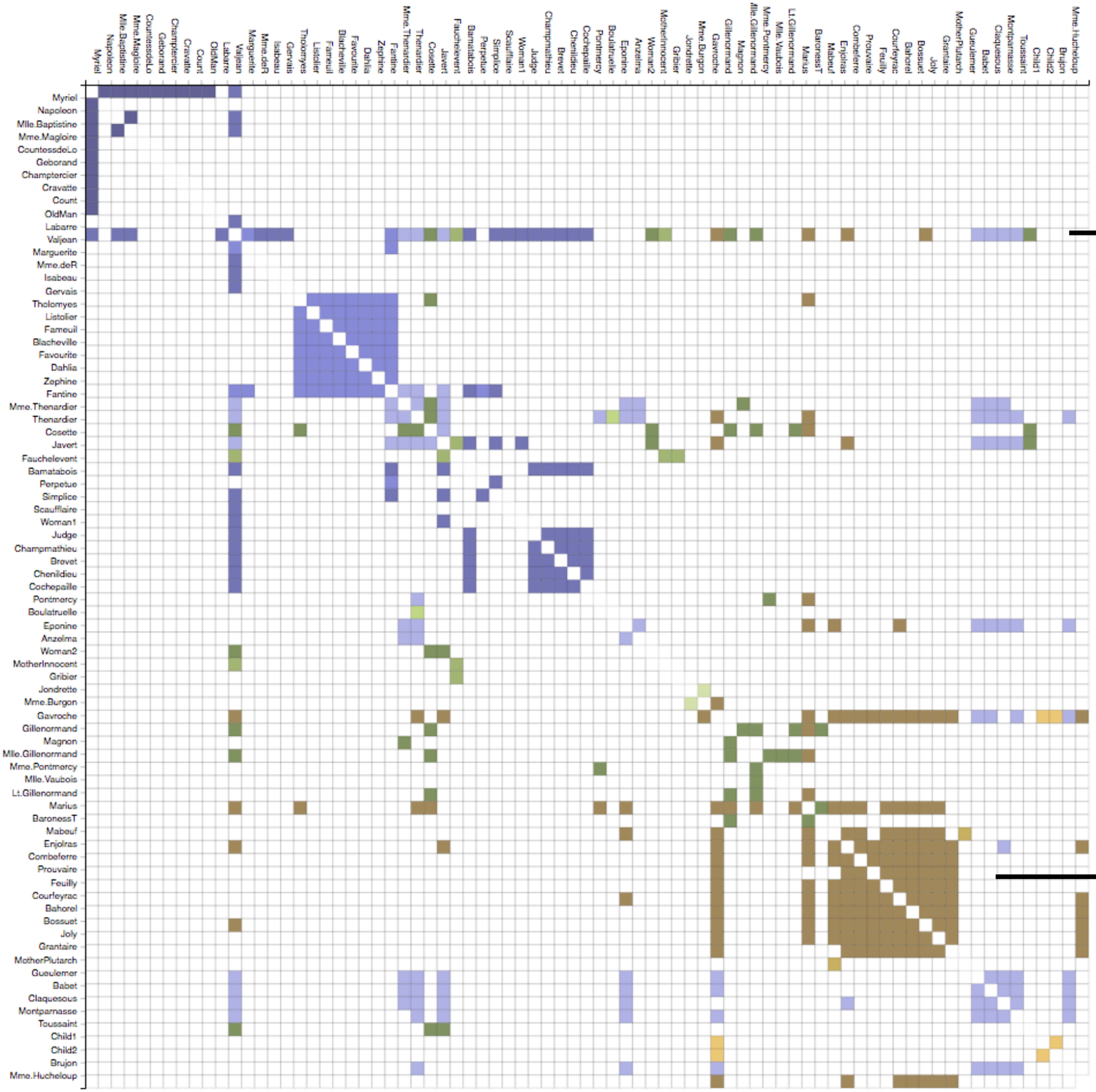
# Adjacency Matrices

**Table-based method** – Fill “cells” if row and column connect

Order matters here!

Symmetry aids interpretation

# Les Misérables co-occurence



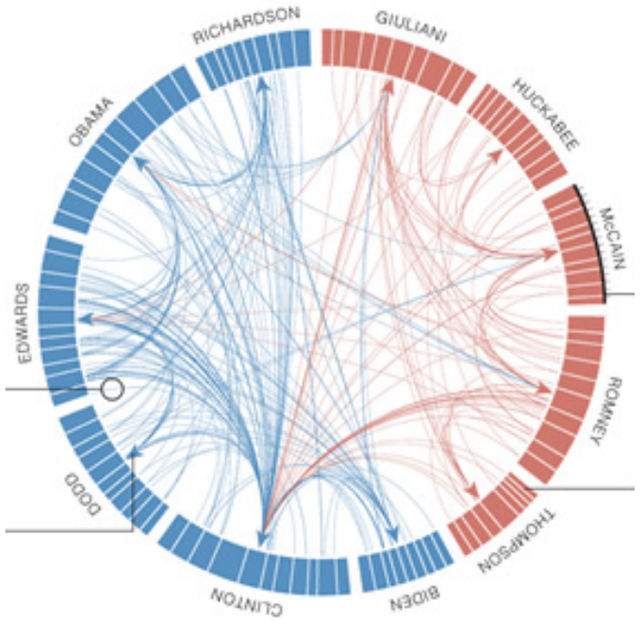

— High centrality

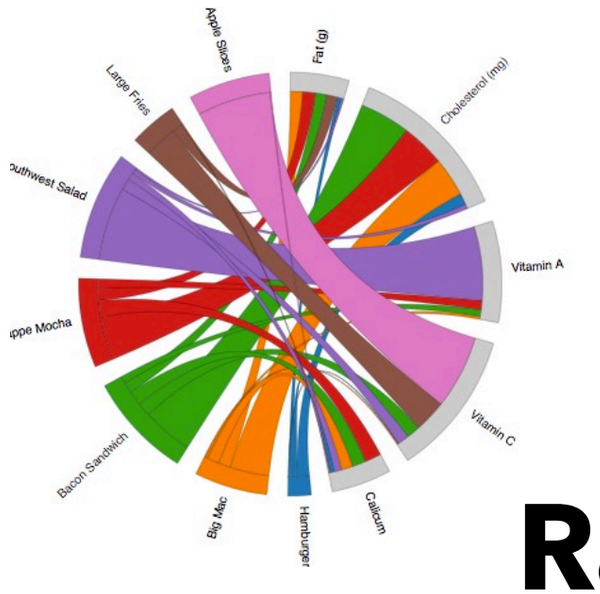
*Valjean*

—— High connectivity

*Les Amis de l'ABC*

https://bl.ocks.org/micahstubbs/7f360cc66abfa28b400b96bc75b8984e



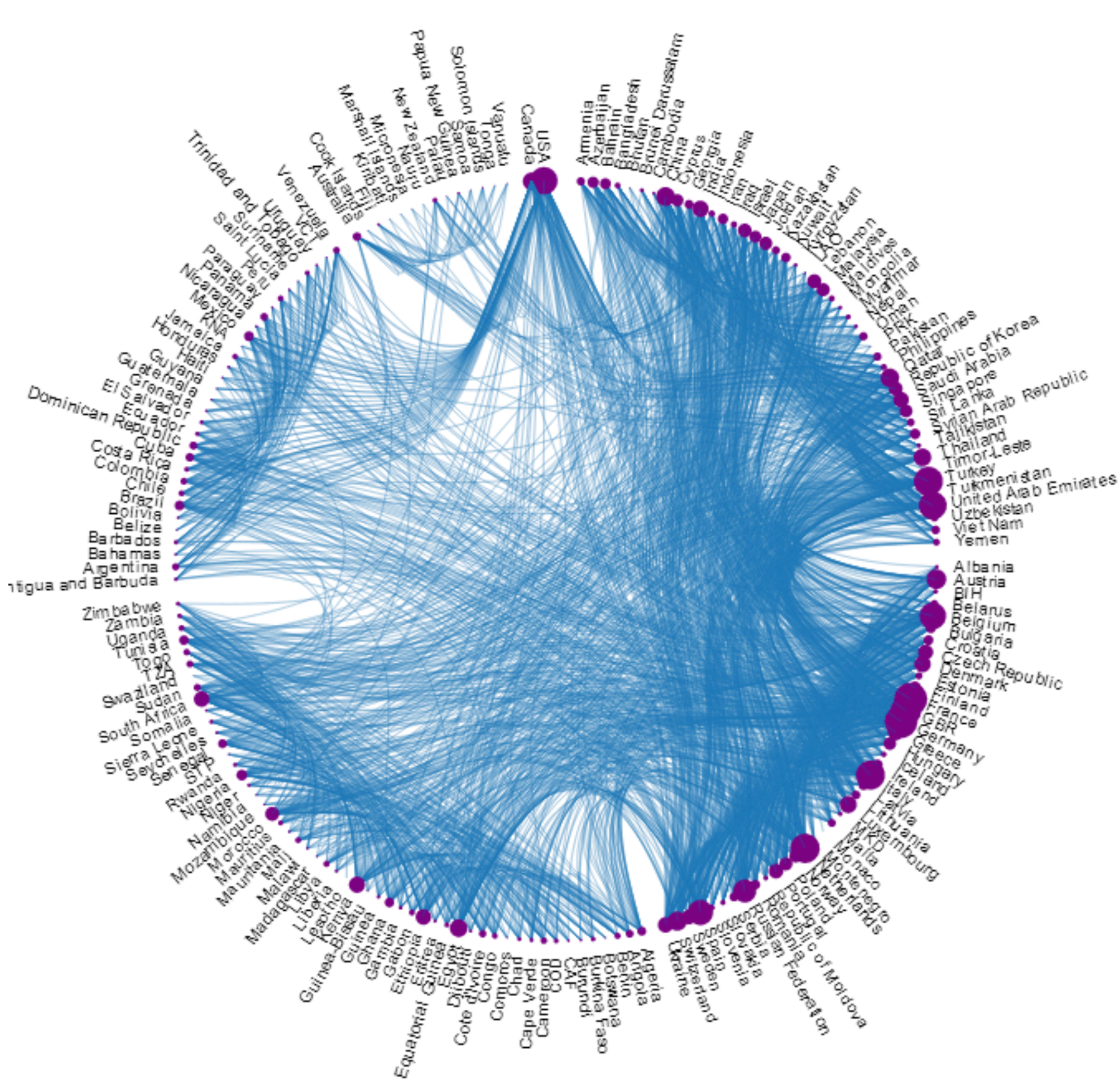

# Radial & Chord

**Put the nodes on a circle** – Use circumference for attribute

Edges cross into circle and arc

Encode meaning into circle position

Aggregate edges into blocks for more legibility*


Papua New Guinea
Solomon Islands
Vanuatu
Tonga
Canada
USA
Armenia
Azerbaijan
Bahrain
Bangladesh
Bhutan
Brunei Darussalam
Cambodia
China
Cyprus
Georgia
India
Indonesia
Iran
Iraq
Israel
Japan
Jordan
Kazakhstan
Kuwait
Kyrgyzstan
Lao PDR
Lebanon
Malaysia
Maldives
Mongolia
Myanmar
Nepal
Oman
DPRK
Pakistan
Philippines
Qatar
Republic of Korea
Saudi Arabia
Singapore
Sri Lanka
Syrian Arab Republic
Tajikistan
Thailand
Timor-Leste
Turkey
Turkmenistan
United Arab Emirates
Uzbekistan
Viet Nam
Yemen
Albania
Austria
BIH
Belarus
Belgium
Bulgaria
Croatia
Czech Republic
Denmark
Estonia
Finland
France
GBR
Germany
Greece
Hungary
Iceland
Ireland
Italy
Latvia
Lithuania
Luxembourg
FYROM
Malta
Monaco
Montenegro
Netherlands
Norway
Poland
Portugal
Republic of Moldova
Romania
Russian Federation
Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Ukraine
Algeria
Angola
Benin
Botswana
Burkina Faso
Burundi
CAF
COD
Cameroon
Cape Verde
Chad
Comoros
Congo
Cote d'Ivoire
Djibouti
Egypt
Eritrea
Equatorial Guinea
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Kenya
Lesotho
Liberia
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Namibia
Niger
Nigeria
Rwanda
STP
Senegal
Seychelles
Sierra Leone
Somalia
South Africa
Sudan
Swaziland
TZA
Togo
Tunisia
Uganda
Zambia
Zimbabwe
Antigua and Barbuda
Argentina
Bahamas
Barbados
Belize
Bolivia
Brazil
Chile
Colombia
Costa Rica
Cuba
Dominican Republic
Ecuador
El Salvador
Grenada
Guatemala
Guyana
Haiti
Honduras
Jamaica
MEXICO
RNA
Nicaragua
Panama
Paraguay
Peru
Saint Lucia
Suriname
Trinidad and Tobago
Uruguay
VCT
Venezuela
Australia
Cook Islands
Fiji
Kiribati
Marshall Islands
Micronesia
Nauru
New Zealand
Palau
Samoa


https://flourish.studio/2018/07/25/how-to-make-a-chord-diagram/


Marina
Nob Hill
Pacific Heights
Russian Hill
Castro
Haight
Mission
Noe
Potrero
South Of Market
Western Addition
Downtown
Financial District

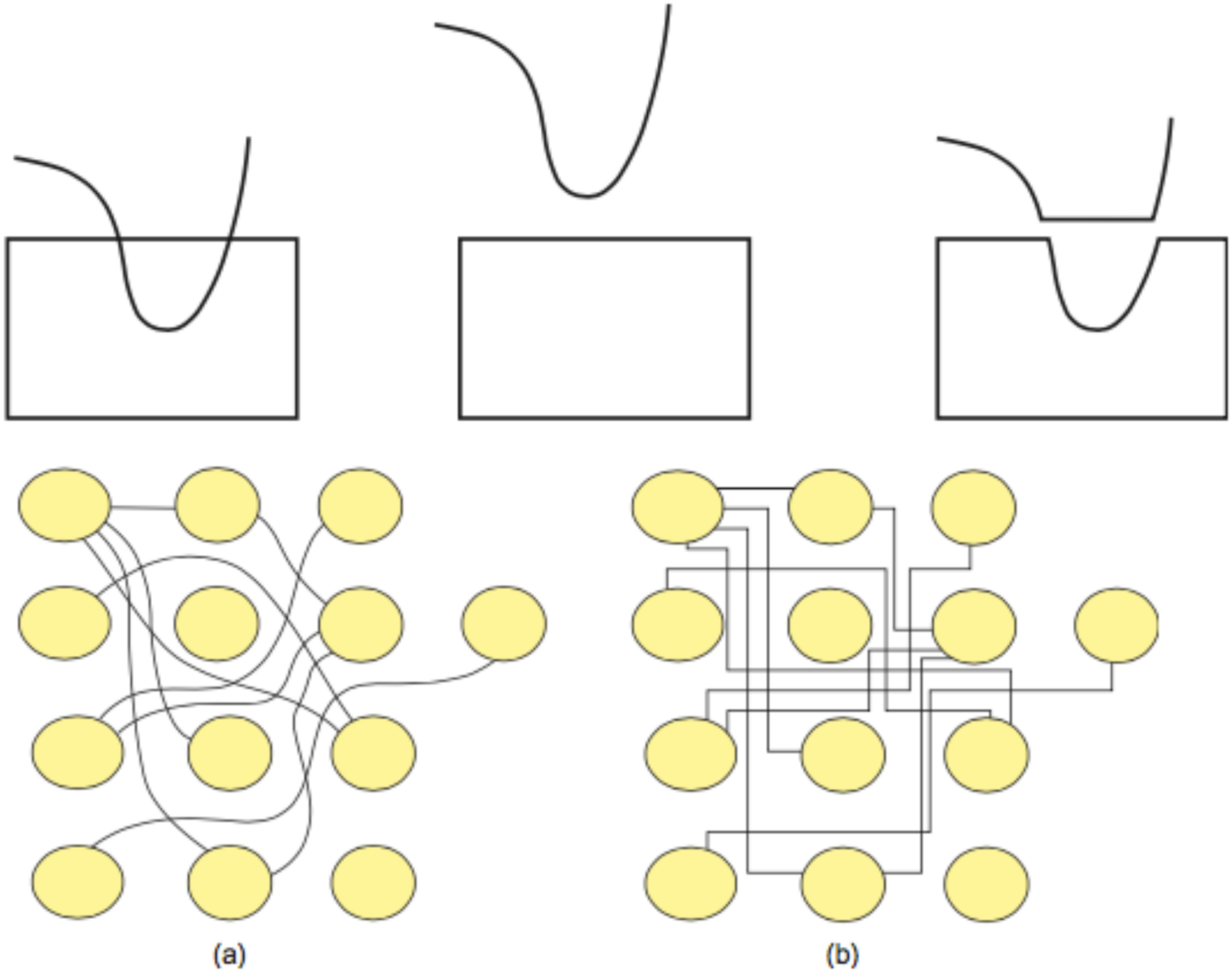
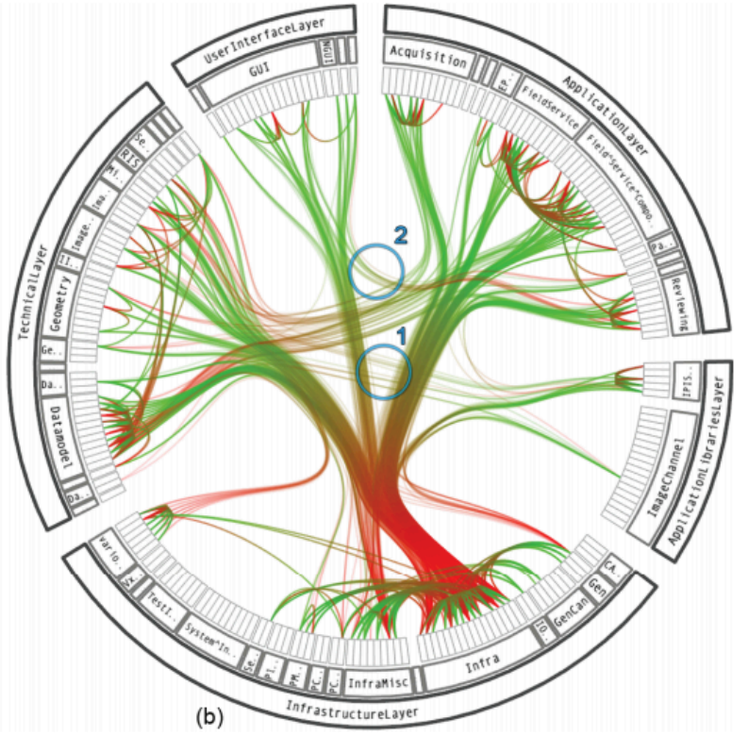



**Figure 6.7** In (a), smooth continuous contours are used to connect nodes in the diagram; in (b), lines with abrupt changes in direction are used. It is much easier to perceive connections with the smooth contours.

Ware, C., 2000. Information visualization: design for perception. *Morgan Kauffman, San Mateo, CA*.



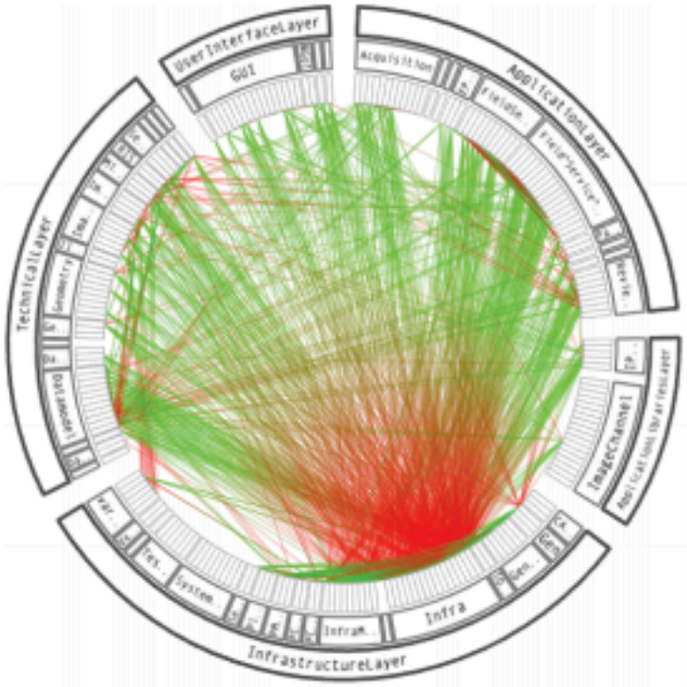

# Edge Bundling

## Bundle together edges with similar trajectories

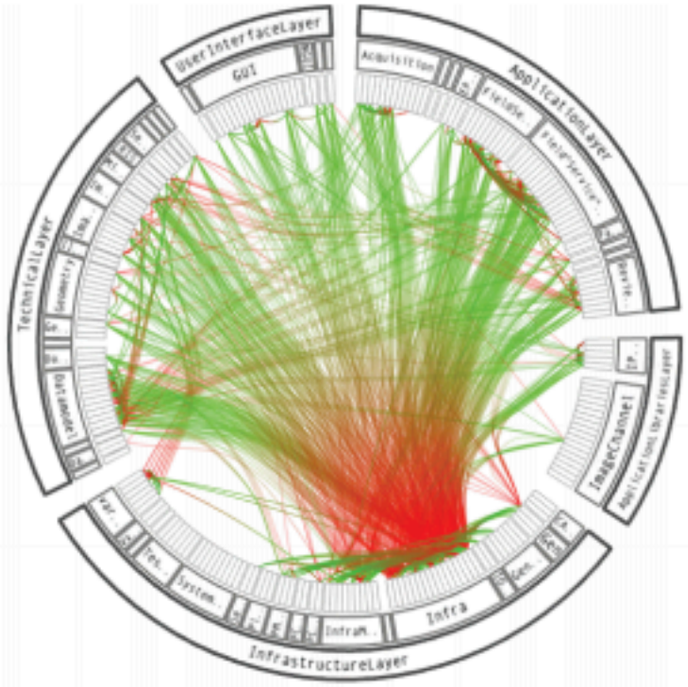
Best w/hierarchical data

Angles, curved splines, alpha blending

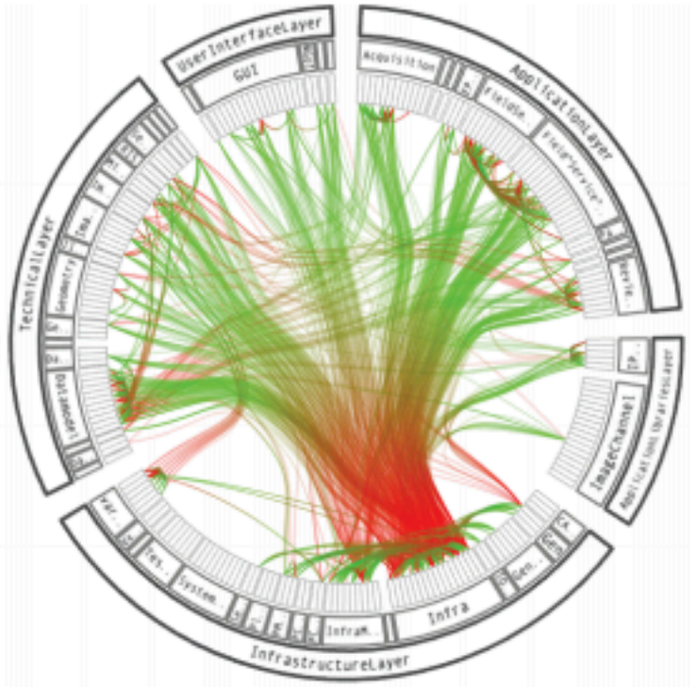
Doesn’t need a radial layout –
Use force-direction for complex cases



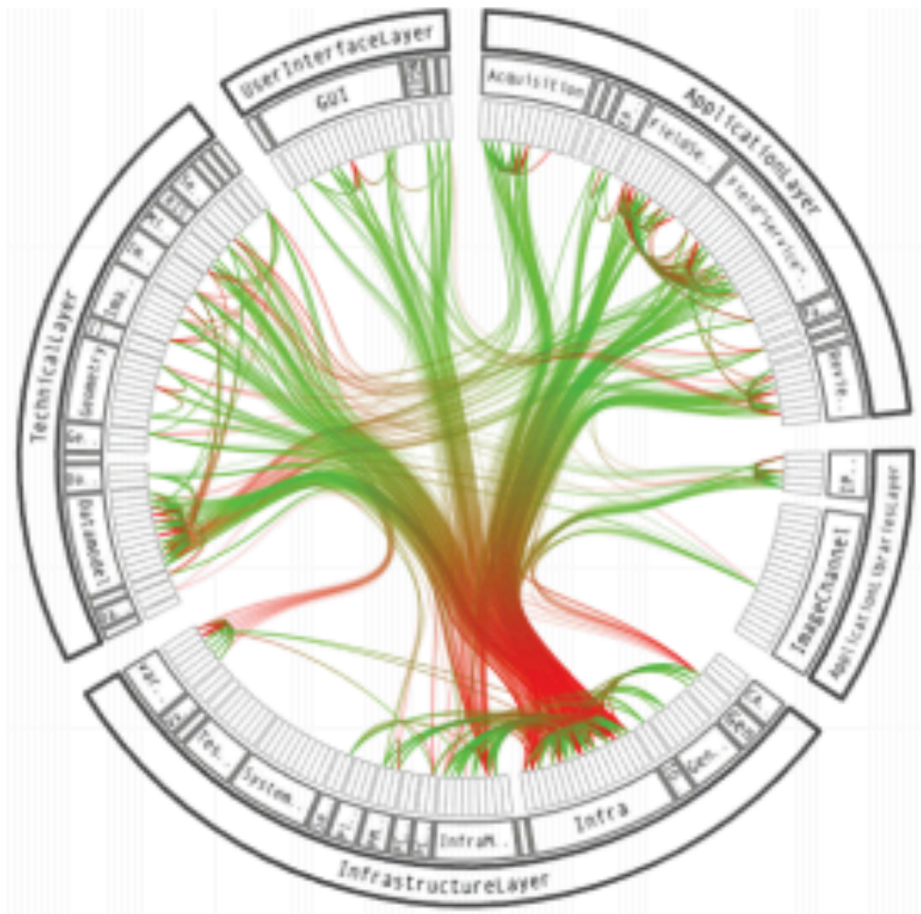

$\beta = 0$



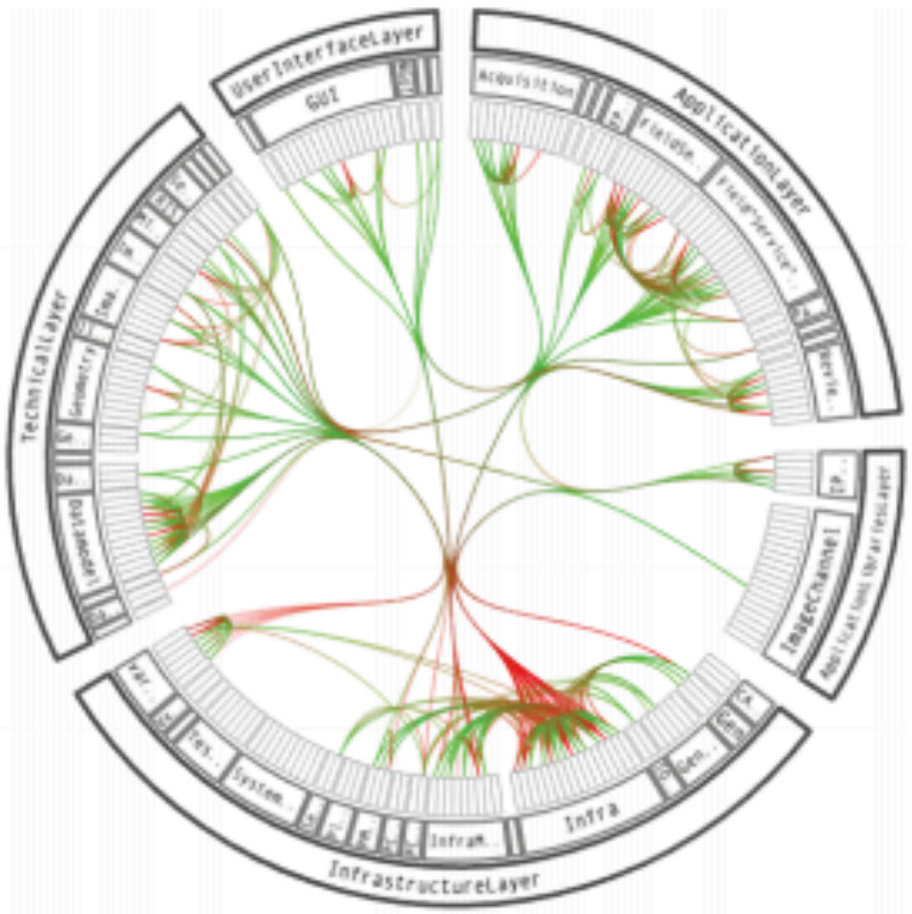

$\beta = 0.25$




$\beta = 0.5$

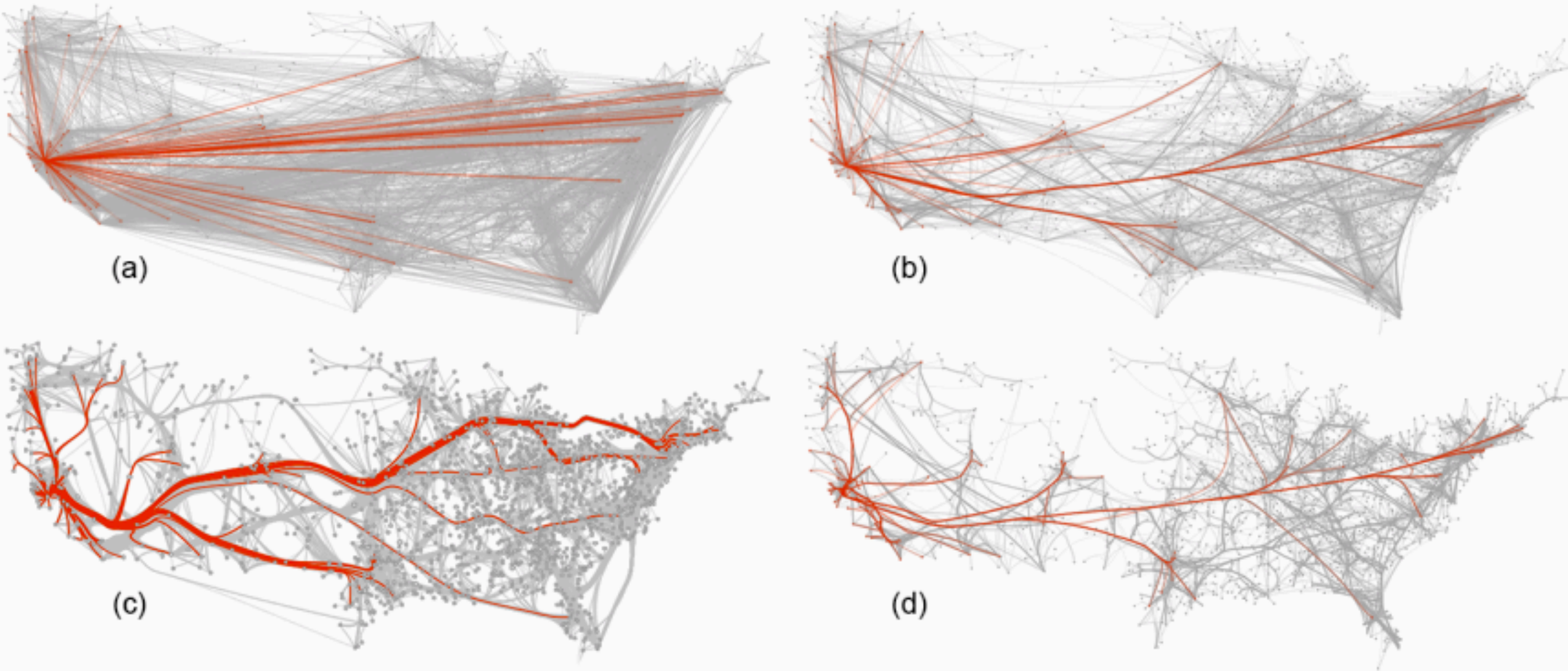



$\beta = 0.75$




$\beta = 1$

Holten, D., 2006. Hierarchical edge bundles: Visualization of adjacency relations in hierarchical data.

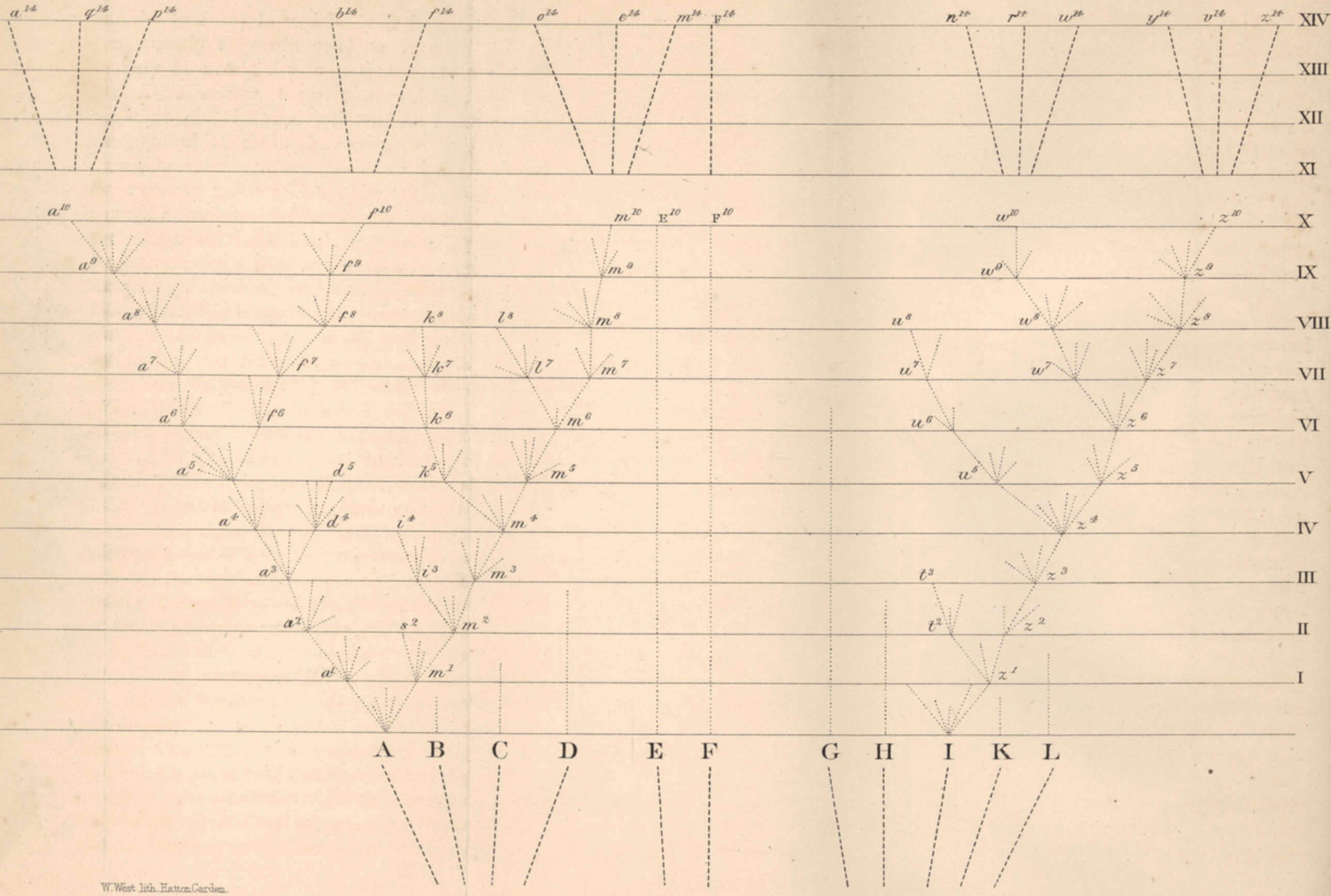



Holten, D. and Van Wijk, J.J., 2009. Force-Directed Edge Bundling for Graph Visualization.

# Considerations for design:

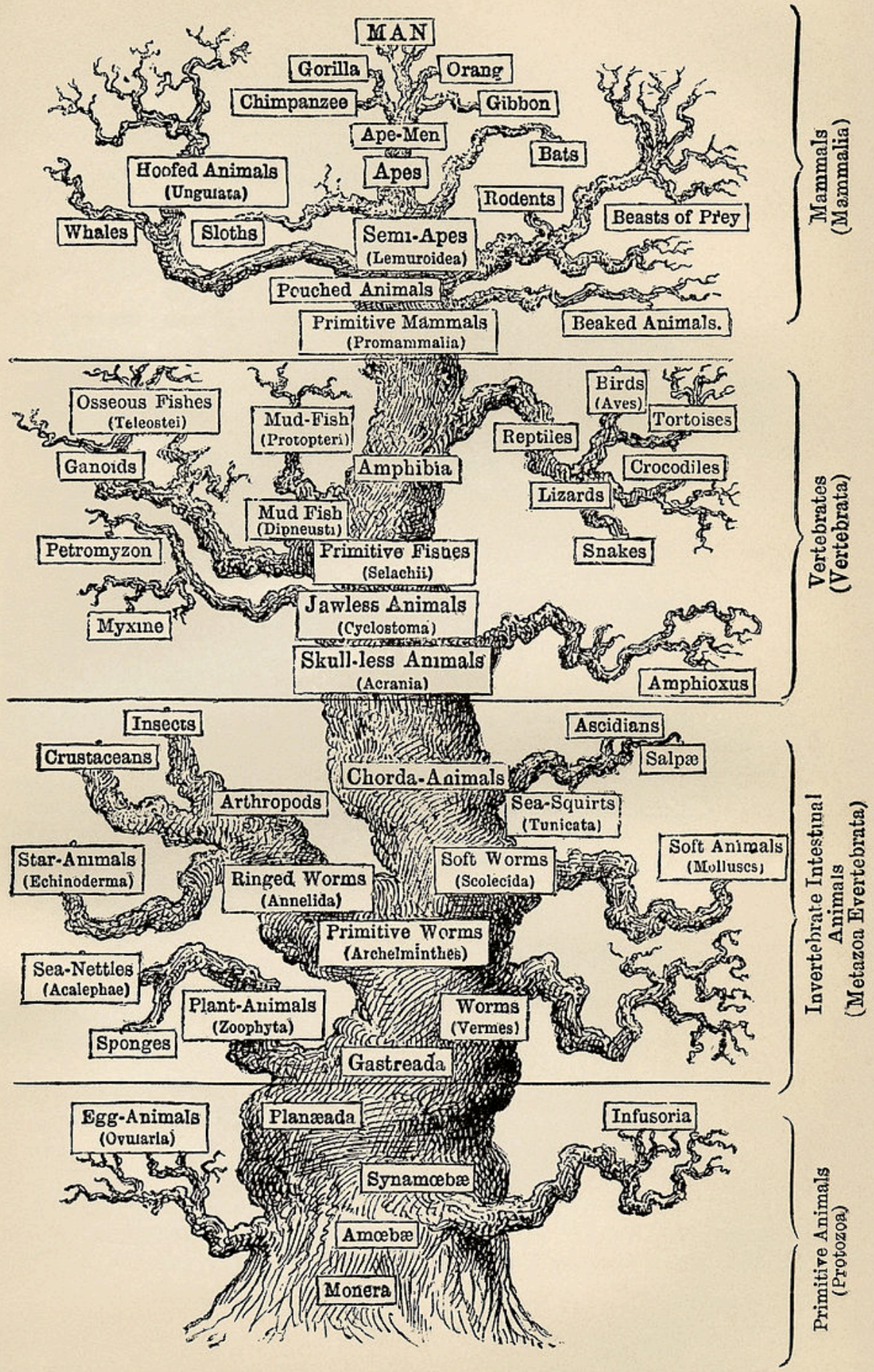
- Focus first on the insights
- Choose layout strategically
- Remember that network diagrams can lead to overconfidence
- Use few other visual channels
- Know when to give up and show something else instead!

# Trees & Hierarchies
# (optional content)

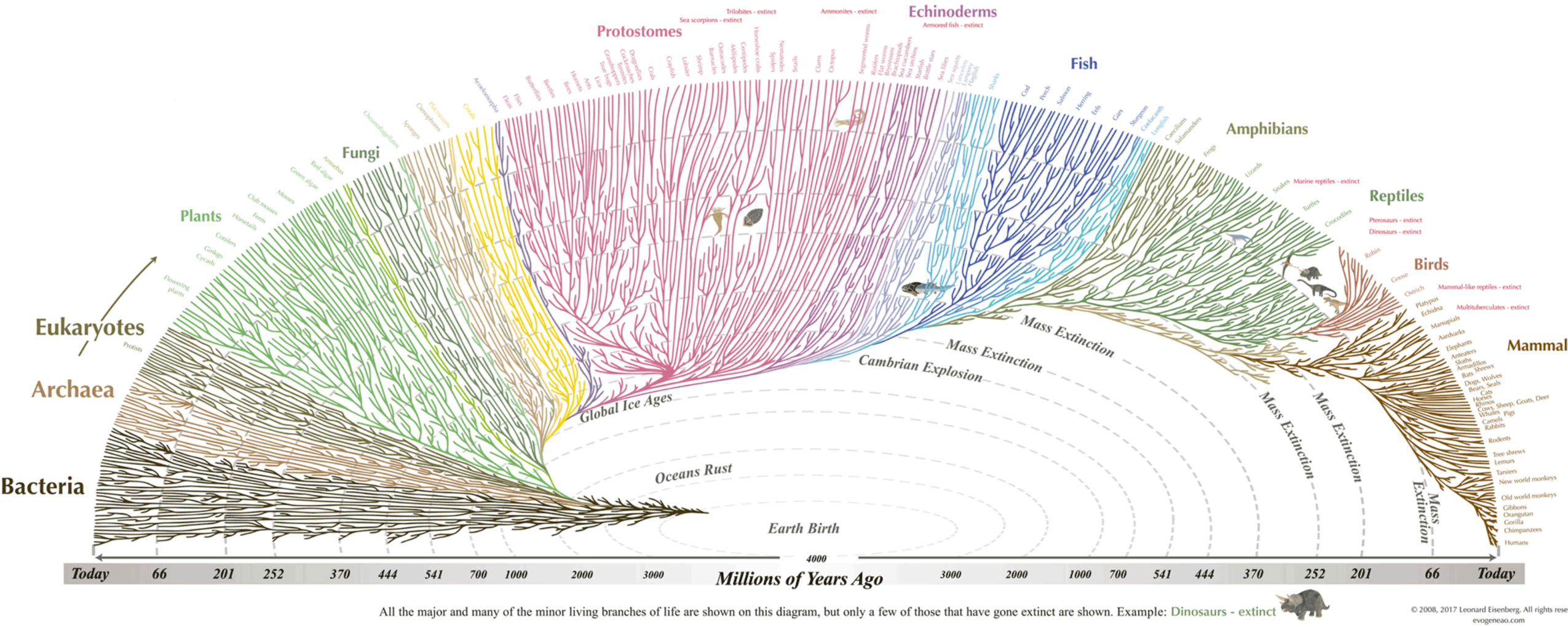



Charles Darwin, On the Origin of Species

# PEDIGREE OF MAN.



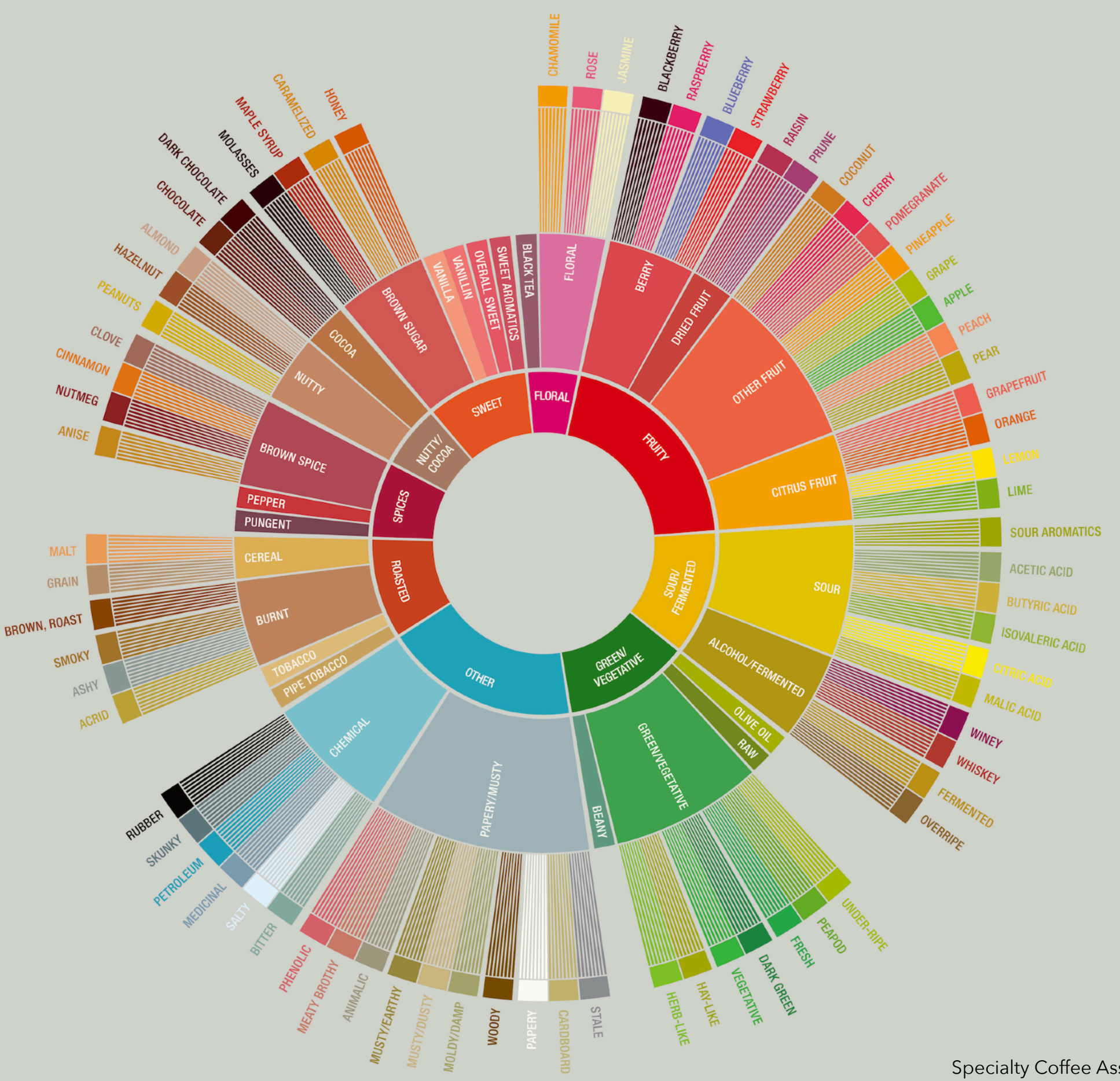

Ernst Haeckel, The Evolution of Man



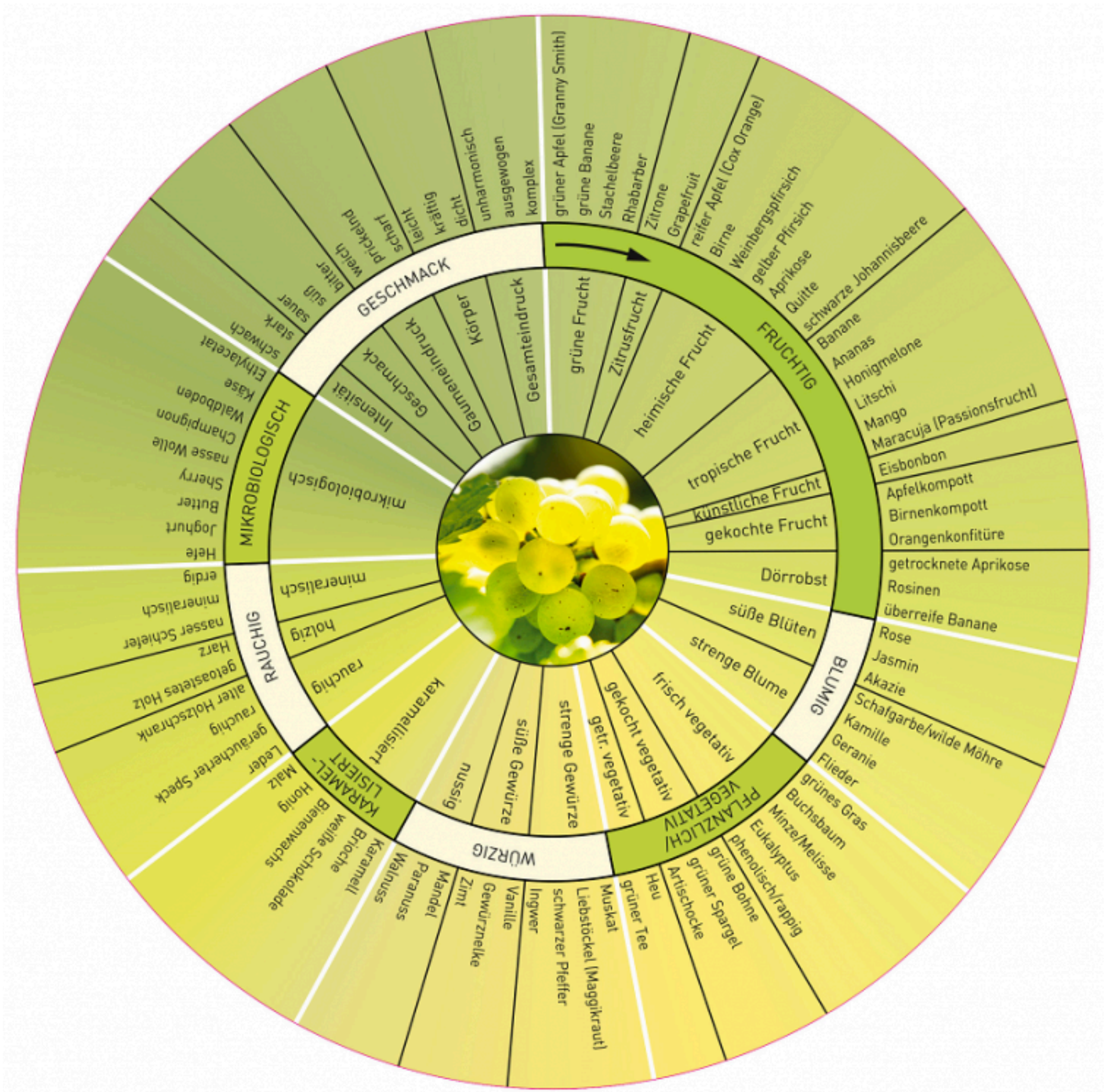

All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct



https://www.evogeneao.com/explore/tree-of-life-explorer




Specialty Coffee Association of America




Deutsches Weininstitut

# 2019 NCAA DIVISION I MEN'S BASKETBALL CHAMPIONSHIP BRACKET

NCAA.com

First Round MARCH 21–22 | Second Round MARCH 23–24 | Regional Semifinals MARCH 28–29 | Regional Finals MARCH 30–31 | National Semifinals APRIL 6

## FIRST FOUR

DAYTON
MARCH 19–20

Watch On truTV

- 16 Prairie View (22-12) 76
- 16 F. Dickinson (20-13) 82
- **W**
- 11 Belmont (26-5) 81
- 11 Temple (23-9) 70
- **E**

- 78 N. Dakota St. (18-15) 16
- 74 NC Central (18-15) 16
- **E**
- 74 Arizona St. (22-10) 11
- 65 St. John's (21-12) 11
- **W**

## EAST
WASHINGTON, D.C.

- 1 Duke (29-5) 85
- 16 North Dakota St. 62
- 1 Duke 77 — Columbia
- 8 VCU (25-7) 58
- 9 UCF (23-8) 73
- 9 UCF 76
- 1 Duke 75
- 5 Mississippi St. (23-10) 76
- 12 Liberty (28-6) 80
- 12 Liberty 58 — San Jose
- 4 Virginia Tech (24-8) 66
- 13 Saint Louis (23-12) 52
- 4 VT 67
- 4 VT 73
- 1 Duke 67
- 6 Maryland (22-10) 79
- 11 Belmont 72
- 6 Maryland 67 — Jacksonville
- 3 LSU (26-6) 79
- 14 Yale (22-7) 74
- 3 LSU 69
- 3 LSU 63
- 7 Louisville (20-13) 76
- 10 Minnesota (21-13) 86
- 10 Minnesota 50 — Des Moines
- 2 Michigan St. (28-6) 76
- 15 Bradley (20-14) 65
- 2 Mich. St. 70
- 2 Mich. St. 80
- 2 Mich. St. 68
- 2 Mich. St. 51

## WEST
ANAHEIM

- 1 Gonzaga (30-3) 87
- 16 Fairleigh Dickinson 49
- 1 Gonzaga 83 — Salt Lake City
- 8 Syracuse (20-13) 69
- 9 Baylor (19-13) 78
- 9 Baylor 71
- 1 Gonzaga 72
- 5 Marquette (24-9) 64
- 12 Murray St. (27-4) 83
- 12 Murray St. 62 — Hartford
- 4 Florida St. (27-7) 76
- 13 Vermont (27-6) 69
- 4 Florida St. 90
- 4 Florida St. 58
- 1 Gonzaga 69
- 6 Buffalo (31-3) 91
- 11 Arizona St. 74
- 6 Buffalo 58 — Tulsa
- 3 Texas Tech (26-6) 72
- 14 Northern Ky. (26-8) 57
- 3 Texas Tech 78
- 3 Texas Tech 63
- 7 Nevada (29-4) 61
- 10 Florida (19-15) 70
- 10 Florida 49 — Des Moines
- 2 Michigan (28-6) 74
- 15 Montana (26-8) 55
- 2 Michigan 64
- 2 Michigan 44
- 3 Texas Tech 75
- 3 Texas Tech 61

## FINAL FOUR
MINNEAPOLIS
APRIL 6 AND 8

## NATIONAL CHAMPIONSHIP
APRIL 8

3 Texas Tech | Virginia 1

#MarchMadness

Watch the tournament on these networks or online at NCAA.COM/MARCHMADNESS

tbs · CBS · TNT · truTV

March 21 and 23 first-/second-round sites: Hartford, Salt Lake City, Des Moines, Jacksonville. March 22 and 24 first-/second-round sites: Tulsa, Columbus, Columbia, San Jose. March 29 and 31 regional sites: Louisville, Anaheim. March 29 and 31 regional sites: Washington, D.C., Kansas City.

DON'T BET ON IT

The NCAA opposes all forms of sports wagering

## SOUTH
LOUISVILLE

- 63 Virginia 1
- 80 Virginia 1
- 53 Virginia 1
- 63 Virginia 1 — Columbia
- 71 Virginia (29-3) 1
- 56 Gardner-Webb (23-11) 16
- 51 Oklahoma 9
- 72 Mississippi (20-12) 8
- 95 Oklahoma (19-13) 9
- 49 Oregon 12
- 73 Oregon 12 — San Jose
- 54 Wisconsin (23-10) 5
- 54 UC Irvine 13
- 64 Kansas St. (25-8) 4
- 72 Oregon (23-12) 12
- 70 UC Irvine (30-5) 13
- 75 Purdue 3
- 99 Purdue 3
- 61 Villanova 6 — Hartford
- 61 Villanova (25-9) 6
- 57 Saint Mary's (22-11) 11
- 87 Purdue 3
- 61 Purdue (23-9) 3
- 48 Old Dominion (26-8) 14
- 94 Tennessee 2
- 77 Iowa 10 — Columbus
- 72 Cincinnati (28-6) 7
- 79 Iowa (22-11) 10
- 83 Tennessee 2
- 77 Tennessee (29-5) 2
- 70 Colgate (24-10) 15

## MIDWEST
KANSAS CITY

- 77 Auburn 5
- 80 N. Carolina 1
- 81 N. Carolina 1 — Columbus
- 88 North Carolina (27-6) 1
- 73 Iona (17-15) 16
- 59 Washington 9
- 61 Utah St. (28-6) 8
- 78 Washington (26-8) 9
- 97 Auburn 5
- 89 Auburn 5 — Salt Lake City
- 78 Auburn (26-9) 5
- 77 New Mexico St. (30-4) 12
- 75 Kansas 4
- 87 Kansas (25-9) 4
- 53 Northeastern (23-10) 13
- 71 Kentucky 2
- 59 Ohio St. 11 — Tulsa
- 59 Iowa St. (23-11) 6
- 62 Ohio St. (19-14) 11
- 58 Houston 3
- 74 Houston 3
- 84 Houston (31-3) 3
- 55 Georgia St. (24-9) 14
- 62 Kentucky 2
- 56 Wofford 7 — Jacksonville
- 84 Wofford (29-4) 7
- 68 Seton Hall (20-13) 10
- 62 Kentucky 2
- 79 Kentucky (27-6) 2
- 44 Abilene Christ. (27-6) 15

Second Round MARCH 23–24 | Regional Semifinals MARCH 28–29 | Regional Finals MARCH 30–31 | National Semifinals APRIL 6 | First Round MARCH 21–22

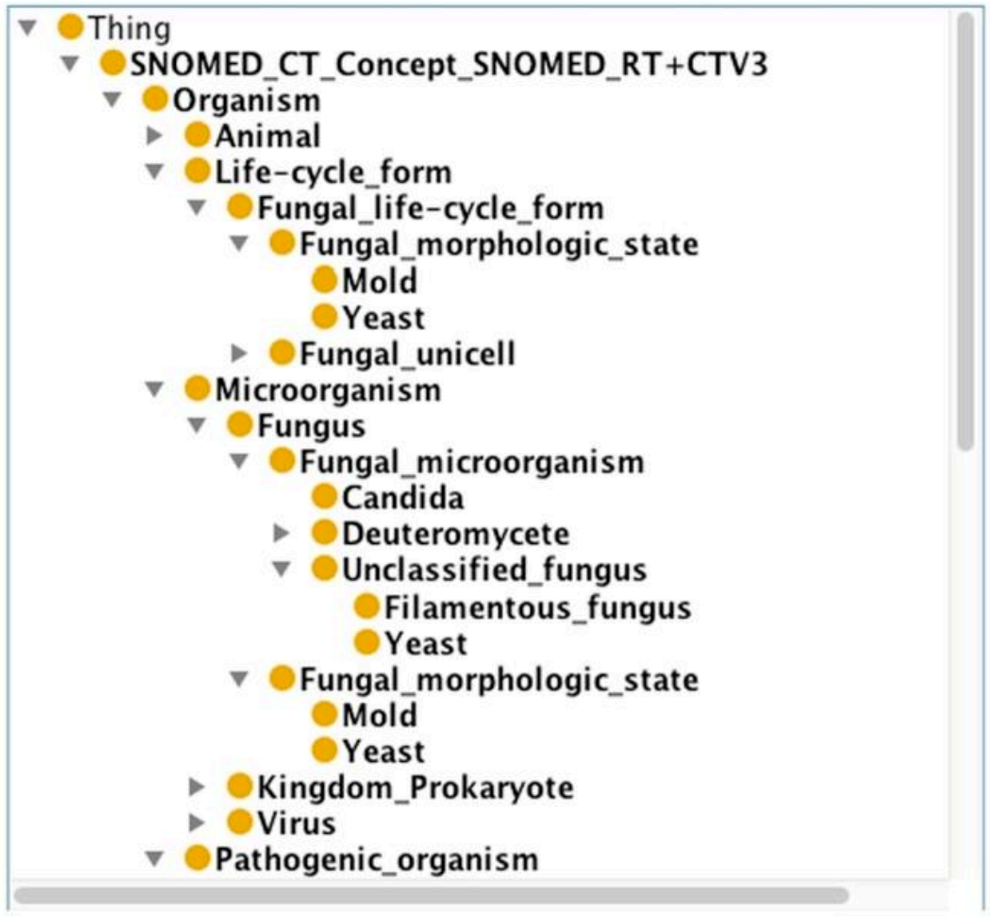
# Tree Layout

**Indented List** Indent for levels, shallow

**Network Diagram** Node-link, layout key

**Space-filling** Enclose subtrees within areas

**Layered/Icicle** “unwrapped” enclosure




# Indented List

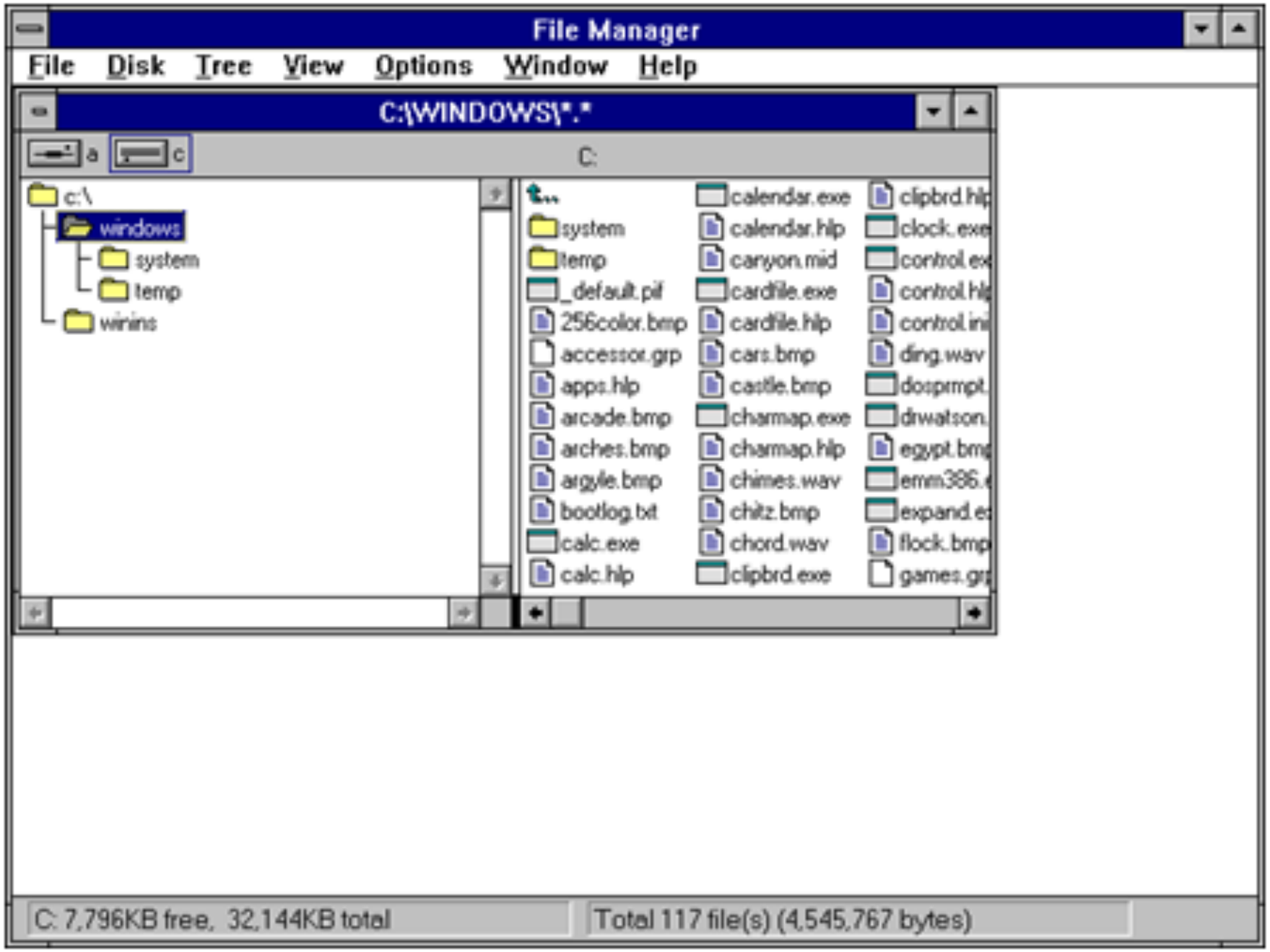
## Indent child nodes in a list

Familiar visual metaphor

Shallow, brief hierarchies

Expand/contract affordance

Battle between breadth and depth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File Disk Tree View Options Window Help
C:\WINDOWS*.*
a c
C:
c:\
windows
system
temp
winins
system
temp
_default.pif
256color.bmp
accessor.grp
apps.hlp
arcade.bmp
arches.bmp
argyle.bmp
bootlog.txt
calc.exe
calc.hlp
calendar.exe
calendar.hlp
canyon.mid
cardfile.exe
cardfile.hlp
cars.bmp
castle.bmp
charmap.exe
charmap.hlp
chimes.wav
chitz.bmp
chord.wav
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clipbrd.hlp
clock.exe
control.exe
control.hlp
control.ini
ding.wav
dosprmpt.
drwatson.
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emm386.
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flock.bmp
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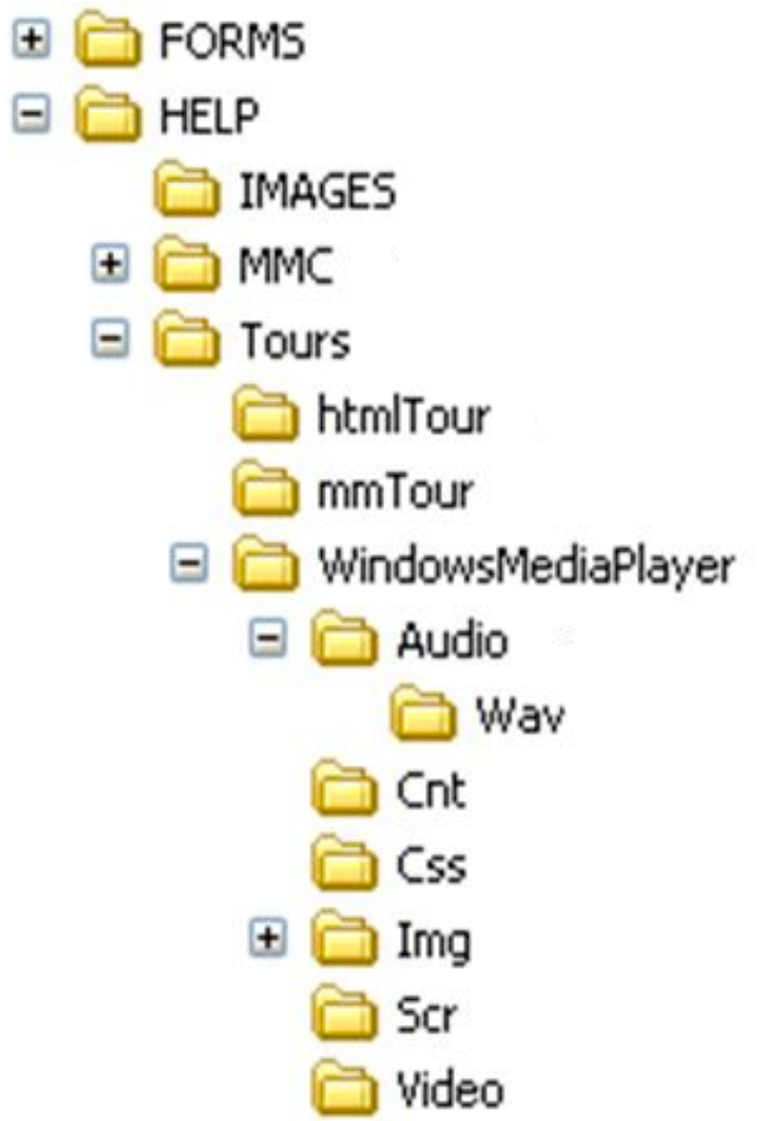
Total 117 file(s) (4,545,767 bytes)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MMC
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mmTour
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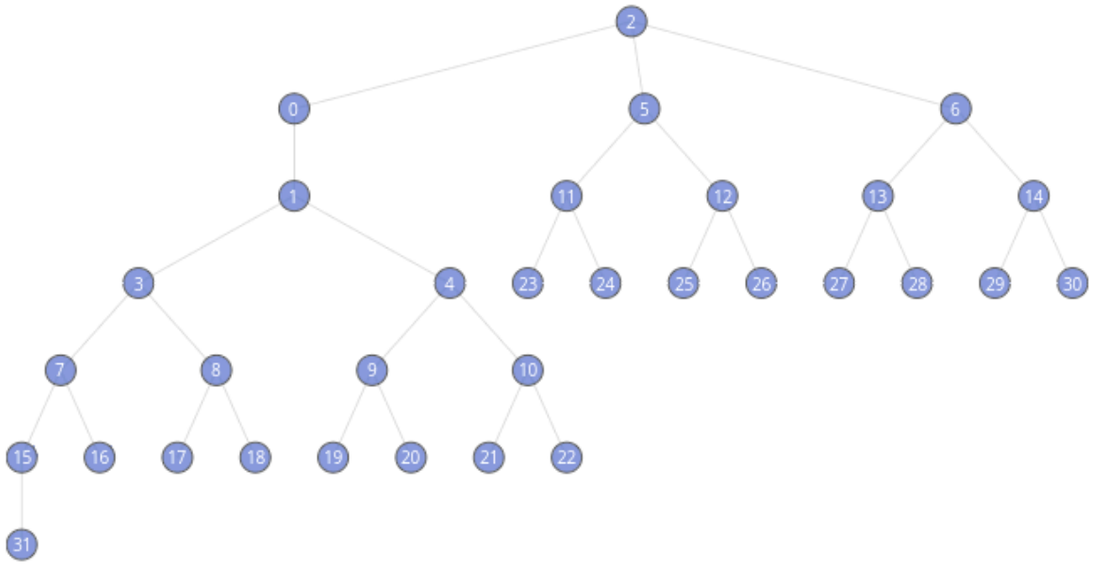
Css
Img
Scr
Video




# Node-Link Diagram

## Depth on one axis, breadth on the other

Left-right or top-bottom property

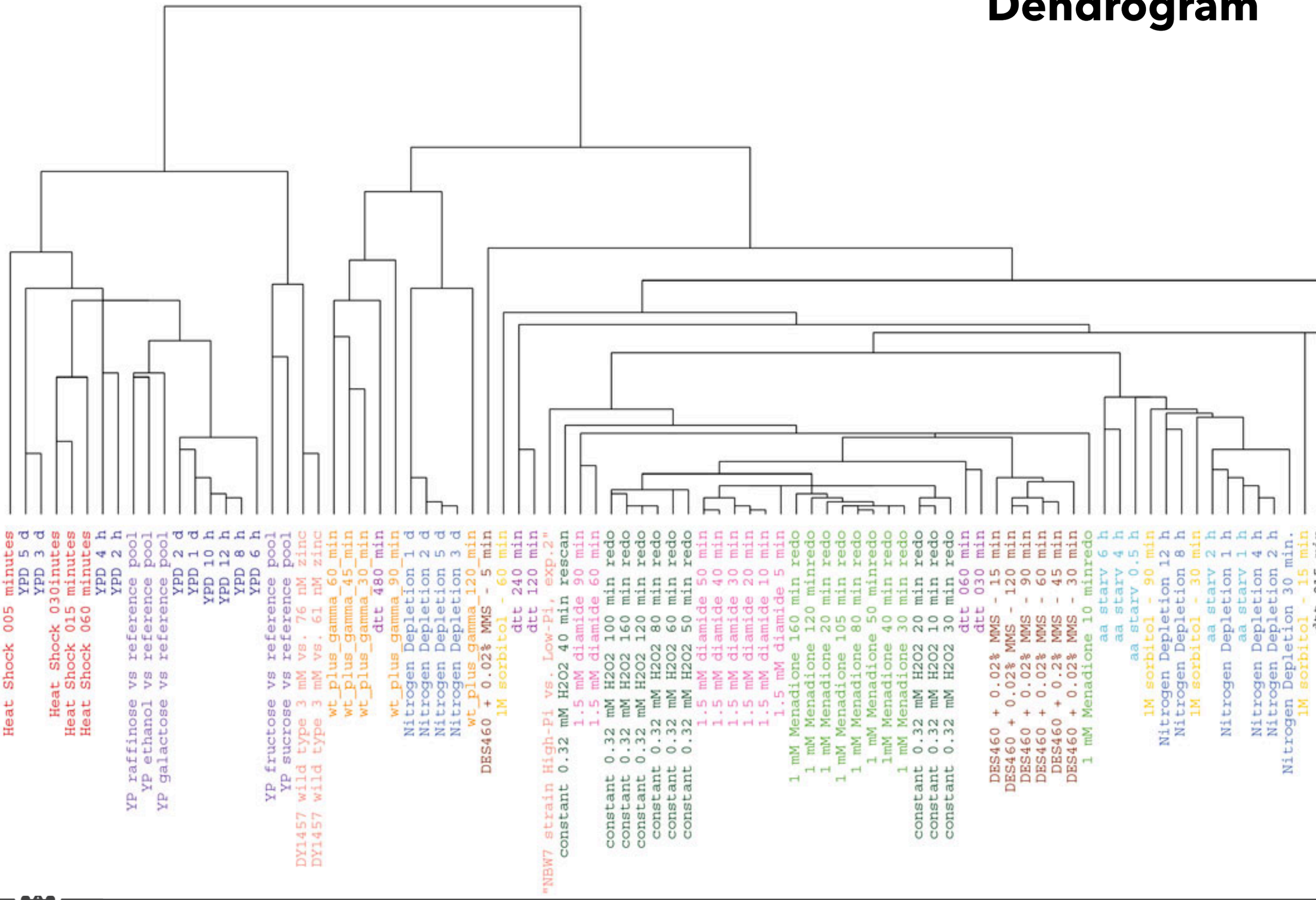
Hard to use space properly

Expand/contract affordance

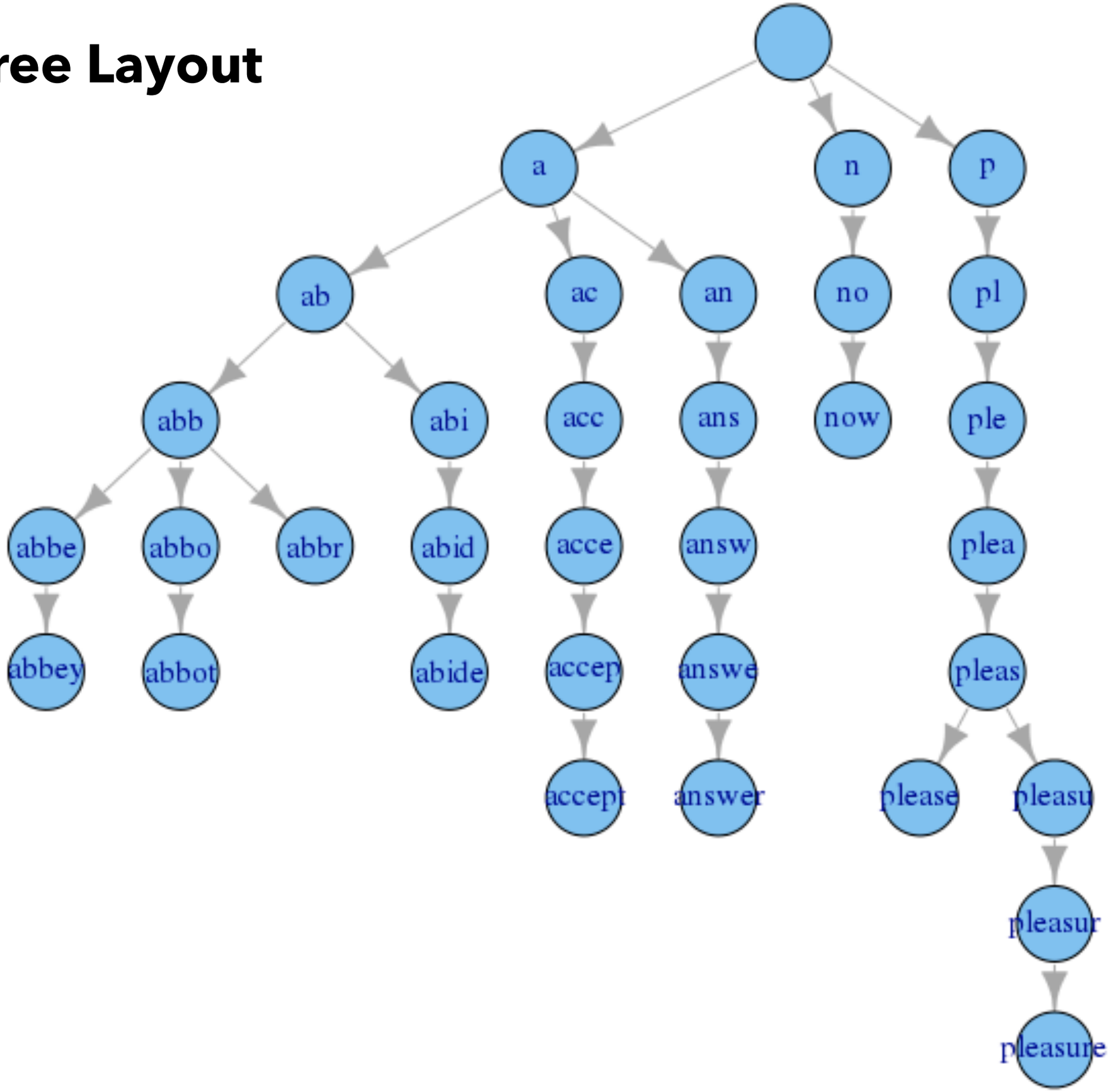
Still will run out of space!

Cluster 4: oxidative stress response genes

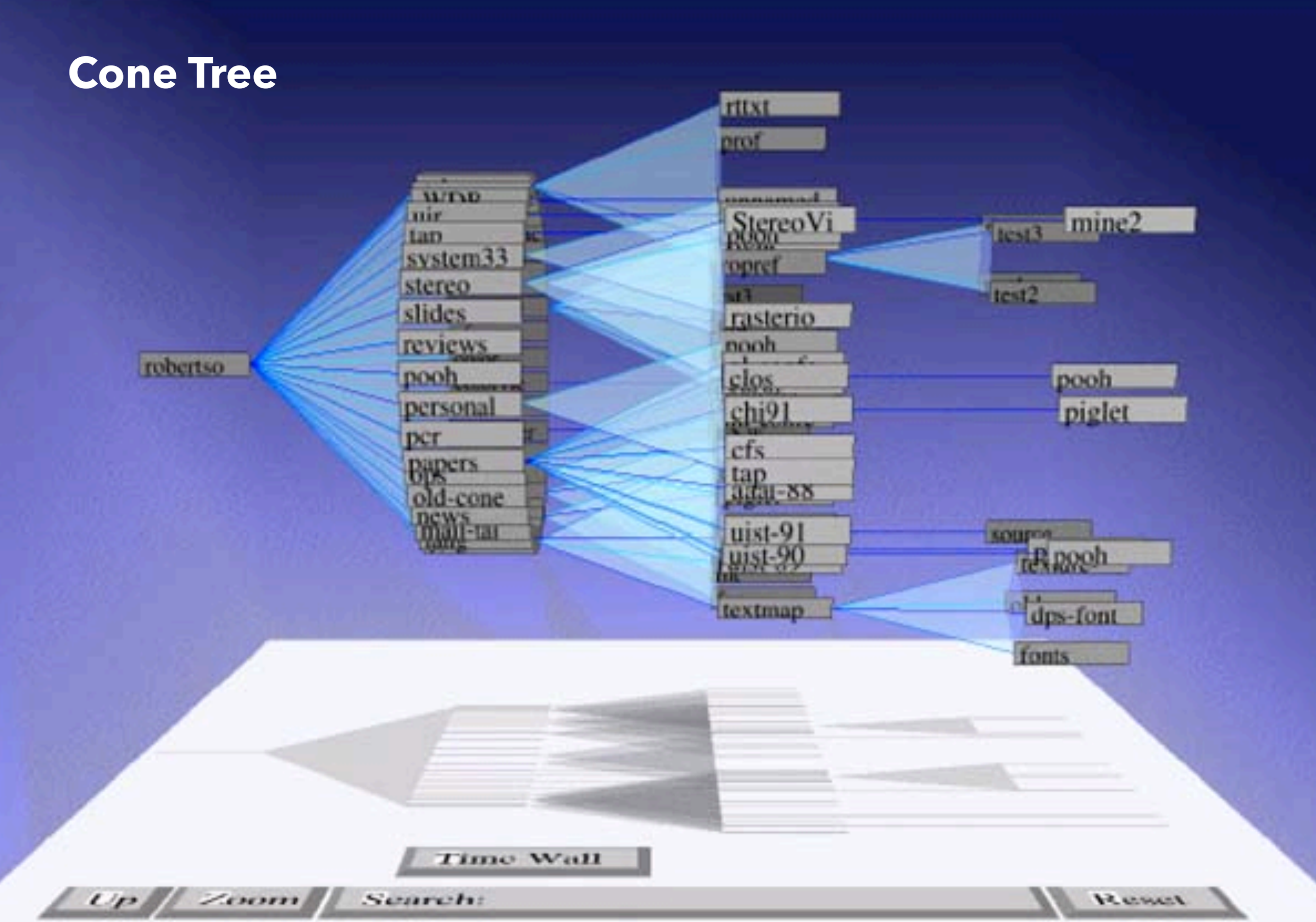
# Dendrogram



# “Tidy” Tree Layout



# Cone Tree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cfs
tap
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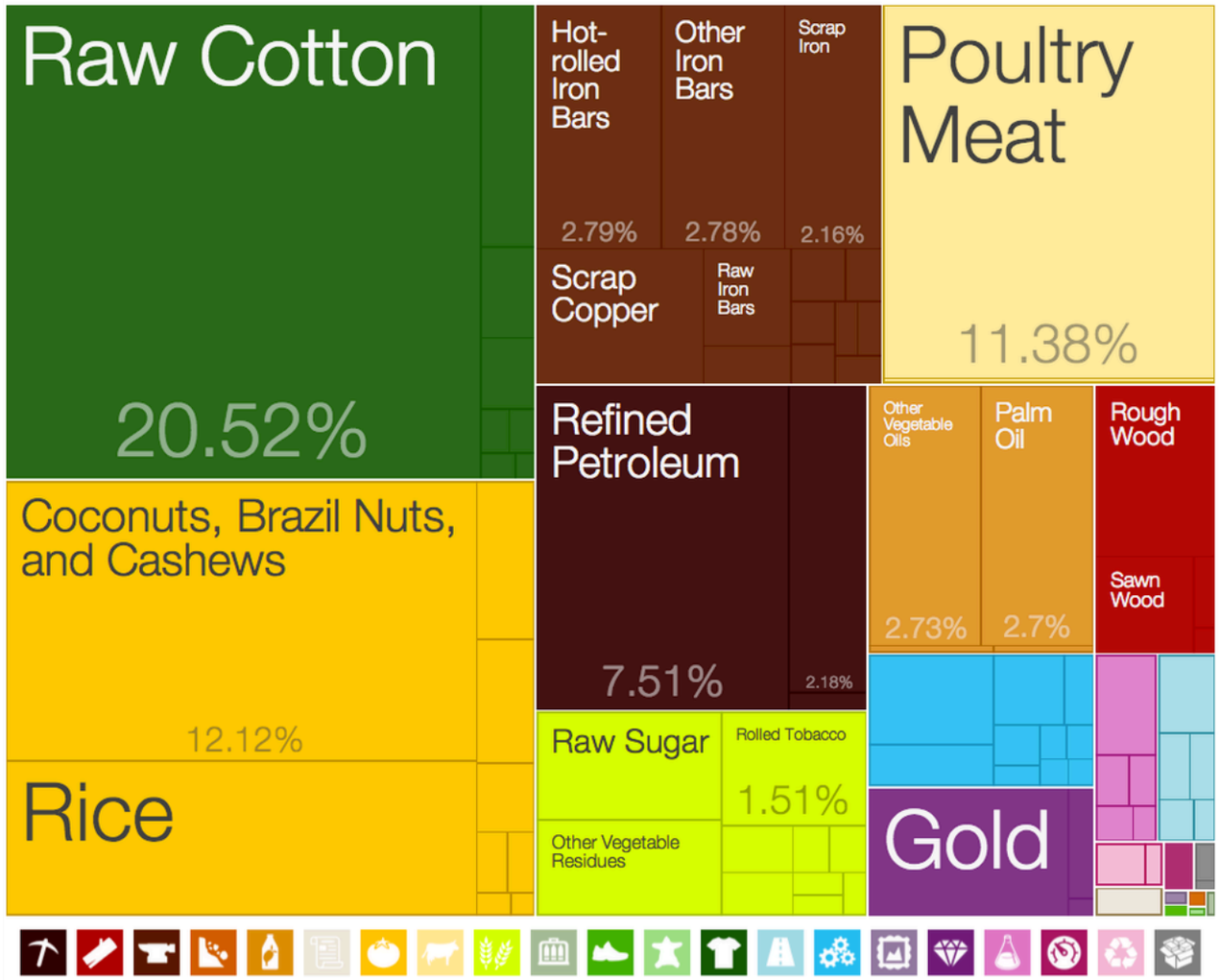



# Space-filling Diagrams

## Nest child nodes within parent nodes

"Fixed" space consumption

(but nodes may get too small)

MIT Economic Observatory, Benin Exports

# “Treemap”

| Color | Kind | Size | Files |
|---|---|---|---|
| | Application | 76.2 GB | 462 |
| | iTunes Document | 71.4 GB | 10876 |
| | Document | 42.0 GB | 108347 |
| | QuickTime Player Doc | 38.6 GB | 1153 |
| | TextEdit Document | 28.0 GB | 45764 |
| | Preview Document | 26.5 GB | 39911 |
| | FLAC File | 14.5 GB | 631 |
| | Keynote Presentation | 11.0 GB | 105 |
| | ISO Disk Image | 9.0 GB | 3 |
| | Camera Raw | 6.7 GB | 305 |

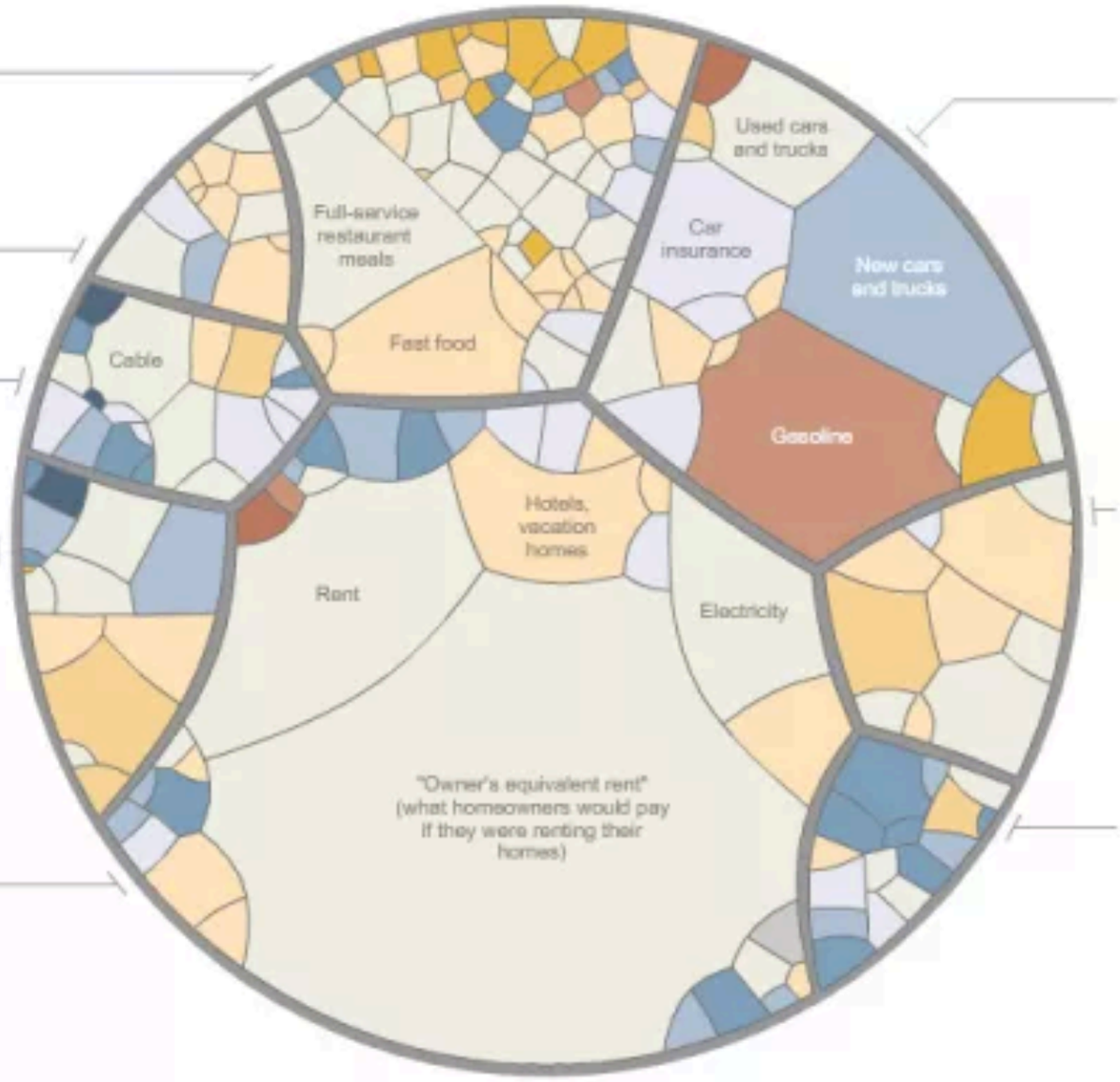
## An Average Consumer's Spending

*Each shape below represents how much the average American spends in different categories. Larger shapes make up a larger part of spending.*

*Color shows change in prices from March 2007 to March 2008*

-10% -2 0 +2 +4 +6 +10 +20 +40%

ZOOM IN ZOOM OUT




**Food and beverages 15%**
The high price of oil is a factor that has made food prices rise quickly.

**Miscellaneous 3%**

**Recreation 6%**

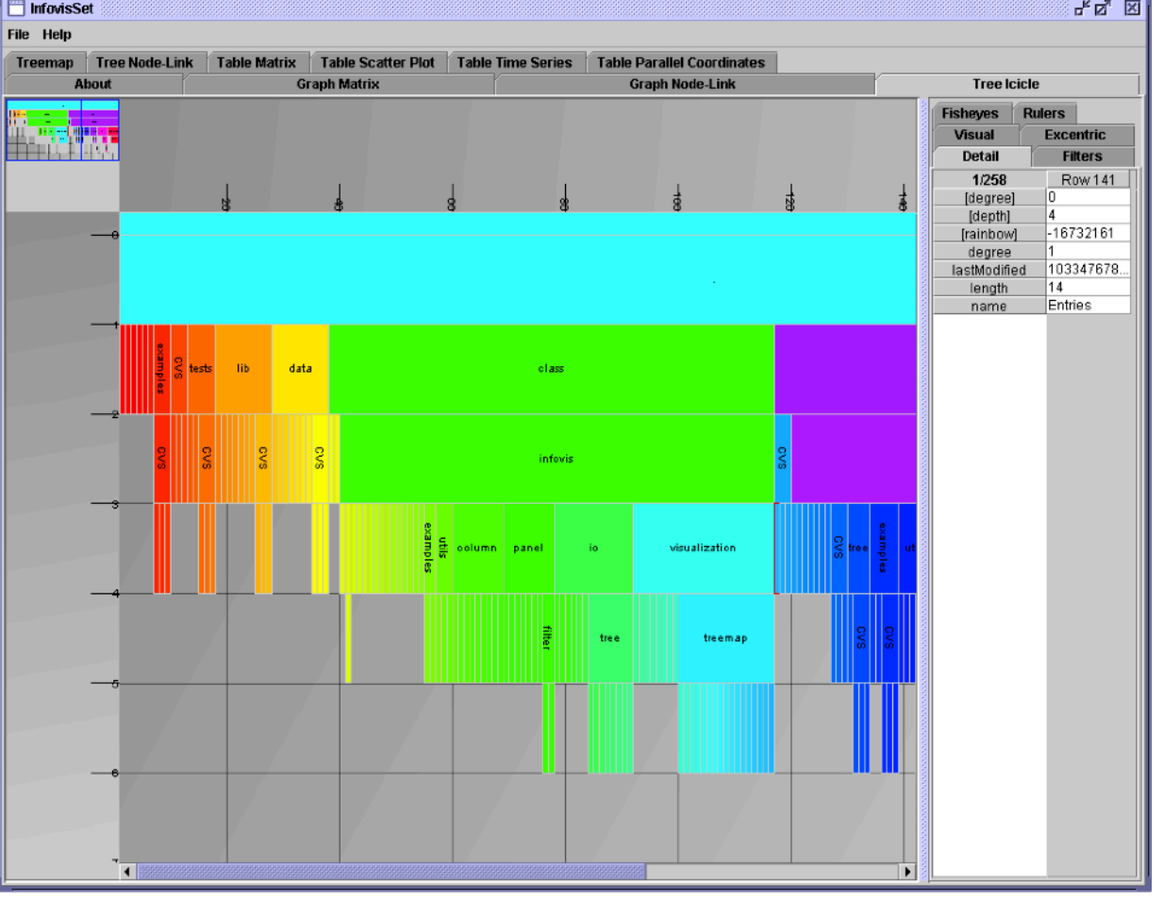
**Education/Communication 6%**
Cellphones were added to the index in 1997. Because the Consumer Price Index can be slow to add new goods, which are often cheaper, it may overstate parts of inflation.

**Housing 42%**
In the C.P.I., home ownership costs track rent prices more closely than housing prices. This means inflation may have been understated when home prices were rising faster than rents.

**Transportation 18%**
Gas is 5.2 percent of spending nationwide, but only 3.8 percent in the New York area.

**Health care 6%**
As a group, the elderly spend about twice as much of their budget on medical care.

**Apparel 4%**
The ratio of spending on women's clothes to that on men's clothes is about 2 to1.




# Layered Diagrams

## "Unwrapped" space-filling

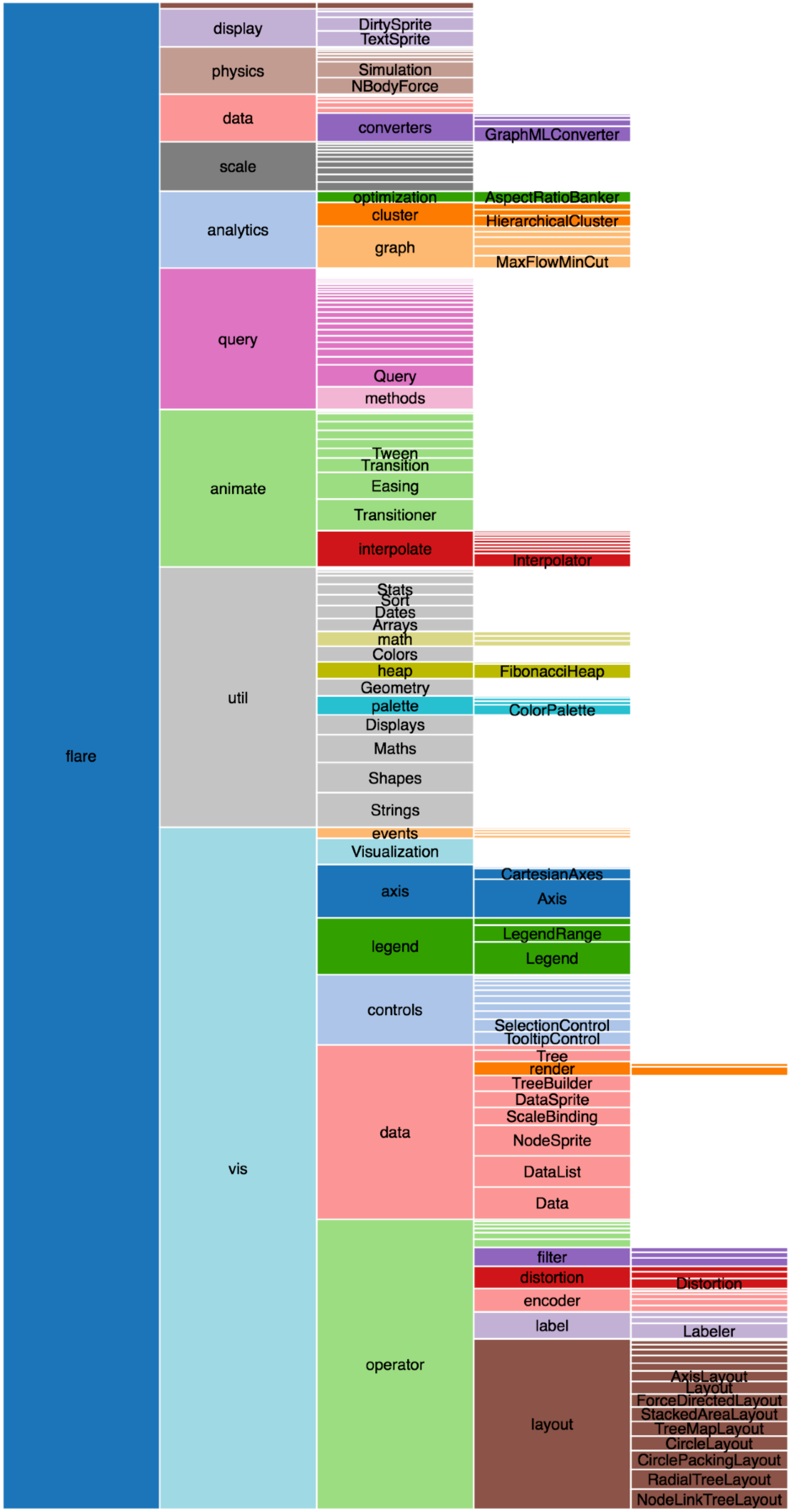
Depth in layers, nodes get area equal to subtree size

More depth cues than enclosure

Risk of small elements due to breadth, fixed depth limit onscreen

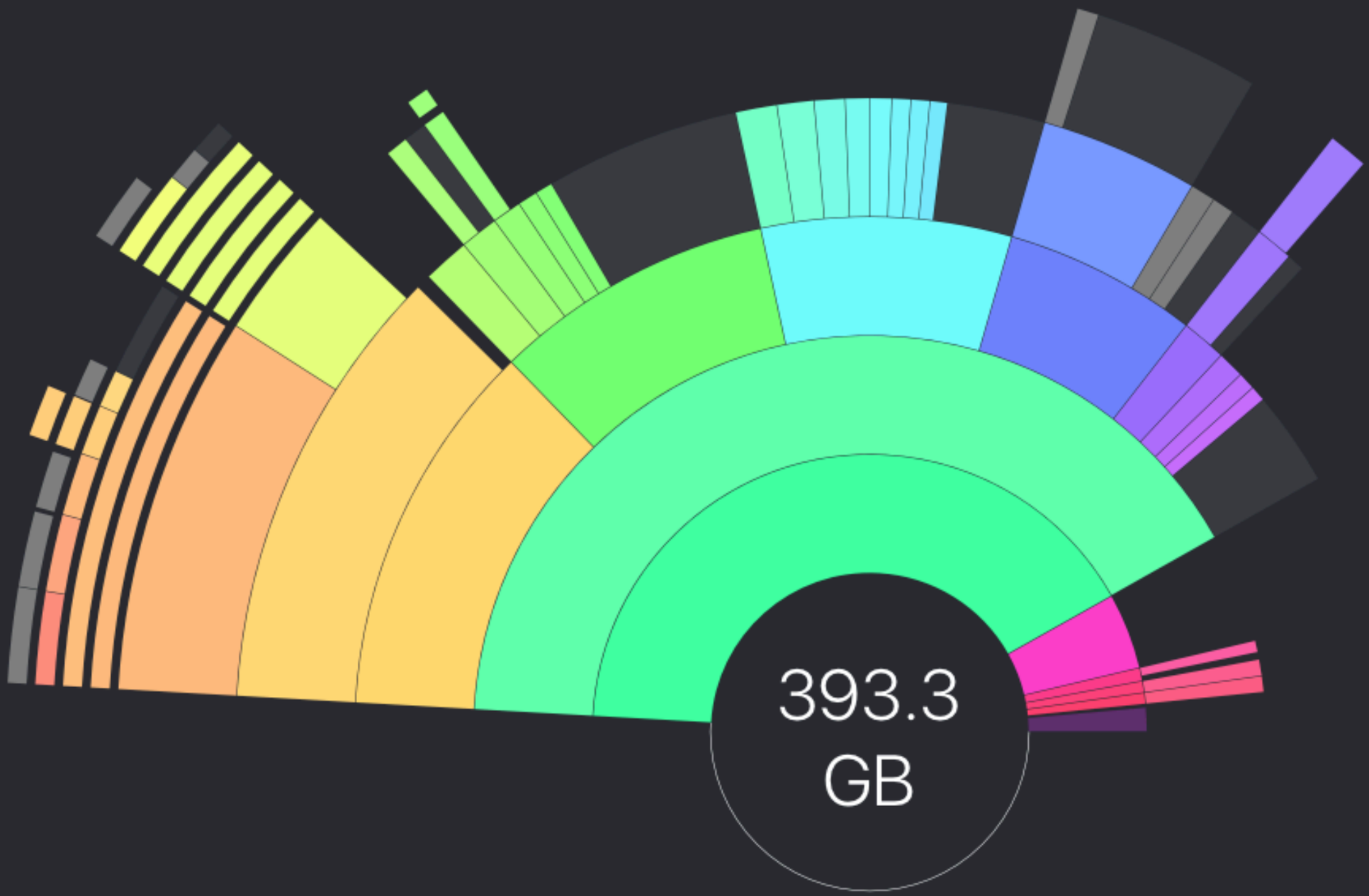
Infovis Toolkit, Fekete

# Icicle Plot

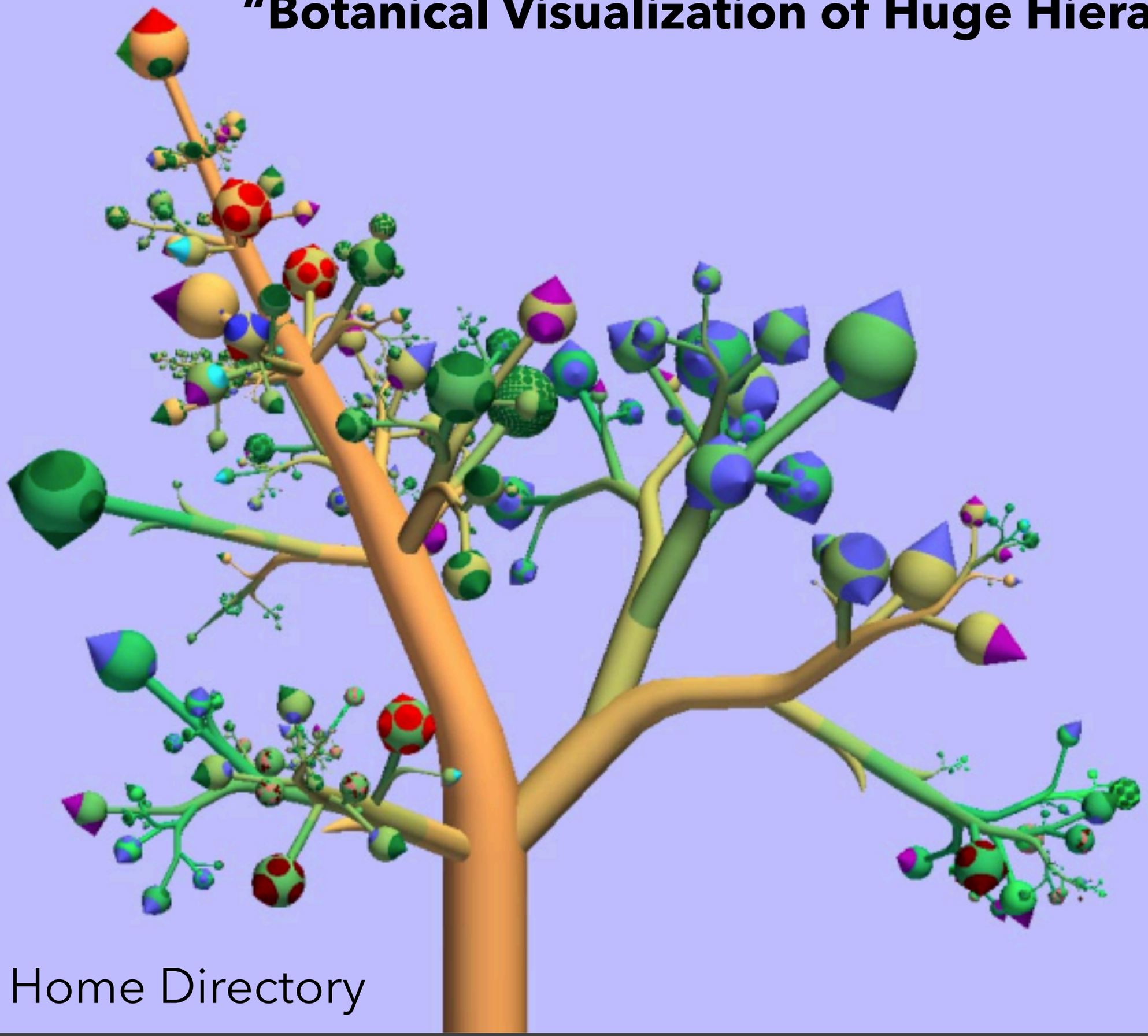



Jeff Rzeszotarski ◉ Cornell University ◉ jeffrz@cornell.edu

# Sunburst Plot



# “Botanical Visualization of Huge Hierarchies”



Unix Home Directory

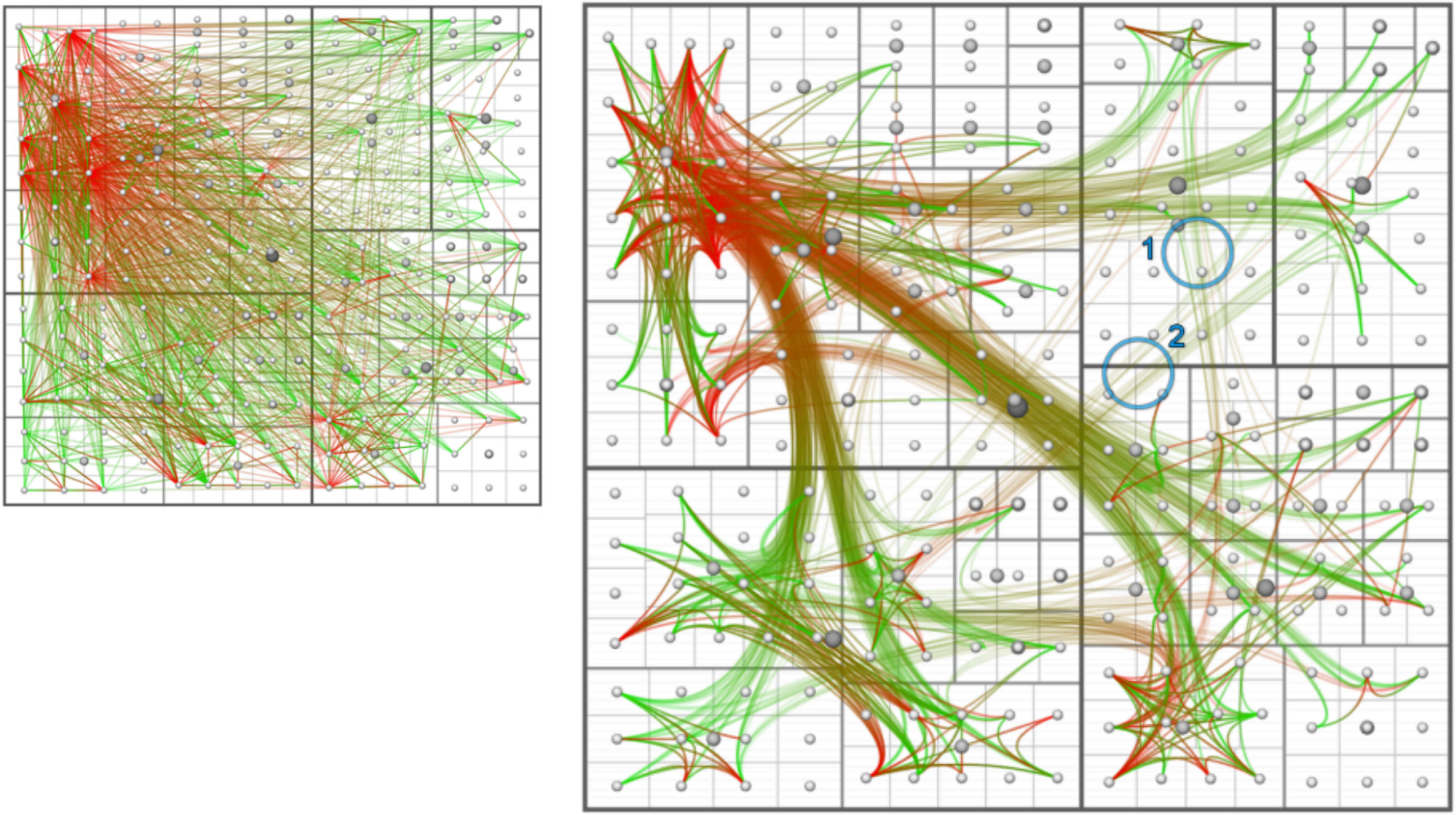



Fig. 15. The software system from figure 13 and its associated call graph (caller = green, callee = red) visualized using a squarified treemap layout (node labels disabled) for comparison with figure 11b. The encircled regions highlight the same parts of the system as in figure 13.

Holten, D., 2006. Hierarchical edge bundles: Visualization of adjacency relations in hierarchical data.